Leaning-Against-the-Wind: Which Policy and When?*

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Abstract

This paper quantitatively examines which of the following three widely-used leaning-against-the-wind policies is effective in stabilizing aggregate fluctuations: i) a monetary policy that responds to the loan-to-GDP ratio, ii) a countercyclical LTV policy, and iii) a countercyclical capital requirement policy. In particular, we estimate a New Keynesian model with financial frictions using U.S. data and find that a monetary policy rule that responds positively to the loan-to-GDP ratio destabilizes the economy while a countercyclical LTV policy has almost no effect. On the contrary, a countercyclical capital requirement policy is the most desirable in stabilizing GDP, inflation, and loans. However, the stabilization effect of the optimal countercyclical capital requirement policy is concentrated during periods in which financial shocks played a large role.

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1 Introduction

The Great Recession, followed by the collapse of financial markets, ignited a debate between two contrasting views on how to moderate financial cycles[1], so-called "Leaning-Against-the-Wind (henceforth LAW)". One view suggests the monetary authority should be ready to tighten whenever financial imbalances show signs of building up, even if inflation appears to be under control in the near term.[2] On the contrary, a group of researchers (Bernanke, 2013; Yellen, 2014; Svensson, 2018) point out the limitation of monetary policy when targeting multiple policy objectives. They instead propose additional policy tools, so-called, macroprudential policies. These policies are designed to strengthen the resilience of the financial system by limiting the build-up of financial fragility to prevent potential economic downturns (BIS, 2010). However, this debate has not been settled among both academic researchers and policymakers.

In this paper, we contribute to this ongoing debate by quantitatively comparing the impact of policies designed to curb the financial cycle. Previous studies focus on one policy, making it difficult to compare the effect of such a policy against other policies. Moreover, most models have a limited number of frictions or shocks, which may lead to underestimation of the effect of a particular policy. To fill the gap, we extend the model introduced by Iacoviello (2015) with various financial frictions by adding New Keynesian ingredients. We then estimate the model using U.S. data and quantitatively assess the policies' effectiveness in reducing the volatility of macroeconomic variables such as GDP and inflation.

In the estimated model, we consider three types of leaning-against-the-wind policies. The first one is a LAW monetary policy in the form of an extended Taylor rule that systematically increases the interest rate in response to a higher loan-to-GDP ratio. The other two are macroprudential policies widely used in practice (Cerutti, Claessens, and Laeven, 2017; Kim and Mehrotra, 2018): One is a countercyclical loan-to-value (henceforth LTV) regulation that tightens the LTV ratio when the loan-to-GDP ratio increases. The other is a countercyclical capital requirement (henceforth CCR) policy in line with the Basel III regulation that requires banks to accumulate sufficient capital buffers in good times for the possible capital losses in bad times.

We find that each policy has a different effect. First, the LAW monetary policy not only increases the volatility of inflation and GDP but also that of loans and the loan-to-GDP ratio. Second, though the countercyclical LTV regulation is effective in lowering the variation in loans and the loan-to-GDP

[1] We use financial cycles, credit cycles, and credit swings interchangeably.

[2] See BIS (2014) and Gourio, Kashyap, and Sim (2018) for further discussion.

ratio, it is nearly ineffective in stabilizing inflation and GDP. Last but by no means least, we find that the CCR policy is the most desirable in stabilizing GDP, inflation, loans, and loan-to-GDP ratio. Our results support the view that macroprudential policies should be used to moderate credit cycles.

We also further extend our analysis on the CCR policy by deriving the optimal CCR policy (in the sense of a simple rule) and studying how the historical paths of GDP and loans would appear if the policy were implemented. We find that the optimal CCR policy is only effective during periods in which financial shocks (e.g., housing demand, borrowers' default, and LTV shocks) play a significant role in driving the aggregate dynamics. In particular, had the optimal CCR policy been implemented during the Great Recession in which these shocks were more dominant, the U.S. would have experienced a substantially faster recovery in 2009 and after. Our findings suggest that when implementing a CCR policy, policymakers should take care to discern whether economic fluctuations arise from financial shocks, rather than focusing on the variations of loans or loan-to-GDP ratios themselves.

