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ARTICLE

Financial or non-financial shocks: rivals that play together

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Abstract

This paper estimates a model using Bayesian methods and data from the USA (1990Q1–2019Q2) to explore how the financial sector contributes to business cycles through banks' asset channel and the quality of capital adequacy constraint. The paper shows that the contribution of financial and non-financial shocks varied before, during, and after the 2008 financial crisis; housing demand and asset price shocks are the main contributors, and the credit shocks are the most persistent. In addition, the paper presents the application of macroprudential tools, along with their impact on the economy in general, and on welfare in particular. The findings illustrate that the tools which control household borrowing ability, such as loan-to-value or debt-to-income ratios, do not impact welfare significantly. However, the impact of policies on the leveraged sector is substantial. The paper proposes macroprudential policies that allow policy-makers to stabilize the economy without changing welfare. Such policies, however, should be timely, targeted, and temporary; otherwise, they may cause disruptions.

Keywords: Financial intermediary; crisis; capital adequacy; macroprudential policy

1. Introduction

Real and financial shocks have been of varying importance in the past decades in the USA. The significance of real, that is, non-financial, shocks in economic fluctuations is well documented in the vast corpus of literature regarding Real Business Cycles (RBC) models. On the other hand, financial shocks were a central component of at least two of the last four recessions in the USA, the 1990–1991 recession and the 2008 Great Recession. However, in recent years, financial factors have come under increasing control due to the strict financial regulations that were implemented after the 2008 crisis [Financial-Stability-Reports (2018) and Reports (2019)]. The impact of these regulations can be seen, for example, in Figure 1 which presents the National Financial Conditions Leverage Subindex (NFCILEVERAGE). The financial condition was looser before the crisis, it got tighter during the crisis, and after the crisis it was kept around the average.

Since the crisis, a host of dynamic equilibrium models focused either on the role of the financial sector in propagating shocks that originate elsewhere or on financial and non-financial shocks individually. Although there are merits to such approaches for building intuition, they fall short of offering a full analysis of key factors in business fluctuations, especially at the onset of a crisis when numerous sets of shocks aggravate each other. As a result, the weight of perturbations that originate directly in the financial sector or the interaction between financial and non-financial

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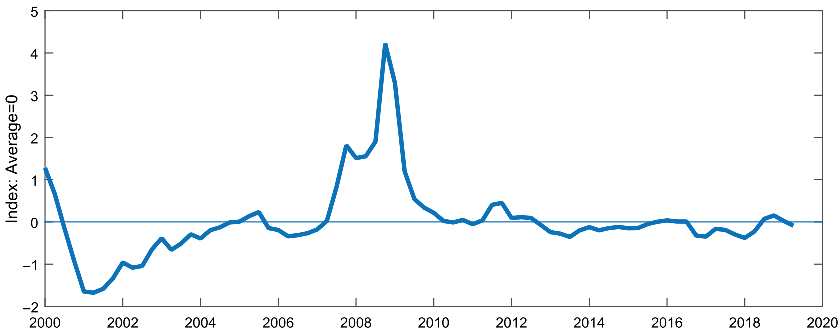

Figure 1. National Financial Conditions Leverage Subindex (NFCILEVERAGE). "Positive values indicate financial conditions that are tighter than average, while negative values indicate financial conditions that are looser than average." Source: Federal Reserve Bank of Chicago.

shocks in building up business cycle fluctuations, as investigated in the works of Jermann and Quadrini (2012) for example, has been less widely explored.

This paper aims to fill this gap by addressing the following key questions: (*i*) what have been the contributions of financial and non-financial shocks to business cycles before, during, and after the 2008 financial crisis (up to 2019)? (*ii*) what is the role of the quality of financial capital adequacy constraints in business cycles? (*iii*) what are the optimal macroprudential policies based on a welfare analysis to mitigate financial risks?

To answer these questions, this paper develops a model based on Alpanda and Zubairy (2016) by introducing financial intermediary agents to the lender–borrower relationship. The model features five types of agents: a heterogeneous household sector (lender, borrower, and renter), financial sector (banker), government, housing, and good producers. Then, US data from 1990Q1 to 2019Q2 and Bayesian methods are used to estimate the model and simulate the behavior of the economy. Both financial and non-financial shocks are investigated in this paper: TFP, consumption preference, housing demand, investment, borrowing ability of households (LTV), and lastly, a new shock into the literature, the shock to the inertia in the capital adequacy constraint of financial intermediaries.

The model choice is based on the following considerations. The specified general equilibrium aspect of the model of this paper offers a more precise analysis of the macroeconomic responses to shocks.[1] Heterogeneity in the household sector leads to the existence of the credit market which is one of the main channels in propagating financial shocks. In adherence to US regulation, this paper applies a collateral constraint to restrict borrower households in the credit market through a LTV ratio set by the authorities.[2] Heterogeneity in the household sector in this paper features three different households which interact in housing and credit markets. The model therefore mirrors the stylized fact of the presence of lenders, borrowers, and renters in reality without making it an endogenous decision, which in turn, provides the possibility of assessing various shocks and related channels especially in the housing market.

The existence of a financial sector leads to following features. First, it provides the possibility of transferring resources across agents over time. Second, the existence of a financial sector makes it possible to study financial channels as banks are engaged in both deposit and credit markets. In this paper as in reality, the financial sector faces a capital adequacy constraint when obtaining deposits.[3] This modeling provides simple, intuitive arrangements to carefully assess the role of capital adequacy constraint. One avenue for this assessment is through the introduction of a new financial shock into the literature, in the form of a shock to the inertia of the capital adequacy constraint which impacts the ability of the financial sector to partially deviate from the leverage ratio targets, set by the authorities, beyond one period. The financial sector modeling of this paper is standard and widely used in the literature, for example, Iacoviello (2015) and Rubio (2020).[4]

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The paper finds that the main drivers of output boom and bust before and during the crisis were the housing demand and investment shocks which have continued to play an important part in the pre-COVID crisis growth. The estimation results indicate that the non-financial shocks have made the biggest contribution to aggregate output growth in recent years, while the financial shocks were preeminent during the 2008 crisis. The results confirm that the shock to the capital adequacy constraint plays an important role in the financial accelerator by changing bank's leverage decisions from an exogenous regulatory target to an endogenous financial problem. In the 2008 crisis, this occurred firstly through lax financial conditions due to weaker market disciplines among bank shareholders or debilitated effective regulations [Malherbe (2020)] during the boom time which triggers arise for leveraged investment, and secondly through the increase in housing demands which incentivize financial agents in heating up the mortgage market by increasing liabilities. The increase in both housing supply and demand stimulates the housing market and accelerates financial shocks through housing channels exposing both the real and financial sectors to shocks. The results indicate that even though the shock to the capital adequacy constraint is not driving output, it does steer much of the behavior of interest spreads.

The impact of macopructential policies on the economy and welfare are another focus of this paper. This analysis is achieved assessing the welfare effects of different macroprudential policies when applied alone or together. To do so, two forms and three types of macroprudential policy tools as well as two policy mixes are investigated. The first form is a macroprudential policy on financial capital constraint, represented by the liabilities-to-assets (LTA) ratio.[5] The second form concerns the borrower's constraint, which is governed by two policies, the loan-to-value (LTV) ratio and the cap on the debt-to-income (DTI) ratio [inspired by the model of Gelain et al. (2013)]. Both policies affect the borrowing ability of households; the LTV by balancing between mortgages and house values, and the DTI by associating mortgages with household incomes. The welfare changes are computed following Rubio and Carrasco-Gallego (2014) by comparing the simulation of the model based on the estimation results without any macroprudential policy to the counterfactual model where model parameters are set to their estimated values and macroprudential tools are active.

The results of this paper indicate that macroprudential policies on capital and credit constraints impact welfare in different ways. The paper finds that macroprudential policies which control the credit market, that is, LTV and DTI, create a welfare trade-off between households. This occurs through the housing market. As a result, social/total welfare stays neutral. On the other hand, the findings illustrate that social welfare increases with a higher LTA. A higher LTA relaxes the capital constraint and makes more mortgages available for households at a lower price. Households are consequently better off.[6]

This paper suggests that there are sets of macroprudential policy mixes, including LTA-LTV and LTA-DTI, in which there is no impact on social welfare. These policies are important for policy-makers in their attempts to balance/stabilize the economy based on policy/social interests without changing total welfare. In addition, this paper provides a theoretical background which supports known empirical results. By simulating the behavior of the economy in the presence of macroprudential policies, the paper confirms the empirical assertion by Claessens et al. (2013) that macroprudential tools are time-inconsistent, that is, a tool that is efficient in boom periods may slow down economic recovery during a recession.

1.1. Literature review

This paper fuses various strands of the literature including crisis, housing, banking, and macroprudential policies. To the best of my knowledge, this paper is one of the first to assess the quality of the financial capital adequacy constraint. Gerali et al. (2010), Brunnermeier and Sannikov (2014), Gersbach et al. (2015), Gertler and Kiyotaki (2015), and Queralto (2020) to name but a few conduct their analysis based on the intermediary role of the financial sector between savers and borrowers in order to identify the origin of financial crisis and the role of financial disrupts.

However, none of these papers study the quality of the financial capital adequacy constraint and its interactions with real and financial sectors in an estimated general equilibrium model.

The idiosyncratic financial and non-financial shocks are mostly studied separately in the literature. Chugh (2013) examines external financial frictions; Rubio (2011) studies the financial shocks through the mortgage market and Ghiaie (2020) investigates the impacts of real shocks on the financial market. In the current paper, the financial and non-financial shocks are studied and estimated simultaneously for the purpose of capturing the interdependence between agents and markets.

This paper contributes to the housing literature, for example, Ge et al. (2020) and Rubio (2014), by casting light upon hitherto ignored areas, such as the interdependencies between housing and both the financial sector and macroprudential policies.

Maroprudential policies have been widely studied, for example in Rubio and Carrasco-Gallego (2014), Tomuleasa (2015), Angelini et al. (2015) and Kahou and Lehar (2017), but most contributions remain silent about the welfare impacts of macroprudential policies when they are in effect together (policy mixes). The current paper not only assesses the mechanisms through which macroprudential policies impact the economy when applied individually or together but also divulges the optimal macroprudential policies which increase welfare.