Our paper is related to an extensive literature that documents the effectiveness of macroprudential policies. Bailliu, Meh, and Zhang (2015) estimate a model using Canadian data and reach a similar conclusion to ours in that the benefits of macroprudential policies are more significant in the presence of financial shocks. However, the macroprudential policy in their model is ad-hoc, mainly because of the absence of collateral constraints and the banking sector. We incorporate these ingredients into our model so that we can compare the effectiveness of different macroprudential policies under a unified framework. Moreover, we estimate the model using U.S. data. Quint and Rabanal (2014) derive their optimal simple macroprudential policy rules conditional on each shock in a model estimated on Euro area data. Instead, our optimal macroprudential rule is derived conditional on all shocks, allowing us to evaluate its effectiveness over the historical U.S. business cycle. Suh (2012) derives the optimal simple macroprudential policy rules conditional on all shocks but does not estimate the model.

Kiley and Sim (2017) focus on the welfare effect of a macroprudential policy, which is a time-varying tax on the bank's leverage. Instead, we consider a policy that regulates not only the bank's balance sheet but also the borrowers' balance sheet. In addition, we concentrate on the effectiveness of policies on aggregate fluctuations. Ingholt (2020) compares the effect of countercyclical LTV and debt-service-to-income policies in a model that does not impose financial frictions on entrepreneurs. In contrast to his work, we compare the effect of countercyclical LTV and capital requirement policies in a model that does have financial frictions on entrepreneurs, which we find to be crucial in explaining aggregate fluctuations.

Last but not least, the work by Gelain, Lansing, and Natvik (2018) is closely related to ours with regards to the effect of a LAW monetary policy. They conclude that monetary policy should not lean against the credit swings in a model in which Fisher dynamics of debt is at work. We find that their argument holds in our model as well. While they only focus on a LAW monetary policy, our focus is on comparing the effects of LAW monetary and macroprudential policies.

The remainder of this paper is organized as follows. Our model is introduced in Section 2. In Section 3, we estimate the model and study the effect of various policies conditional on important shocks. Section 4 derives the optimal CCR policy and studies its effectiveness in stabilizing business cycles in the U.S. Section 5 concludes the paper.

2 Model

The model introduced in this section includes borrowing constraints on both lenders and borrowers and nominal rigidity, both which are crucial in studying the effects of various policies designed to curb credit swings. In particular, we build upon the model of Iacoviello (2015) by incorporating New Keynesian features similar to Canova, Coutinho, Mendicino, Pappa, Punzi, and Supera (2015).[3] The economy consists of patient households, impatient households, entrepreneurs, banks, retailers, and the monetary authority. Banks lend funds to both impatient households and entrepreneurs while they draw deposits from patient households.

2.1 Households

Patient households have a higher discount factor than impatient households. Hence, at the steady state, only patient households save, while impatient households borrow up to their borrowing limit. In addition, as in Iacoviello (2015), we assume that the borrowing limit for impatient households binds in a neighborhood of the steady state.

2.1.1 Patient Households

The patient households (savers), denoted by superscript s, choose a stream of consumption, C_t^s, hours worked, N_t^s, housing stock, H_t^s, investment, I^s, capital holding, K_t^s, the capital utilization rate, $u_{k,t}^s$, and real deposits, d_t, that maximizes:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_s^t \left[\varepsilon_t^c \log\left(C_t^s - hC_{t-1}^s\right) + \varepsilon_t^c \varepsilon_t^h \nu_h^s \log H_t^s - \nu_n^s \frac{\left(N_t^s\right)^{1+\varphi}}{1+\varphi} \right], \tag{2.1}$$

[3] Iacoviello (2005) also has financial frictions with New Keynesian features but does not have banks.

subject to the following budget constraint:

$$C_t^s + I_t^s + p_t^H \left(H_t^s - H_{t-1}^s\right) + d_t + AC_{d^s}(d_t) = w_t^s N_t^s + r_{t-1}^d \frac{d_{t-1}}{\pi_t} + r_t^{ks} u_{k,t}^s K_{t-1}^s - \Psi_s(u_{k,t}^s) K_{t-1}^s + Div_t \quad (2.2)$$

and the capital accumulation process given by:

$$K_t^s = \varepsilon_t^k I_t^s \left[1 - \frac{s_s}{2}\left(\frac{I_t^s}{I_{t-1}^s} - 1\right)^2\right] + (1-\delta) K_{t-1}^s. \quad (2.3)$$

In the utility function, β_s is the discount factor of patient households, h is the degree of habit formation, φ is the inverse of Frisch elasticity. ν_h^s is the relative weight on housing preference, and ν_n^s captures the disutility from working. ε_t^c is an exogenous shock to a preference for consumption and housing labeled as an aggregate spending shock following Iacoviello (2015). ε_t^h is a housing demand shock.

In the budget constraint, p_t^H is the price of housing relative to consumption goods, r_t^d is the nominal gross interest rate on deposits, and π_t is the gross inflation rate. r_t^{ks} and w_t^s are the rental rate of capital and the real wage that patient households receive, respectively. $\Psi_s(u_{k,t}^s)K_{t-1}^s$ is a cost of capital utilization, where $\Psi_s(u_{k,t}^s) = \rho^{u^s} \frac{{u_{k,t}^s}^{\frac{1}{1-\psi_s}} - 1}{\frac{1}{1-\psi_s}}$. $AC_{d^s}(d_t)$ is a convex cost of adjusting deposits from one period to the next. The functional form for the adjustment costs is $AC_{d^s}(x_t) = \frac{\kappa_{d_s}}{2}\frac{(x_t - x_{t-1})^2}{x}$, where κ_{d_s} measures the degree of the adjustment cost, and x is the steady state value of variable x_t. Div_t represents the dividends from retailers.

In the capital accumulation process, s_s determines the patient households' investment adjustment cost, δ is the capital depreciation rate, and ε_t^k is the marginal efficiency of investment (henceforth MEI) shock.

2.1.2 Impatient Households

The impatient households (borrowers), denoted by superscript b, choose a stream of consumption, C_t^b, hours worked, N_t^b, and housing stock, H_t^b, and real loans from banks, l_t^b, that maximizes:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_b^t \left[\varepsilon_t^c \log\left(C_t^b - hC_{t-1}^b\right) + \varepsilon_t^c \varepsilon_t^h \nu_h^b \log H_t^b - \nu_n^b \frac{\left(N_t^b\right)^{1+\varphi}}{1+\varphi}\right], \quad (2.4)$$

where β_b is the impatient households' discount factor. Their budget constraint is:

$$C_t^b + p_t^H \left[H_t^b - H_{t-1}^b \right] + \frac{r_{t-1}^b}{\pi_t} l_{t-1}^b + AC_{l^b}(l_t^b) = w_t^b N_t^b + l_t^b + \varepsilon_t^b, \tag{2.5}$$

where r_t^b is the nominal gross interest rate on loans, w_t^b is the real wage, and $AC_{l^b}(l_t^b)$ is a cost of adjusting loans. ε_t^b is a default shock faced by impatient households, which redistributes wealth from banks to impatient households. ν_h^b is the relative weight on housing preference, and ν_n^b captures the disutility from working. Moreover, impatient households are subject to a borrowing constraint:

$$l_t^b \leq \rho_b \frac{l_{t-1}^b}{\pi_t} + (1 - \rho_b) \left[\gamma_t^{Hb} \mathbb{E}_t \frac{p_{t+1}^H H_t^b}{r_t^b / \pi_{t+1}} \right], \tag{2.6}$$