Finally, this paper complements studies on the effect of financial and real frictions on business cycle fluctuations, for example, Mumtaz and Zanetti (2016) and Zanetti (2019) which evaluate business cycles with an emphasis on the role of labor market search frictions, by including micro-founded real and financial sectors to address the potential interconnectedness of financial and non-financial channels going through households' and banks' balance sheets.

This paper is organized as follows: The next section presents the model. Section 3 estimates the parameters and describes the results of the estimation, impulse response function (IRF) response analysis, channels, and mechanisms. Section 4 outlines the impact of different macroprudential policies and their welfare analysis. Section 5 offers a conclusion on the findings of this paper.

2. Model

Superscripts P, I, R stand for Patient (lender), Impatient (borrower), Renter households, respectively, and B for Bankers (financial intermediary agents). The households' problem are standard and follow Alpanda and Zubairy (2016). There is a unit measure of each type of infinitely lived household. The model is real, and thus all prices in the economy are relative prices, with the price of consumption serving as numeraire.

2.1 Household

2.1.1 Patient (lender) households

The patient households' problem is

$$\max_{c_t^P, d_t, h_t^P, l_t^P} E_t \sum_{\tau=t}^{\infty} \beta_P^{\tau-t} \left\{ \varepsilon_{c\tau} \log c_\tau^P + \varphi_h^P \varepsilon_{h\tau} \varepsilon_{c\tau} \log h_{\tau-1}^P - \varphi_l^P \frac{(l_\tau^P)^{1+\iota}}{1+\iota} \right\}$$

$$s.t.$$

$$\begin{aligned}
(1+\tau_c)c_t^P + p_t^h h_t^{Ph} + \frac{i_t^k}{\varepsilon_{it}} + d_t &\leq \omega_t^P + \Gamma_t^P - \tau_t^P - AC_t^P \\
h_t^{Ph} &= [h_t^P - (1-\delta_h)h_{t-1}^P] + [h_t^R - (1-\delta_h)h_{t-1}^R] \\
i_t^k &= k_t - (1-\delta_k)k_{t-1}
\end{aligned} \tag{2.1}$$

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$$\omega_t^P = w_t^P l_t^P + p_t^R h_t^R + (1 + r_{t-1})d_{t-1} + r_t^k k_{t-1}$$

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

where t represents time. $0 < \beta_P < 1$ is the discount factor of patient households. φ_h^P and φ_l^P represent the relative importance of housing and labor, respectively, for patient households in the utility function. ι is the inverse of the Frisch elasticity of labor supply. A representative patient household at time t consumes c_t^P, accumulates housing h_t^{Ph} at relative price p_t^h, supplies labor l_t^P, saves deposit d_t in the financial sector, and is the owner of capital k_t. Capital is borrowed by firms in order to produce non-housing goods. After production, the undepreciated part of capital is returned to the household such that capital investment is i_t^k. The patient household owns two types of houses: residential houses h^P and rental houses h^R.[7] The depreciation rates on housing and capital are δ_h and δ_k, respectively. To summarize, the patient household has four saving opportunities: residential housing, rental housing, capital, and deposits. ε_{ct} is a shock to preferences for consumption and housing jointly, that is, aggregate spending shock. ε_{ht} is a housing demand shock. ε_{it} is an investment shock. These shocks will be explained in the estimation Section 3.

Total income ω_t^P is composed of wage w_t^P, rent from renters at price p_t^R, and return on deposit and capital with interest rates r_t and r_t^k, respectively. The government transfer is Γ_t^P. Total tax paid by the patient household (apart from VAT) τ_t^P comprises taxes on total income, property, and return on deposits and capital. τ_c is the tax on consumption (VAT), τ_w stands for the income tax rate, τ_p for the property tax rate, τ_d and τ_k for the tax rates on deposits and capital, respectively.

The last term in the budget constraint is the adjustment cost $AC^P = AC_t^{Pk} + AC_t^{Pd} + AC^{Ph}$ where $AC_t^{Pk} = \frac{\psi_k}{2}\frac{(k_t - k_{t-1})^2}{\bar{k}}$, $AC_t^{Pd} = \frac{\psi_{dh}}{2}\frac{(d_t - d_{t-1})^2}{\bar{d}}$, $AC_t^{Ph} = \frac{\psi_{hp}}{2} p_t^h \left[\frac{(h_t^P - h_{t-1}^P)^2}{\bar{h}^P} + \frac{(h_t^R - h_{t-1}^R)^2}{\bar{h}^R}\right]$.

The First Order Conditions (FOCs) with respect to residential and rental houses, respectively, are

$$\left(1 + \frac{\partial AC_t^P}{\partial h_t^P}\right) p_t^h = \beta_P E_t \left[\frac{\varphi_h^P \varepsilon_{ht} \varepsilon_{ct}}{\lambda_t^P h_t^P} + \frac{\lambda_{t+1}^P}{\lambda_t^P}\left((1 - \delta_h - \tau_p) p_{t+1}^h - \frac{\partial AC_{t+1}^P}{\partial h_t^P}\right)\right] \tag{2.2}$$

$$\left(1 + \frac{\partial AC_t^P}{\partial h_t^R}\right) p_t^h - (1 - \tau_w) p_t^R = \beta_P E_t \left[\frac{\lambda_{t+1}^P}{\lambda_t^P}\left((1 - \delta_h - \tau_p) p_{t+1}^h - \frac{\partial AC_{t+1}^P}{\partial h_t^R}\right)\right] \tag{2.3}$$

where λ_t^P is the Lagrange multiplier of the budget constraint at time t.

The FOCs with respect to consumption, deposit, capital and labor, respectively, are

$$(1 + \tau_c)\lambda_t^P = \frac{\varepsilon_{ct}}{c_t^P} \tag{2.4}$$

$$1 = \beta_P E_t \left[\frac{\lambda_{t+1}^P}{\lambda_t^P}(1 + (1 - \tau_d) r_t)\right] \tag{2.5}$$

$$\frac{1}{\varepsilon_{it}} + \frac{\partial AC_t^P}{\partial k_t} = \beta_P E_t \left[\frac{\lambda_{t+1}^P}{\lambda_t^P}\left(\frac{1}{\varepsilon_{it+1}}(1 - \delta_k) + (1 - \tau_k) r_{t+1}^k + \tau_k \delta_k - \frac{\partial AC_{t+1}^P}{\partial k_t}\right)\right] \tag{2.6}$$

$$\varphi_l^P (l_t^P)^\iota = \lambda_t^P (1 - \tau_w) w_t^P \tag{2.7}$$

2.1.2 Impatient (borrower) households

The problem of impatient households is

$$\max_{c_t^I, M_t, h_t^I, l_t^I} E_t \sum_{\tau=t}^{\infty} \beta_I^{\tau-t} \left\{ \varepsilon_{c\tau} \log c_\tau^I + \varphi_h^I \varepsilon_{h\tau} \varepsilon_{c\tau} \log h_{\tau-1}^I - \varphi_l^I \frac{(l_\tau^I)^{1+\iota}}{1+\iota} \right\}$$

$$s.t.$$

$$(1+\tau_c)c_t^I + p_t^h h_t^{Ih} + (1+r_{t-1}^b)M_{t-1} \leq w_t^I l_t^I + M_t + \Gamma_t^I - \tau_t^I - AC_t^I$$

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

$$\tau_t^I = \tau_w \left[w_t^I l_t^I - r_{t-1}^b M_{t-1} \right] + \tau_p p_t^h h_{t-1}^I$$

$$M_t \leq \rho_m M_{t-1} + (1-\rho_m)\varepsilon_{mt}\theta p_t^h h_t^I \tag{2.8}$$

β_I is the discount factor of impatient households. Impatient households at time t consume c_t^I, accumulate housing h_t^I, can request a mortgage M_t at rate r_t^b from the financial sector and receive total income ω_t^I for providing labor l_t^I with wage w_t, and get transfers Γ_t^I from the government. h_t^{Ih} is impatient housing investment. Total tax paid by the borrower, τ_t^I, is composed of income and property taxes. AC^I is the adjustment cost on mortgages and housing where $AC_t^I = \frac{\psi_m}{2}\frac{(M_t - M_{t-1})^2}{\bar{M}} + \frac{\psi_{hi}}{2} p_t^h \frac{(h_t^I - h_{t-1}^I)^2}{\bar{h}^I}$. The last equation in the impatient problem (2.8) is the borrowing constraint. The borrowing constraint is standard and used in the literature, for example, in Justiniano et al. (2015), Alpanda and Zubairy (2016) and Alpanda and Zubairy (2017). This constraint restricts the impatient household mortgage to a fraction of its housing value. θ is the LTV ratio in housing and ρ_m captures the persistence in the borrowing constraint and the fact that in practice, borrowing limits are not readjust every quarter [Iacoviello (2015)]. This friction is a channel which connects the real economy to the financial side. ε_{mt} is a shock to the LTV and so to the borrowing ability of the household.

The first-order conditions with respect to consumption, impatient households, mortgages and labor, respectively, are

$$(1+\tau_c)\lambda_t^I = \frac{\varepsilon_{ct}}{c_t^I} \tag{2.9}$$

$$p_t^h - \frac{\lambda_t^m}{\lambda_t^I}(1-\rho_m)\varepsilon_{mt}\theta p_t^h + \frac{\partial AC_t^I}{\partial h_t^I} = \beta_I E_t \left[\frac{\varphi_h^I \varepsilon_{ht}\varepsilon_{ct}}{\lambda_t^I h_t^I} + \frac{\lambda_{t+1}^I}{\lambda_t^I}\left((1-\delta_h-\tau_p)p_{t+1}^h - \frac{\partial AC_{t+1}^I}{\partial h_t^I} \right) \right] \tag{2.10}$$

$$1 - \frac{\lambda_t^m}{\lambda_t^I} + \frac{\partial AC_t^I}{\partial M_t} = \beta_I E_t \left[\frac{\lambda_{t+1}^I}{\lambda_t^I}\left(1 + (1-\tau_w)r_t^b - \frac{\partial AC_{t+1}^I}{\partial M_t} \right) - \frac{\lambda_{t+1}^m}{\lambda_t^I}\rho_m \right] \tag{2.11}$$

$$\varphi_l^I (l_t^I)^\iota = \lambda_t^I (1-\tau_w) w_t^I \tag{2.12}$$

where λ_t^I is the Lagrange multiplier of the budget constraint and λ_t^m is the Lagrange multiplier of the borrowing constraint at time t.

2.1.3 Renter households

Renter households are hand-to-mouth and consume what they earn. Introducing renters enables us to monitor their behavior and thus obtain a comprehensive analysis of housing channels.

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Without renters, patient households have three ways of transferring their wealth, namely residential houses, capital, and deposits; the existence of renters opens up another transfer channel that can impact house prices and other macro-variables. 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 renters' problem is

$$\max_{c_t^R, h_t^R, l_t^R} E_t \sum_{\tau=t}^{\infty} \beta_R^{\tau-t} \left\{ \varepsilon_{c\tau} \log c_\tau^R + \varphi_h^R \varepsilon_{h\tau} \varepsilon_{c\tau} \log h_{\tau-1}^R - \varphi_l^R \frac{(l_\tau^R)^{1+\iota}}{1+\iota} \right\}$$

$$s.t.$$

$$(1+\tau_c)c_t^R + p_t^R h_t^R \leq (1-\tau_{wr}) w_t^R l_t^R + \Gamma_t^R \tag{2.13}$$

β_R is the discount factor of renter households. A representative renter at the beginning of period t consumes c_t^R and rents a rental house h_t^R at current price p_t^R from the patient household. The renter receives utility in the next period (the end of period t) when changes his housing, which introduces a dynamic feature in the renter's problem. Renters cannot smooth their consumption by borrowing and lending. The renter supplies labor l_t^R to the economy and earns wage w_t^R. Because their income level is low, the government charges a lower tax on their wages, $\tau_{wr} < \tau_w$. Their income is made up of their wage and the government transfer Γ_t^R. The first-order conditions with respect to consumption, rental housing, and labor, respectively, are

$$(1+\tau_c)\lambda_t^R = \frac{\varepsilon_{ct}}{c_t^R} \tag{2.14}$$

$$p_t^R = \beta_R \frac{\varphi_h E_t[\varepsilon_{ht+1}^R \varepsilon_{ct+1}]}{\lambda_t^R h_t^R} \tag{2.15}$$

$$\varphi_l^R (l_t^R)^\iota = \lambda_t^R (1-\tau_{wr}) w_t^R \tag{2.16}$$

where λ_t^R is the Lagrange multiplier of the budget constraint at time t.

2.2 Financial intermediary (banker)

A representative banker consumes and intermediates between other agents. The banker issues liabilities d_t and assets a_t. The borrowers are either households who borrow in the form of mortgages M_t, or government[8] whose borrowings are termed government bonds b_t^g. The banker's utility function and budget constraint are

$$\max_{c_t^B, a_t, d_t} E_t \sum_{\tau=t}^{\infty} \beta_B^{\tau-t} \log c_\tau^B$$

$$(1+\tau_c)c_t^B + (1+r_{t-1})d_{t-1} + a_t + AC_t^B \leq d_t + (1+r_{t-1}^b)a_{t-1}$$

$$a_t = b_t^g + M_t$$

$$a_t - d_t \leq \varepsilon_{bt}(a_{t-1} - d_{t-1}) + (1-\varepsilon_{bt})(1-\overline{\phi})a_t \tag{2.17}$$

At time t, the bank consumes c_t^B, receives new deposits and the return on last-period loans, and pays the interest on its liabilities. AC^B is the adjustment cost of issuing liabilities and assets where $AC_t^B = \frac{\psi_a}{2} \frac{(a_t - a_{t-1})^2}{\bar{a}} + \frac{\psi_{db}}{2} \frac{(d_t - d_{t-1})^2}{\bar{d}}$. β_B is the discount factor of bankers.

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The last equation in the banker's problem (2.17) is the capital constraint similar to Iacoviello (2015) which limits the bank's lending to a fraction of its liabilities. ε_{bt} is a shock to the inertia in the capital adequacy constraint. This dynamic constraint provides the possibility of a deviation from the LTA ratio target $\overline{\phi}$, set by the authorities, so the bank is able to partially adjust to the target beyond one period. To better understand the mechanism, one can divide the capital constraint in (2.17) by a_t and use $\Phi_t \equiv 1 - \phi_t = \frac{a_t - d_t}{a_t}$ as the definition of the capital-to-asset ratio. As a result, the capital-to-asset ratio Φ_t is

$$\Phi_t = \varepsilon_{bt} \frac{a_{t-1}}{a_t} \Phi_{t-1} + (1 - \varepsilon_{bt}) \overline{\Phi} \tag{2.18}$$

This equation indicates that if financial conditions impose $0 < \varepsilon_b \leq 1$, the capital-to-asset ratio is a function of asset and so it is an endogenous variable (as asset a_t is endogenous). For example in the extreme case $\varepsilon_b = 1$, the percentage change in the capital-to-asset ratio is exactly equal to the percentage change of assets, that is, $\% \frac{\Delta \Phi_t}{\Phi_{t-1}} = \% \frac{\Delta a_t}{a_{t-1}}$. On the other hand, if the bank has to perfectly follow the regulation each period that is, $\varepsilon_b = 0$ the leverage ratio is set to the regulation target $\overline{\phi}$ and so it is exogenous.

The first-order conditions with respect to consumption, liabilities, and assets, respectively, are

$$(1 + \tau_c) \lambda_t^B = \frac{1}{c_t^B} \tag{2.19}$$

$$1 - \frac{\partial AC_t^B}{\partial d_t} = \frac{\lambda_t^\phi}{\lambda_t^B} + \beta_B E_t \frac{\lambda_{t+1}^B}{\lambda_t^B} \left(1 + r_t - \varepsilon_{bt+1} \frac{\lambda_{t+1}^\phi}{\lambda_{t+1}^B} + \frac{\partial AC_{t+1}^B}{\partial d_t} \right) \tag{2.20}$$

$$1 + \frac{\partial AC_t^B}{\partial a_t} = (\overline{\phi}(1 - \varepsilon_{bt}) + \varepsilon_{bt}) \frac{\lambda_t^\phi}{\lambda_t^B} + \beta_B E_t \frac{\lambda_{t+1}^B}{\lambda_t^B} \left(1 + r_t^b - \varepsilon_{bt+1} \frac{\lambda_{t+1}^\phi}{\lambda_{t+1}^B} - \frac{\partial AC_{t+1}^B}{\partial a_t} \right) \tag{2.21}$$

where $\lambda_t^B, \lambda_t^\phi$ are the Lagrange multipliers of the budget constraint and the borrowing constraint at time t, respectively.

2.3 Firms and Housing producers

Patient, impatient, and renter households work for the representative firm and receive wages depending on different labor elasticities, $\iota_P, \iota_I, \iota_R$. 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

$$Y_t = A_t k_{t-1}^\alpha ((l_t^P)^{\iota_P} (l_t^I)^{\iota_I} (l_t^R)^{\iota_R})^{1-\alpha} \tag{2.22}$$

where A_t is a technology shock. The firm maximizes its profit

$$\max_{k_t, l_t^P, l_t^I, l_t^R} Y_t - w_t^P l_t^P - w_t^I l_t^I - w_t^R l_t^R - r_t^k k_{t-1} \tag{2.23}$$

Since markets are perfectly competitive, the market prices are

$$\alpha \frac{Y_t}{k_{t-1}} = r_t^k \tag{2.24}$$

$$(1 - \alpha) \iota_i \frac{Y_t}{l_t^i} = w_t^i, \quad i = P, I, R \tag{2.25}$$

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In the economy, there is a continuum of measure-one firms and perfectly competitive housing producers which provide housing to households.[9] In each period, housing producers buy the undepreciated part of houses from households at a relative price p_t^h, then invest i_t^h to produce new houses h_t. Hence, they maximize their benefit as:

$$E_t \sum_{\tau=t}^{\infty} \beta_P^{\tau-t} \frac{\lambda_\tau^P}{\lambda_t^P} [p_\tau^h (h_\tau - (1-\delta_h) h_{\tau-1}) - i_\tau^h] \tag{2.26}$$

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.[10] Production is subject to an adjustment cost defined as a fraction of investment. As a result, housing production follows the law of motion:

$$\left[1 - \frac{\psi_{hp}}{2} \left(\frac{i_t^h}{i_{t-1}^h} - 1\right)^2\right] i_t^h = h_t - (1-\delta_h) h_{t-1} \tag{2.27}$$

The FOC with respect to housing reveals the house price:

$$\begin{aligned} p_t^h &\left[1 - \psi_{hp}\left(\frac{i_t^h}{i_{t-1}^h} - 1\right) \frac{i_t^h}{i_{t-1}^h} - \frac{\psi_{hp}}{2}\left(\frac{i_t^h}{i_{t-1}^h} - 1\right)^2\right] \\ &+ \beta_P E_t p_{t+1}^h \left[\frac{\lambda_{t+1}^P}{\lambda_t^P} \psi_{hp} \left(\frac{i_{t+1}^h}{i_t^h} - 1\right)\left(\frac{i_{t+1}^h}{i_t^h}\right)^2\right] = 1 \end{aligned} \tag{2.28}$$

2.4 Government and market clearing

The government collects all taxes from all agents,

$$T_t = \tau_c C_t + \tau_t \tag{2.29}$$

where T is the total tax revenue of the government. $C_t = c_t^P + c_t^I + c_t^R + c_t^B$ is total consumption. $\tau_t = \tau_t^P + \tau_t^I + \tau_{wr} w_t^R l_t^R$ is total tax paid by households. In each period, the government has access to bonds b_t^g, and total tax T_t, to pay its liabilities to the banker, lump-sum transfers Γ_t, and government spending g_t.