where ρ_b allows for slow adjustment of loans in line with the observation that most households do not refinance every period. As in Gelain, Lansing, and Natvik (2018) and Ingholt (2020), this budget constraint allows for Fisher dynamics. That is, when most of the stock of debt is determined by decisions made in the past, real debt can be influenced by inflation. γ_t^{Hb} is the impatient households' loan-to-value (LTV) ratio, which determines their borrowing capacity for a given expected value of housing stock. We assume that this ratio varies according to:

$$\gamma_t^{Hb} = \gamma_0^{Hb} \varepsilon_t^{lb} - \gamma_1^{Hb} \left(\frac{l_t / GDP_t}{l / GDP} - 1 \right), \tag{2.7}$$

where GDP_t denotes GDP and l_t is the total loans made by banks. Variables without a time subscript are the steady-state levels of the corresponding variables. The first term on the right-hand side is subject to a shock, ε_t^{lb}, capturing exogenous changes in the banks' lending standard on impatient households. We label this shock as the impatient households' LTV shock. The second term captures the systematic response of the LTV ratio to the loan-to-GDP ratio, reflecting a popular macroprudential policy that aims to stabilize the household debt. If $\gamma_1^{Hb} > 0$, the LTV ratio falls when loans increase relative to GDP, discouraging impatient households' borrowing.

2.2 Entrepreneurs

Entrepreneurs, denoted by superscript e, produce intermediate goods X_t^e and sell those at price p_t^X in a competitive market. They use labor supplied by households, their own housing, H_{t-1}^e, capital produced by themselves, K_{t-1}^e, and capital rented from patient households, K_{t-1}^s. The Cobb-Douglas production technology is:

$$X_t^e = \varepsilon_t^z \left(\left(K_{t-1}^e\right)^{\omega_k} \left(K_{t-1}^s\right)^{1-\omega_k} \right)^{\alpha} \left(H_{t-1}^e\right)^{\nu} \left(\left(N_t^s\right)^{\omega_n} \left(N_t^b\right)^{1-\omega_n} \right)^{(1-\alpha-\nu)}, \tag{2.8}$$

where ε_t^z is the total factor productivity (TFP) shock, and ν and α are the share of housing and physical capital in production, respectively. $1-\omega_k$ and ω_n are the share of patient households' capital and labor in production, respectively. Entrepreneurs choose a stream of consumption, C_t^e, capital, K_{t-1}^e, the capital utilization rate, $u_{k,t}^e$, real loans from banks, l_t^e, that maximizes:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_e^t \log\left(C_t^e - hC_{t-1}^e\right) \tag{2.9}$$

subject to the budget constraint:

$$\begin{aligned} C_t^e + I_t^e + p_t^H[H_t^e - H_{t-1}^e] + w_t^s N_t^s + w_t^b N_t^b + r_t^{ks} K_{t-1}^s + \frac{r_t^e}{\pi_t} l_{t-1}^e + AC_{l^e}(l_t^e) + \Psi_e(u_{k,t}^e) K_{t-1}^e \\ = p_t^X X_t^e + l_t^e + \varepsilon_t^e \end{aligned} \tag{2.10}$$

and the capital accumulation process given by:

$$K_t^e = \varepsilon_t^k I_t^e \left[1 - \frac{s_e}{2} \left(\frac{I_t^e}{I_{t-1}^e} - 1 \right)^2 \right] + (1-\delta) K_{t-1}^e. \tag{2.11}$$