Hence, the government's budget constraint is

$$(1 + r_{t-1}^b) b_{t-1}^g + g_t + \Gamma_t = b_t^g + T_t \tag{2.30}$$

Transfers to each household depend on level parameters, ϑ_P, ϑ_I, ϑ_R, which are specific to the type of household, so

$$\Gamma_t = \Gamma_t^P + \Gamma_t^I + \Gamma_t^R \tag{2.31}$$

$$\Gamma_t^i = \vartheta_i Y_t, \quad i = I, P, R. \tag{2.32}$$

Market clearing for this economy is

$$Y_t = C_t + i_t^h + i_t^k + g_t \tag{2.33}$$

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

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Table 1. Calibrated parameters

Parameters	Symbol	Value
Discount factors	$\beta_P, \beta_I, \beta_R, \beta_B$	0.993, 0.981, 0.981, 0.922
Housing preference	$\varphi_h^P, \varphi_h^I, \varphi_h^R$	0.13, 0.20, 0.44
Labor supply parameter	φ_l	0.51
Depreciation rates	δ_h, δ_k	0.0083, 0.021
Transfer share	$\vartheta_P, \vartheta_I, \vartheta_R$	0.059, 0.058, 0.036
Loan-to-value ratio	θ	0.70
Liabilities-to-assets ratio	$\overline{\phi}$	0.90
Labor shares in production	$\iota_P, \iota_I, \iota_R$	0.23, 0.51, 0.26
Capital share in production	α	0.28
Inverse labor supply elasticity	ι	1
Inertia in borrowing constraint	ρ_m	0.85
Taxes	$\tau_k, \tau_c, \tau_p, \tau_d$	0.65, 0.05, 0.14/4, 0.15
Income taxes	τ_w, τ_{wr}	0.30, 0.20

3. Estimation and results

3.1 Calibration

Table 1 presents the model parameters values, which are calibrated as follows using quarterly US data to match steady state targets. The discount factors of households and the banker are set to target a 3% annual risk-free interest rate on deposits and a 6% annual interest rate on loans. Depreciation rates are set to 0.83% for housing and 2% for capital to target a 5% housing investment to GDP ratio and a 15% non-housing investment to GDP ratio (so total investment/GDP equal to 20%) according to the US Bureau of Economic Analysis GDP data and the Flow of Funds Accounts (FOF; Federal Reserve Board). Housing preferences $\varphi_h^P, \varphi_h^I, \varphi_h^R$ are set to 0.13, 0.20, 0.44, respectively, to secure $h_P/h = 0.27$, $h_I/h = 0.37$, $h_R/h = 0.36$, according to the Residential Finance Survey (RFS) and American Housing Survey (AHS). $\iota_P, \iota_I, \iota_R$ are set to 0.23, 0.51, 0.26, respectively, to target wage shares. The labor supply parameter is calibrated in order to get a one unit of patient labor supply at the steady state. Capital share in production α is set to 0.28 to insure a capital-to-GDP equal to 1.75 annually, based on the US Bureau of Economic Analysis capital data. The parameters for transfer shares $\vartheta_P, \vartheta_I, \vartheta_R$ are set to 0.059, 0.058, 0.036, respectively, to balance the budget constraints.[11] The LTV ratio is calibrated to fix the mortgage-to-housing value around 0.70 according to the AHS. The LTA ratio is set to 0.90 to be consistent with historical data on banks' balance sheets [Iacoviello (2005)]. All tax rates are set based on the US tax codes mentioned in Zubairy (2014). Inertia in borrowing constraint is set based on Alpanda and Zubairy (2016). The inverse of the Frisch elasticity of labor supply is set to 1 in line with Smets and Wouters (2007).

3.2 Results

There are six shocks in the model, namely shocks to: preference ε_c, housing demand ε_h, technology ε_A, investment ε_i, LTV ε_m, and the inertia in capital adequacy constraint of financial intermediaries ε_b. They follow AR(1) process

$$\log(\varepsilon_{it}) = \rho_i \log(\varepsilon_{it-1}) + \epsilon_{it}, \quad \epsilon_{it} \sim N(0, \sigma_i), \quad i = c, h, i, m \tag{3.1}$$

$$\log(A_t) = \rho_A \log(A_{t-1}) + \epsilon_{At}, \quad \epsilon_{At} \sim N(0, \sigma_A) \tag{3.2}$$

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Table 2. Estimation results

Parameter	Symbol	Pri. mean	Post. mean	90% HPD interval		De.	Pri sd	Post. sd
shock processes								
St. Dev., preference shock	σ_c	0.0205	0.0242	0.0211	0.0271	I.G	0.025	0.0019
St. Dev., housing shock	σ_h	0.0346	0.1742	0.1355	0.2080	I.G	0.050	0.0221
St. Dev., inv. shock	σ_i	0.0081	0.2012	0.1734	0.2266	I.G	0.025	0.0191
St. Dev., LTV shock	σ_m	0.0115	0.0469	0.0365	0.0576	I.G	0.025	0.0066
St. Dev., tfp shock	σ_A	0.0070	0.0075	0.0065	0.0085	I.G	0.025	0.0006
St. Dev., bank shock	σ_b	0.0025	0.3223	0.2540	0.3924	I.G	0.025	0.0475
Autocor., preference shock	ρ_c	0.90	0.8315	0.7989	0.8615	Be.	0.05	0.0194
Autocor., housing shock	ρ_h	0.90	0.8696	0.8377	0.8956	Be.	0.05	0.0178
Autocor., inv. shock	ρ_i	0.90	0.8642	0.8367	0.9004	Be.	0.05	0.0212
Autocor., LTV shock	ρ_m	0.90	0.9934	0.9881	0.9992	Be.	0.05	0.0038
Autocor., tfp shock	ρ_A	0.90	0.8411	0.8185	0.8697	Be.	0.05	0.0164
Autocor., bank shock	ρ_b	0.90	0.9297	0.9066	0.9522	Be.	0.05	0.0142
structural parameters								
Adj. cost,B. deposit	ψ_{db}	0.140	0.1387	0.0887	0.2174	Ga.	0.125	0.0415
Adj. cost,P. deposit	ψ_{dh}	0.135	0.0338	0	0.0666	Ga.	0.125	0.0225
Adj. cost,P. capital	ψ_k	1.730	5.0003	4.6063	5.3469	Ga.	0.500	0.2287
Adj. cost,I. mortgage	ψ_m	0.250	0.2574	0.0707	0.4331	Ga.	0.125	0.1088
Adj. cost,B. assets	ψ_a	0.470	0.4528	0.3261	0.5796	Ga.	0.125	0.0848
Adj. cost,P. housing	ψ_{hp}	0.200	0.1452	0.0301	0.2451	Ga.	0.125	0.0694
Adj. cost,I. housing	ψ_{hi}	0.200	0.2854	0.0317	0.5603	Ga.	0.125	0.1794
Adj. cost,HP. housing	ψ_h	2.480	15.642	11.708	20.598	Ga.	1.500	2.8463
Inertia in B. capital	$\overline{\varepsilon_b}$	0.240	0.63	0.6149	0.6665	Ga.	0.125	0.0167

P: patient household, I: impatient, B: banker, HP: housing producer, I.G: inverse gamma, Be: beta, Ga: gamma, HPD: highest posterior density interval. The number of replications for the Metropolis–Hastings algorithm is set to 100000. Final value of minus the log posterior (or likelihood): −1077.754.

$$\log\left(\varepsilon_{bt}/\overline{\varepsilon_b}\right) = \rho_b \log\left(\varepsilon_{bt-1}/\overline{\varepsilon_b}\right) + \epsilon_t^b, \qquad \epsilon_t^b \sim N(0, \sigma_b) \tag{3.3}$$

Following six shocks in the models, six time series are used to estimate the model. These series including real GDP, real consumption, real mortgages, real house prices, interest spreads, and total factor productivity are detrended and demeaned US quarterly data from 1990Q1 to 2019Q2.[12]

Dynare and Bayesian methods, as introduced in An and Schorfheide (2007), are used for the estimation. The optimizer for the mode computation is that introduced by Sims et al. (1999). The first 40 observations (1990Q1–1999Q4) are used as a training sample for the Kalman filter. The prior values are set as follows. It is assumed that all parameters are independent a priori. The housing stock adjustment costs are set as in Alpanda and Zubairy (2016). The adjustment cost for housing producers is set as in Roi et al. (2007). The inertia in the capital constraint at the steady state $\overline{\varepsilon_b}$, prior mean of standard deviations and autocorrelation of shocks, and the rest of adjustment costs are based on the estimation findings of Iacoviello (2015). This arrangement covers a wide range of outcomes.[13]

Table 2 presents the results of the estimation. The estimation shows that all the shocks are persistent with autocorrelation coefficients exceeding 0.83. The LTV shock for which the autocorrelation coefficient is around 0.99 is the most persistent meaning that even a small shock will affect future values for a very long time. Figure 2 presents the mean over time of the posterior distribution of the smoothed shocks to the capital adequacy constraint and housing demand. As

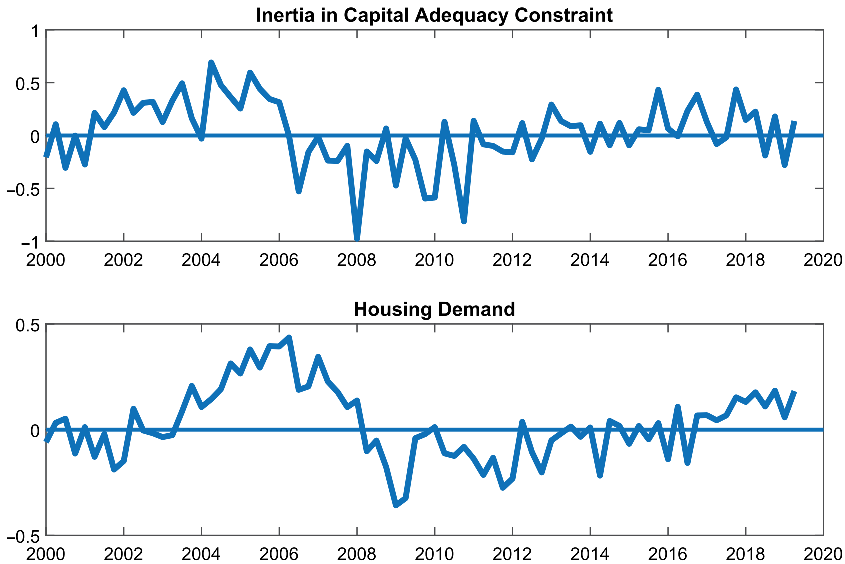

Figure 2. The mean over time of the posterior distribution of the smoothed shocks: (top) Inertia in capital adequacy constraint, and (bottom) housing demand.

the figure indicates, ε_{bt} was getting higher in the years preceding the 2008 financial crisis, that is, the financial condition was looser leading to high deviations from the regulatory target by banks; during the crisis, we observe negative shocks to ε_{bt}, that is, capital constraints were complied with more strictly and banks; thus, they had a greater commitment to follow the regulatory target. After 2012, the financial conditions were more strict than before the crisis but looser than during the crisis (see Financial-Stability-Reports (2018) and Reports (2019), Section 3: leverage in the financial sector) which can be observed by shocks to ε_{bt} around the mean. The housing demand shock arose before the crisis and at its maximum at 2006. It reduced afterward and touched its minimum in 2009. It has also been around its average in recent years. However, housing demand has followed a positive trajectory since 2017, which could be related to the US expansionary policy.

The household and bank deposit adjustment costs are estimated at 0.03 and 0.13. This difference between deposit adjustment costs shows that changing deposits is cheaper and easier for households than for bankers. In addition, the estimation indicates that for patient households, changing deposits is more convenient than changing houses (with an adjustment cost coefficient estimated at 0.14) or changing capital (with a coefficient estimated at 5). The result for the capital adjustment cost is consistent with the findings of Smets and Wouters (2007). The housing producer adjustment cost is estimated at 15. This result is roughly consistent with Justiniano et al. (2015). The estimated values for capital and housing producer adjustment costs confirm the existence of a high inertia in housing and capital investment.

The housing adjustment costs for impatient households is estimated twice of that of patient households. In addition, impatient households are subject to a mortgage adjustment cost. It shows that changing housing is therefore rather difficult for impatient households than patient households, who use their own resources to accumulate wealth. The inertia in capital adequacy constraint is estimated at 0.63 which is higher than average. This illustrates that in average throughout the sample period, the financial sector had a high degree of freedom to deviate from the regulatory target and avoid an instant recapitalization after facing a shock.

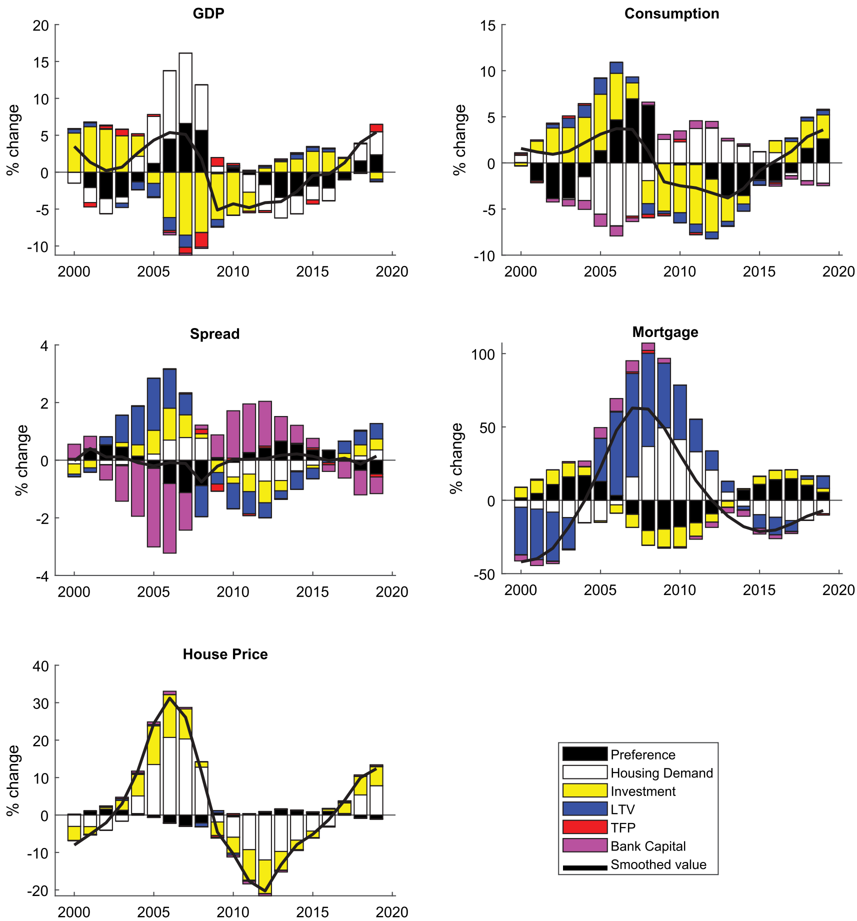

Figure 3. Historical decomposition of the estimated model. The solid line is the smoothed value of the respective variables in deviations from their steady state.

3.3 Contribution of shocks

Figure 3 illustrates the historical shock decomposition for the variables further to the data from 2000Q1 to 2019Q2. The results outline that the preference, housing demand, and investment shocks made the biggest contributions to output before the crisis, while the TFP and LTV shocks were added to this list during the crisis. In recent years, the preference, housing demand, and TFP shocks, which are all considered as non-financial shocks, have made the biggest contribution to output.[14] This result could be explained by the introduction of strict financial regulations after the crisis, such that financial shocks have progressively come under control. Financial shocks, such as LTV and capital adequacy shocks, are more dominant in interest spreads and mortgages, while in house prices, the mix of financial and non-financial (housing and investment) shocks are the major contributors.

While the impact of typical financial shocks such as those to investment and LTV is evident in the model, the contribution of the capital adequacy shock as a pure direct financial shock to the financial sector is an interesting point of discussion. The capital adequacy shock does not make a major contribution to output or house prices but provided an important input in consumption, interest spreads, and mortgages, especially before the financial crisis. The explanation is as follows.

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Before the financial crisis, the market experienced a positive shock to ε_b which could be interpreted as a change in the market discipline induced by shareholders of the bank or by financial conditions. As explained in the financial sector Section 2.2, this led the banks to stray from the set targets. As a result, the capital constraint was relaxed and the economy experienced a decrease in the capital-to-asset ratio. This had a positive impact on mortgages and thus on housing demand, investment, and consumption. After the crisis, and especially between 2010 and 2013, we observe tighter financial conditions, that is, a negative shock to ε_b. This reduces the contribution of the shock in the real variables. However, the spread is significantly influenced by the shock. To be more precise, by subtracting equations (2.21) from (2.20) (for simplicity, ignoring the adjustment costs)[15], the spread is defined as a function of the inertia in capital adequacy constraint ε_{bt}:

$$r_t^b - r_t = \frac{(1-\overline{\phi})\lambda_t^{\phi}}{\beta_B E_t \lambda_{t+1}^B}(1-\varepsilon_{bt}) \tag{3.5}$$

which indicates that the capital adequacy shock has a substantial impact on the interest spread between deposits and loans; the greater the inertia, the more relaxed the constraint and the smaller the spread.

Table 3 presents the accumulative contribution of each shock to the historical deviations in output, consumption, and house prices from their respective steady states before and during the 2008 financial crisis, and in recent years, that is, 2016–2019Q2. The results show that housing demand and investment shocks were the main drivers of the output boom and bust before and during the crisis. They have also played a dominant role in the growth of recent years. From 2005, the negative contribution of financial shocks started to reduce output. However, at the same time, non-financial shocks such as that to housing demand were strong enough to drive the economy; the positive contribution of housing demand alone was higher than all the negative impacts of financial shocks. This did not continue for long, however, and was reversed during the crisis; while financial shocks remained on their trajectory, housing demand, and preference shocks dropped drastically after 2008. As a result, the negative contribution of financial shocks offset the contribution of non-financial shocks, and output therefore dropped.

In recent years, both financial and non-financial shocks have contributed positively to growth. Before the crisis, contributions of all financial shocks to house prices were positive. This was reinforced by the impact of housing demand. As a result, a huge increase in house prices is observed. This was reversed entirely during the crisis. All the shocks contributed to a decrease in house prices, with financial shocks the main drivers among them. In recent years, house prices have recovered, and financial and housing-demand shocks have made a positive contribution to this recovery.

3.4 Transmission mechanisms

The previous section illustrates how different shocks contribute in shaping the US economy from 1990 until recent years. This section takes a precise look on the transmission mechanisms of these shocks and how they propagate from one sector to another, then summarizes the model dynamics in response to the estimated shocks with an impulse response analysis.

The favorable financial situation before the crisis facilitated lending by banks, thereby increasing their leverage. As a result, mortgage demand, impatient housing demand, and consequently the return on mortgages all increased. Impatient households could afford this high return and consume more due to the wealth effect, the relaxed borrowing constraint (due to LTV shock), and the relaxed capital constraint (due to the capital adequacy shock). As a result, the financial sector which faces high mortgage demand responded by two actions as follows. First, increasing deposit issuance by proposing a higher interest rate. As a result, patient households reallocate their savings from capital and housing to deposits. The drop in capital investment gradually

Table 3. Historical decomposition (%)

Contribution to	Shock	2005–2007	2008–2010	2016–2019Q2
Output				
	Preference	12.2	6.01	0.75
	Housing demand	25.1	7.13	3.72
	TFP	−0.81	−0.52	1,12
	All non-financial shocks	36.6	12.6	5.60
	Investment	−16.2	−20.1	3.7
	LTV	−5.20	−0.77	−0.03
	Capital adequacy	−0.70	−0.34	−0.04
	All financial shocks	−22.1	−21.2	3.68
House price				
	Preference	−5.63	−2.08	−0.65
	Housing demand	54.5	5.49	10.3
	TFP	−0.20	−0.12	−0.14
	All non-financial shocks	48.6	3.29	9.56
	Investment	29.8	−6.42	13.4
	LTV	0.27	−0.87	0.59
	Capital adequacy	1.97	−0.77	0.97
	All financial shocks	32.0	−8.07	14.9
Consumption				
	Preference	12.9	5.96	1.17
	Housing demand	−18.1	2.89	−3.35
	TFP	−0.17	−0.30	0.01
	All non-financial shocks	−5.39	8.55	−2.16
	Investment	12.9	−12.8	9.17
	LTV	3.54	−2.53	1.04
	Capital adequacy	−2.76	1.79	−1.31
	All financial shocks	13.6	−13.5	8.90

reduces output. Second, the bank may reallocate other assets to mortgages [Merler and Pisani-Ferry (2012)]. This channel needs a careful further investigation and I leave exploration of this topic for future research.