In the utility function, β_e is the entrepreneurs' discount factor. In the capital accumulation process, s_e determines the entrepreneurial investment adjustment cost. In the budget constraint, r_t^e is the nominal gross interest rate on the entrepreneurs' outstanding loans, and $\Psi_e(u_{k,t}^e)K_{t-1}^e$ is a cost of capital utilization, where $\Psi_e(u_{k,t}^e) = \rho^{u^e} \frac{{u_{k,t}^e}^{\frac{1}{1-\psi_e}} - 1}{\frac{1}{1-\psi_e}}$. $AC_{l^e}(l_t^e)$ is a cost of adjusting loans. ε_t^e is a default shock faced by entrepreneurs, which transfers wealth from banks to entrepreneurs. As impatient households, entrepreneurs face a borrowing constraint:

$$l_t^e \leq \rho_e \frac{l_{t-1}^e}{\pi_t} + (1-\rho_e) \left(\gamma_t^{He} \mathbb{E}_t \frac{p_{t+1}^H H_t^e}{r_{t+1}^e / \pi_{t+1}} + \gamma_t^{Ke} K_t^e - \gamma_t^{Ne} (w_t^s N_t^s + w_t^b N_t^b) \right), \tag{2.12}$$

where ρ_e captures a slow adjustment of loans. Contrary to impatient households, entrepreneurs can use both housing and capital stock as collateral when borrowing from banks. γ_t^{He} and γ_t^{Ke} are a fraction of the expected value of housing and capital they can pledge on, respectively. As in the impatient households' problem, γ_t^{He} consists of an exogenous term and a term that captures a systematic response:

$$\gamma_t^{He} = \gamma_0^{He}\varepsilon_t^{le} - \gamma_1^{He}\left(\frac{l_t/GDP_t}{l/GDP} - 1\right), \tag{2.13}$$

where ε_t^{le} represents a shock to banks' lending standard on entrepreneurs, labeled as the entrepreneurial LTV shock. In addition, entrepreneurs are assumed to pay a fraction γ_t^{Ne} of wage bills in advance. We assume $\gamma_t^{Ke} = \gamma_0^{Ke}\varepsilon_t^{le}$ and $\gamma_t^{Ne} = \gamma_0^{Ne}\varepsilon_t^{le}$.

2.3 Banks Banks, denoted by superscript r, collect deposits from patient households and lend to impatient households and entrepreneurs. Their objective function is:

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_r^t \log\left(C_t^r - hC_{t-1}^r\right), \tag{2.14}$$

where β_r is their discount factor and is assumed to be $\beta_r < \beta_s$. Accordingly, banks have an incentive to accumulate debt relative to equity.[4] Their budget constraint is:

$$C_t^r + l_t^b + l_t^e + \frac{r_{t-1}^d}{\pi_t}d_{t-1} + AC_{d^r}(d_t) + AC_{l^{er}}(l_t^e) + AC_{l^{br}}(l_t^b) = d_t + \frac{r_t^e}{\pi_t}l_{t-1}^e + \frac{r_{t-1}^b}{\pi_t}l_{t-1}^b - \varepsilon_t^b - \varepsilon_t^e \tag{2.15}$$

where C_t^r is banks' consumption. As before, $AC_{d^r}(d_t)$, $AC_{l^{er}}(l_t^e)$, and $AC_{l^{br}}(l_t^b)$ denote costs of adjusting deposits, loans to entrepreneurs, and loans to impatient households, respectively. Banks face a constraint on their bank capital:

$$l_t^b + l_t^e - d_t - \varepsilon_t^b - \varepsilon_t^e \geq \rho_r\left(\frac{l_{t-1}^b}{\pi_t} + \frac{l_{t-1}^e}{\pi_t} - \frac{d_{t-1}}{\pi_t} - \varepsilon_{t-1}^b - \varepsilon_{t-1}^e\right) + (1-\rho_r)(\eta_t^b l_t^b + \eta_t^e l_t^e - \varepsilon_t^b - \varepsilon_t^e), \tag{2.16}$$

where ρ_r governs the speed at which banks' capital is adjusted. If we assume $\rho_r = 0$ and $\eta_t^b = \eta_t^e$ for simplicity, equation (2.16) can be rewritten as:

$$\frac{l_t^b + l_t^e - d_t}{l_t^b + l_t^e} \geq \eta_t^b,$$

implying that banks' capital must be greater than a fraction η_t^b of their total assets. Therefore, η_t^b and η_t^e determine how strict the regulation on banks' capital is. Similar to the LTV ratios, the degree of bank