Another noteworthy fact which is captured by the model as shown in Figure 3 (house price) is the *house price downward spiral* when house prices still continue to fall, even after the crisis ends and recovery begins. In the context of the model, the house price downward spiral was a major factor contributing to the slow recovery after the Great Recession.[16] The mechanisms at work in house price behavior are as follows. The positive shock to housing demand was the reason for the initial house price increase after 2004. The increase in housing demand supported the increase in mortgages. Then, as discussed before, patient households prioritized deposits and decreased their housing investment. This, in turn, lowered demand and consequently house prices. In certain periods, this effect dominates the first mechanism, and house prices therefore come down. Impatient households benefit from lower house prices and expand their consumption and housing. This situation, in the presence of a positive shock to the capital adequacy constraint, leads financial agents to ignore the regulations and heat up the mortgage market by decreasing their bond holdings and increasing their liabilities. This is one step before the crisis. After the crisis, the

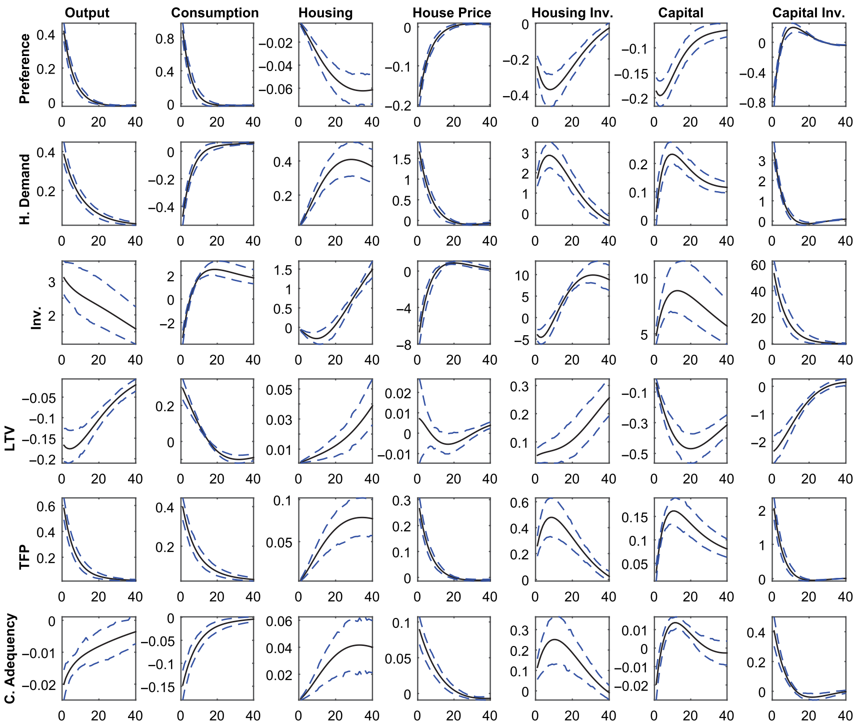

Figure 4. Impulse response analysis for key variables. Y = Percentage. X = Quarter. Solid line: posterior IRF at mean, dash lines: posterior IRF at 90% confidence intervals.

drop in house prices does not end as the recovery begins; they continue to fall. Housing demand and investment shocks are mostly responsible for this fall.

Figure 4 presents the impulse responses of key variables to financial and non-financial shocks estimated in the model. The figure indicates that the shock with the highest impact on GDP is the investment shock (about 3%); the smallest impact comes from the capital constraint shock with an absolute term of 0.02%. The estimated shocks to preference, housing demand, TFP, and investment have positive impacts on output. These positive responses are quite obvious as fully explained in the previous section. On the other hand, the shocks to LTV and capital adequacy lead to a decrease in output. These negative impacts are worth explaining.

First, the LTV: a shock to the LTV ratio has a direct impact on the ability of impatient households to raise mortgages. As a result, a positive shock increases mortgage demand. This pushes up both bank deposit demand (in order to supply mortgage demand) and impatient housing demand. The latter has a positive impact on house prices and housing investment. The rise in house prices brings down patient housing demand and makes space for a rise in consumption, capital, or deposits. Patient households prefer deposits for two reasons: first, the higher deposit demand from the banking sector which results in higher interest rates, and second, the fact that the deposit adjustment cost is much lower than that of capital. The aggregate impact of these mechanisms causes a decrease of 0.18% in output.

Second, the shock to the capital adequacy constraint: as shown in equation (3.4), the shock to the capital adequacy constraint decreases the interest spread (i.e. $r_t^b - r_t$) and relaxes the constraint. This means lower profit and consumption for bankers, and more leverage. This leverage is only possible through higher deposit demand, higher interest, and a higher mortgage supply. Mortgages are available for impatient households but at a higher price. This increases mortgages

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but dampens impatient consumption. As a result, house prices increase, but general consumption and, consequently, output decrease by about −0.02%. The impacts of the increase in house prices on patient households, and the rest of the mechanisms, are similar to the responses of LTV explained above.

4. Macroprudential regulations

4.1 Tools

The recent financial crisis resulted in a crucial role for macroprudential policy tools (hereafter MPTs) to ensure financial stability. This section investigates the application of three MPTs, namely (*i*) LTA ratio, (*ii*) LTV ratio, and (*iii*) DTI ratio. The section below looks at the impact of each of these MPTs and two policy mixes: the LTA-LTV set and LTA-DTI set, through the lens of welfare analysis.

MPTs are varied and apply to different sides of the economy. The LTA policy is an MPT for the financial sector which restricts banks' leverage. The goal is to reduce systematic risk by controlling $\overline{\phi}$ in the model. The LTV policy regulates θ in the model. Both the other MPTs, the LTV and DTI, are imposed to control borrowing constraints and thus have direct impacts on the mortgage and housing markets. The DTI policy puts caps on the credit growth of borrowers. In this paper, the DTI is introduced in the borrowing constraint of the impatient household problem (2.8) following Gelain et al. (2013).[17] As a result, the new borrowing constraint is

$$M_t \leq \rho_m M_{t-1} + (1-\rho_m)[\theta_w(w_t^I l_t^I) + (1-\theta_w)\varepsilon_{mt}\theta p_t^h h_t^I] \tag{4.1}$$

where θ_w is the weight assigned to the borrower's wage income. $\theta_w = 0$ gives the benchmark model. Applying the new borrowing constraint, the FOCs of impatient households in respect to housing and labor change to

$$p_t^h - \frac{\lambda_t^m}{\lambda_t^I}(1-\rho_m)\varepsilon_{mt}(1-\theta_w)\theta p_t^h = \beta_I E_t\left[\frac{\varphi_h^I \varepsilon_{ht}\varepsilon_{ct}}{\lambda_t^I h_t^I} + \frac{\lambda_{t+1}^I}{\lambda_t^I}((1-\delta_h-\tau_p)p_{t+1}^h)\right] \tag{4.2}$$

$$\varphi_l^I (l_t^I)^\iota = [\lambda_t^I(1-\tau_w) + \lambda_t^m(1-\rho_m)\theta_w]w_t^I \tag{4.3}$$

The transmission mechanisms of LTA and LTV are similar to those of shocks to the borrowing constraint and LTV, respectively, which are extensively explained in the previous section. The effective mechanism of DTI policy is also similar to that of the LTV, as both control mortgages. However, the DTI and LTV policies are different in nature. The LTV policy makes mortgages dependent on the housing market. The DTI makes mortgages reliant on real wages, which, from equation (2.25), represent the general situation of the economy and output. So the DTI is a procyclical policy. A strict implementation of a prudent DTI can regulate the housing boom and moderate the crisis. On the other hand, the DTI makes it difficult for the economy to recover after a crisis. The reasons are twofold. Firstly, GDP, capital, and wages decline after the crisis. The DTI policy restricts borrowers to their income, so their access to credit drops. Without a DTI policy, borrowers can raise more credit, even with low incomes. This could lead to a further contribution by impatient households, which might help the economy and boost the recovery. Secondly, a higher DTI results in a lower share of housing as collateral and lower mortgage demand. This reduces impatient consumption. The economy therefore slows down. This is why the policy-maker ought to take on board the fact that macroprudential policy tools should be timely, targeted, and temporary; otherwise, they may hinder growth and slow down recovery.

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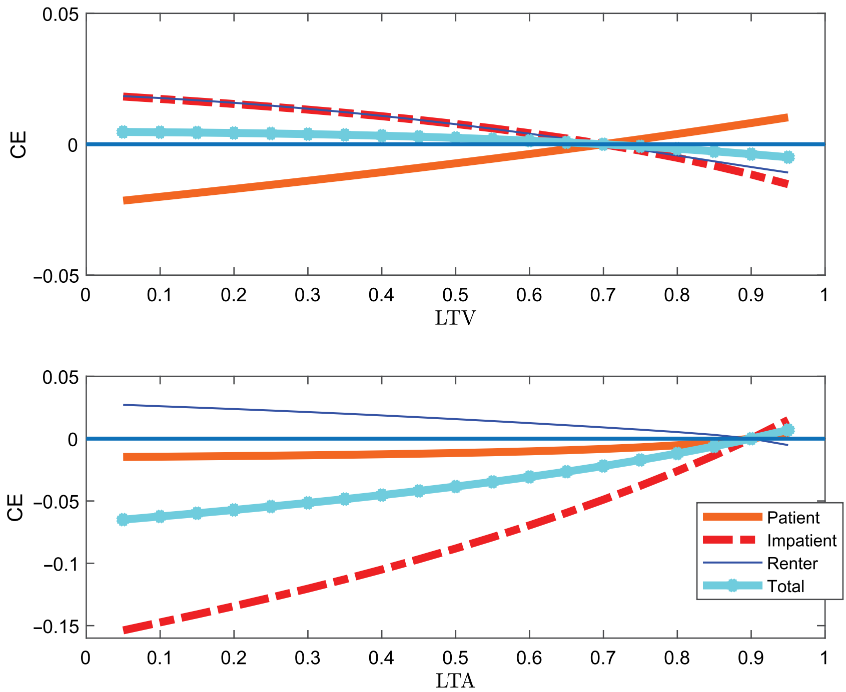

Figure 5. Welfare effect of a single macroprudential policy. (above) The LTV policy when the LTA ratio is fixed to that of the benchmark model. (bottom) The LTA policy when the LTV ratio is fixed to that of the benchmark model. Note that in this framework, CE close to zero means welfare moves around that of the benchmark model and does not mean that welfare is measured as zero.

4.2 Welfare analysis

Welfare impacts in this paper are analyzed following Rubio and Carrasco-Gallego (2014). Patient households', impatient households', and renters' welfare at time t are

$$f_t^i = E_t \sum_{\tau=t}^{\infty} \beta_i^{\tau-t} \left\{ \varepsilon_{c\tau} \log c_\tau^i + \varphi_h^R \varepsilon_{h\tau} \varepsilon_{c\tau} \log h_{\tau-1}^i - \varphi_l^R \frac{(l_\tau^i)^{1+\iota}}{1+\iota} \right\}, \quad i = P, I, R \tag{4.4}$$

The welfare change in terms of consumption equivalent is

$$CE_t^i = \exp\left[(1-\beta_i)(f_t^i - \overline{f}_t^i) \right], \quad i = P, I, R \tag{4.5}$$

CE refers to the amount of consumption that household's need to give away to obtain the benefits from the change in policy. $\overline{f}_t^i$ is welfare in the benchmark model, the model of Section 2 with the estimation results of Section 3. A new policy only changes the respective parameter in the benchmark model permanently from time t, ceteris paribus. With each change in a policy and consequently in the respective parameter, a new simulation is run to calculate f_t^i. The welfare measurement of the economy (or social/total welfare) is the weighted average of households' welfare:

$$CE_t^T = \frac{1}{\overline{c}} \left[\overline{c}^P.CE_t^P + \overline{c}^I.CE_t^I + \overline{c}^R.CE_t^R \right] \tag{4.6}$$

each agent's welfare is weighted by her consumption where $\overline{c}^i, i = P, I, R$ are the steady state of patient, impatient, and renter household consumption, respectively. $\overline{c}$ is the steady state of total consumption.

Figure 5 presents the welfare effects of different LTA and LTV policies separately. The LTA policy has a significant impact on total welfare. While it does not substantially affect patient

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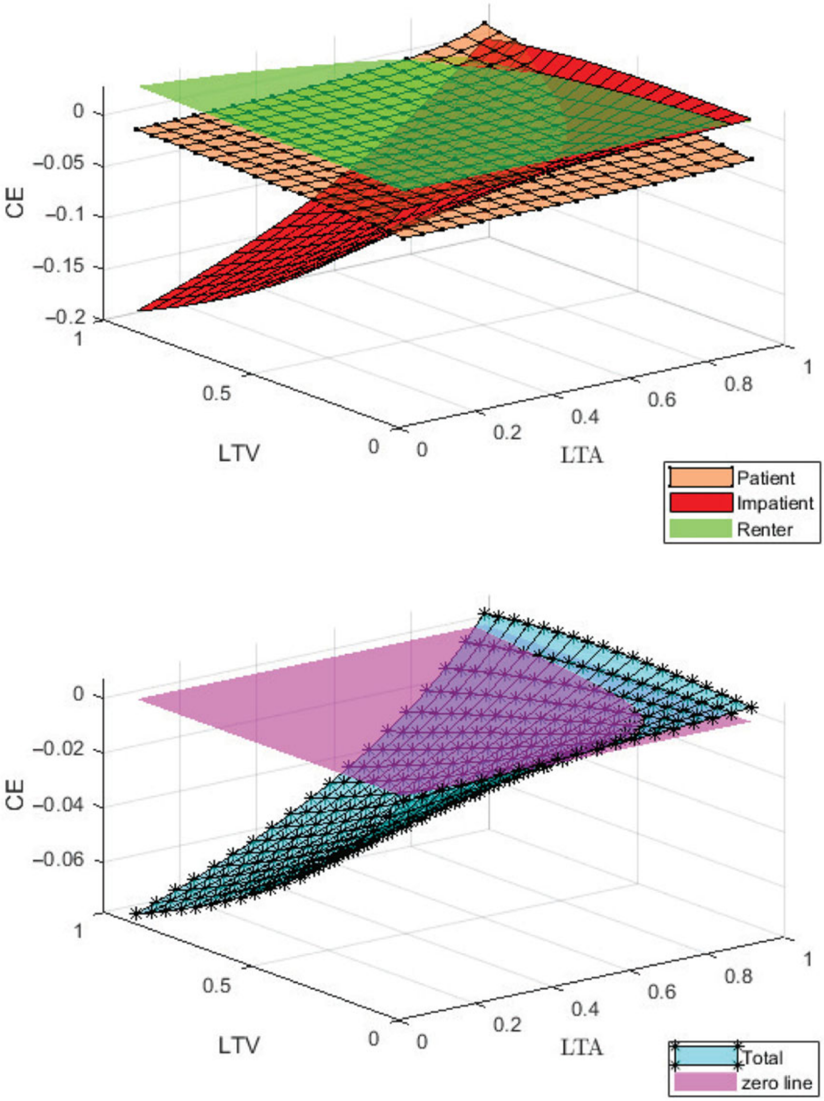

Figure 6. Welfare effect of a macroprudential policy mix: LTV and LTA together.

household welfare, it does have a huge impact on impatient and renter households. The reason is hidden in the mortgage market and mortgage interest r^b. From equation (2.21), the interest on mortgages is a decreasing function of LTA. A higher LTA relaxes the capital constraint and makes more mortgages available for impatient households at a lower price. This has a positive impact on all elements of impatient household welfare. Hence, impatient households are better off and welfare increases with respect to the LTA. For renters, the inverse is true due to the impact of rent prices; house prices and, consequently, rent prices rise due to impatient household demand. On the other hand, patient households do not notice a huge change. Patient household welfare increases slightly with respect to the LTA because of the secondary impact of the Lagrangian multiple of borrowing constraint on deposit interest, as the LTA does not have a direct impact on this interest (see equation (2.20)).

The LTV policy introduces a trade-off between the welfare of patient and impatient household. Impatient households and renters are worse off with higher LTVs; however, patient household

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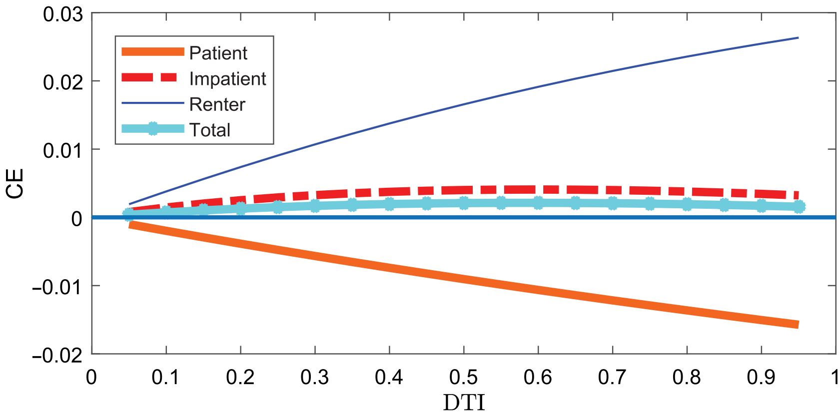

Figure 7. Welfare effect of a single macroprudential policy: DTI when other parameters are set to that of the benchmark.

welfare increases. Once again, the reason is hidden in the mortgage market: this time from the demand side. From equation (2.10), the higher the LTV, the higher the house prices. Renters definitely do not benefit from this situation. Mortgage demand and mortgage interest also increase with the LTV policy. This means a higher LTV results in higher repayments for impatient households in each period. These repayments make impatient households worse off. On the other hand, patient households observe an increase in deposit interest and house prices, but thanks to other ways of smoothing their consumption, the net impact is positive.

Figure 6 presents the welfare effects of policy mixes, when the LTA and LTV policies are in force together. The figure illustrates that there are various policy sets which lead to the same total welfare as the benchmark model. However, the impact of each policy on economic variables and households obviously varies.

Figure 7 depicts the welfare changes brought about by DTI. Applying DTI makes impatient and renter households better off and patient households worse off. The reasons are as follows. The DTI policy abates the power of LTV, as evidenced in equation (4.2). The DTI reduces mortgage demand as it shifts mortgages away from house values to the wage share (from 1.5 times GDP to about 60% of GDP). These channels taper house prices, and the first winners are therefore the renters. The impacts on patient and impatient households follow the same mechanism as that of the LTV policy explained above. The results indicate that introducing the DTI policy into the economy improves total welfare, but not significantly.

The welfare changes induced by a policy mix between LTA and DTI are illustrated in Figure 8. Similar to the previous policy mix, the points on the intersection between total welfare and the zero line are neutral policies. Policy-makers can choose between these points without changing total welfare; however, each point has a different impact on different types of households.

5. Conclusion

This paper applies a DSGE model to estimate and study financial and non-financial shocks and the application of macroprudential policies to an economy incorporating heterogeneous households, a financial sector, government, firms, a housing market, and house producers. The model features two financial frictions: first, borrowing constraints on borrower households based on house values, and second, flexible capital constraints on intermediary agents. This paper examines the impact of six shocks: preference, housing demand, technology, investment, LTV, and lastly, a shock to the inertia in capital adequacy constraint on financial intermediaries. This last shock is a new shock in the literature which captures the effective regulation level in the financial sector.

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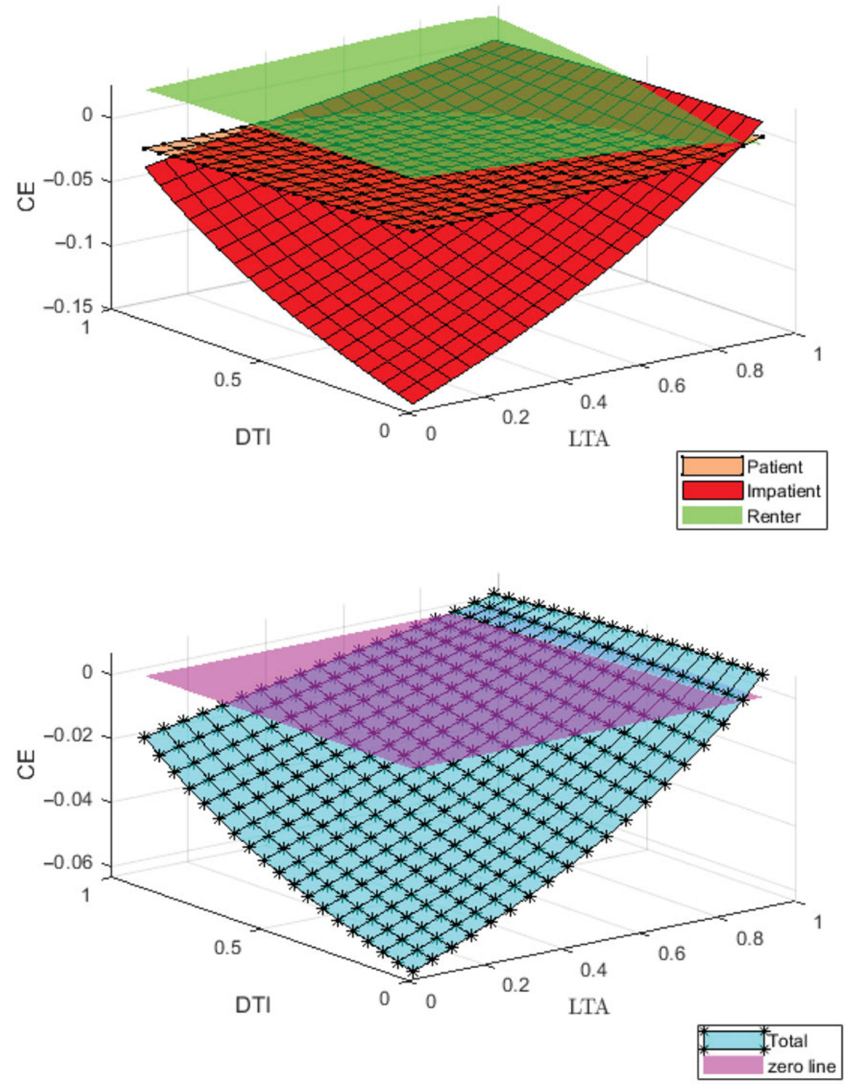

Figure 8. Welfare effect of a macroprudential policy mix: DTI and LTA together.

In addition, the role of macroprudential policy tools in protecting financial stability is assessed through the lens of a welfare analysis.

A few essential points must be made regarding the role of intermediaries in financial shocks. This would be an interesting starting point for future studies. This model does not permit banks to run, though this is not the case in a real economy like that of 2007 when financial corporations which could not meet their obligations were forced to run. Different orientations such as those used by Uhlig (2010), Calvo (2012) and Gertler and Kiyotaki (2015) would make an interesting addition to the model.

The dynamic stochastic general equilibrium (DSGE) model presented here has the ability to explore the impacts of other scenarios, for example, the impacts of fiscal reforms and government or banking defaults, similar to Roubini and Sachs (1989) and Ramey (2011). A government default may occur specifically in response to a government spending shock. One scenario could be a government default in order to provide more transfers to households. This situation could happen

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in an exceptional socio-political situation where governments might need political support. This is the case of some third world countries which have defaulted on their loans to increase public spending [Dinç (2005)].

While the experiments of this paper are illustrative of an important transmission channel of financial and non-financial shocks to business cycles, the paper abstracts the role of conventional and unconventional monetary policy. The latter played a very important role in the dynamic behavior of the economy during the sample period studied in the paper. Exploring the behavior of the model at the Zero Lower Bound and other improvements related to conventional or unconventional monetary policies are all interesting potential extensions of the current paper for future research.

Notes

1 The DSGE frameworks provide preferable tools to assess the impacts of shocks over vector autoregression (VAR) or vector error correction models (VECM), evidenced by Chen et al. (2016).

2 The collateral constraint in this paper is standard and widely used in the literature, for instance Rubio and Carrasco-Gallego (2014), Rubio (2014), Justiniano et al. (2015) etc.

3 Conventional regulatory conditions, for example, Basel supervision structures, suppose a minimum capital to assets ratio for banks, see for example Gertler and Kiyotaki (2010), Gertler and Karadi (2011) for more details.

4 A broad body of literature has dealt with the modeling of the financial sector, for instance, Gersbach et al. (2015), Tchana (2012), and the seminal works of Gerali et al. (2010), Brunnermeier and Sannikov (2014), and Gertler and Kiyotaki (2015). The financial sectors in these models either deal with an Overlapping generations model framework or solve a moral hazard problem enjoying utility from consumption in the period they exit. The model used in the current paper was chosen over these models for three reasons: (i) the model in the current paper uses a standard representative infinitely lived banking sector which allows bankers to receive utility that is linear in consumption each period. This aligns the model more closely to the state of the financial sector in the USA; (ii) the financial sector modeling of this paper is simple and intuitive, presenting an easy way to introduce new features. This offers a tractable and straightforward way of considering a multi-agent model without adding irrelevant complexity; (iii) introducing a bank portfolio, as it is defined in this paper, into the above models requires solving for the optimal portfolio that takes the form of a Constant elasticity of substitution functions (CES) aggregate of various assets similar to Auray et al. (2018). This adds unnecessary complication to the model, especially for the estimation part.

5 The aim of this tool is to build up buffers. The LTA policy has the same characteristic as the Capital Requirement Ratio (CRR). The LTA ratio is defined as Liabilities/Asset, and the CRR is (Assets-Liabilities)/Assets. As a result, CRR = 1 − LTA.

6 The policy-makers should be careful with this tool as a higher LTV makes mortgage loans available to subprime households and so increases the overall risk in the economy. This in turn may lead to a recession once the house prices sunk, similar to 2008. This paper only assesses the dynamics of LTA and not the associated risks.

7 Patient households enjoy living in residential houses, so h^P appears in the utility function and receive rent from rental houses so $p^R h^R$ appears in the budget constraint.

8 For the sake of stability as the government securities are almost risk-free and can be used generally for overnight/short-term borrowing, banks always hold government bonds (for more details, see Ogawa and Imai (2014) and https://www.bloomberg.com/news/articles/2016-10-30/banks-amass-2-4-trillion-hoard-of-bonds-as-bofa-leads-stampede). This amount was over 2.4 trillion dollars in 2016 and 2.55 trillion dollars in 2018. Source: Board of Governors of the Federal Reserve System (USA). The interest rate on mortgage and government bonds are assumed the same in this paper as this is an equilibrium outcome. Since deposits and government bonds are risk-free, the return must be the same as if they are different, the bank allocates all its assets on the product with the higher return. To have a portfolio of two assets, the interest rates should be the same. This is standard in the literature, for example, Alpanda and Zubairy (2016).

9 Similar to Roi et al. (2007).

10 Following Smets and Wouters (2007) and Alpanda and Zubairy (2016).

11 The size of the specific transfers to each type of households does not have a significant impact on the results. These transfers do not affect the model economy; since they are not in the first-order conditions, they are comparatively very small and conditional on output.

12 Data construction/description: data for real GDP, real consumption, real mortgage, and real house prices come from Economic Research Division, Federal Reserve Bank of St. Louis, https://fred.stlouisfed.org. Real GDP: Real Gross Domestic Product, Billions of Chained 2012 Dollars. Real consumption: Real Personal Consumption Expenditures, Billions of Chained 2012 Dollars. Real Mortgage: Households and nonprofit organizations; home mortgages; liability, Level, Billions of Dollars converted in real terms using the GDP deflator. Real house price: S&P/Case-Shiller US National Home Price Index, Index Jan 2000 = 100. Data for TFP: Utilization-adjusted quarterly growth rate of TFP constructed by Fernald (2014), Federal Reserve

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Bank of San Francisco Working Paper 2012–19. Data for Interest spreads: International Financial Statistics – IMF Data, https://data.imf.org/regular.aspx?key = 61545867. All these series are log-transformed and detrended independently by the quadratic trends as described in Iacoviello (2015). As shown in Mills (2013) for example, fitting a quadratic trend captures the modest curvature in such series, while the linear trend fails.

13 Following DSGE literature for example Pfeifer (2014), the prior arrangement should simply look sensible, that is, it has a single peak around a 1 percent standard deviation for example and be somewhat diffuse.

14 The shock category, financial or non-financial, is vastly debated in the literature [see for example Fornari and Stracca (2012)]. The shock category in this paper follows Iacoviello (2015).

15 The complete version of the spread with the adjustment costs is

$$r_t^b - r_t = \frac{1}{\beta_B E_t \lambda_{t+1}^B}\left[\lambda_t^{\phi}(1-\overline{\phi})(1-\varepsilon_{bt}) + \lambda_t^B\left(\frac{\partial AC_t^B}{\partial d_t} + \frac{\partial AC_t^B}{\partial a_t}\right) - \beta_B E_t \lambda_{t+1}^B\left(\frac{\partial AC_{t+1}^B}{\partial d_t} + \frac{\partial AC_{t+1}^B}{\partial a_t}\right)\right] \tag{3.4}$$

16 The data (e.g. FRED) show that it took almost 5 years for the US economy to return to the 2007 level of output per capita. Normally, for an economy like that of the US, it takes less time to return to the pre-recession peak [Christiano (2016)]. Some alternative explanations for the slow US recovery after the Great Recession which are not investigated in this paper are, for instance, the jobless recovery hypothesis [Galí et al. (2012)] and secular stagnation [Baldwin and Teulings (2014)].

17 The borrowing constraint of Gelain et al. (2013) is different than the one is used in this paper. However, the definition of the DTI and how it changes the borrowing constraint follow the same fashion as Gelain et al. (2013): as the DTI increases, “the regulator directs the lender to place more emphasis on the borrower’s wage income when making a lending decision.”

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