[4] The preference of debt over equity can also be introduced by tax treatment on debt, equity dilution cost, or liquidity premium on deposits.

capital regulation is determined by two terms:

$$\eta_t^x = \eta_0^x + \eta_1^x \left(\frac{l_t/GDP_t}{l/GDP} - 1 \right) \quad \text{for} \quad x \in \{b, e\}. \tag{2.17}$$

The first term represents a time-invariant regulation, and the second term captures a systematic response of regulation to total loans in the economy as a share of GDP. When $\eta_1^x > 0$, capital regulation is countercyclical in the sense that it requires banks to hold more bank capital relative to assets when total credit expands more than GDP.

2.4 Retailers A retailer purchases goods from entrepreneurs and converts each good into a specialized intermediate good, indexed by $j \in [0,1]$, at no costs. Then a retailer sells the intermediate good j to the final goods firm at price $P_t(j)$. Final output Y_t is given by:

$$Y_t = \left[\int_0^1 Y_t(j)^{\frac{1}{1+\theta_{p,t}}} dj \right]^{1+\theta_{p,t}}, \tag{2.18}$$

where $\theta_{p,t} > 0$ denotes the price markup in the market for intermediate goods. The cost minimization problem of the final goods firms yields the inverse demand function:

$$Y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\frac{1+\theta_{p,t}}{\theta_{p,t}}} Y_t \tag{2.19}$$

and the aggregate price index $P_t = \left(\int_0^1 P_t(j)^{-\frac{1}{\theta_{p,t}}} dj \right)^{-\theta_{p,t}}$.

Retailers are subject to nominal price rigidity following Calvo (1983), so that, in every period, a fraction ξ_p of retailers index their prices to lagged inflation according to:

$$P_t(j) = \pi_{t-1}^{\iota_p} \pi^{1-\iota_p} P_{t-1}(j),$$

where ι_p represents the degree of indexation. The remaining retailers choose their period t optimal price P_t^* by maximizing the present discounted value of expected future real profits. Formally,

$$\max_{P_t^*} \mathbb{E}_t \sum_{\tau=0}^{\infty} (\xi_p)^\tau \left(\beta_s \frac{\lambda_{t+\tau}}{\lambda_t} \right) \left\{ \left[\frac{P_t^* \chi_{t,t+\tau}}{P_{t+\tau}} - \frac{P_{t+\tau}^X}{P_{t+\tau}} \right] Y_{t+\tau}(j) \right\},$$

subject to the demand constraint (2.19), where $\chi_{t,t+\tau} = \Pi_{k=1}^{\tau} \pi_{t+k-1}^{\iota_p} \pi^{1-\iota_p}$ if $\tau \geq 1$, and $\chi_{t,t} = 1$. λ_t is the marginal utility of patient households.

2.5 Monetary Authority As in Gelain, Lansing, and Natvik (2018), we assume that monetary policy is in the form of an extended Taylor rule, which incorporates the loan-to-GDP ratio as an additional determinant of the policy rate $R_{t+1} = r_t^d$:

$$\frac{R_t}{R} = \left[\left(\frac{R_{t-1}}{R} \right)^{\rho_R} \left[\left(\frac{\pi_t}{\pi} \right)^{\gamma_\pi} \left(\frac{GDP_t}{GDP_{t-1}} \right)^{\gamma_{GDP}} \left(\frac{l_t/GDP_t}{l/GDP} \right)^{\gamma_L} \right]^{1-\rho_R} \right] \epsilon_t^R, \tag{2.20}$$

where ϵ_t^R is an independently and identically distributed (i.i.d.) monetary policy shock with variance σ_R^2. ρ_R governs the policy rate inertia, and γ_π, γ_{GDP}, and γ_L represent the monetary authority's sensitivity to the inflation rate, GDP growth rate, and loan-to-GDP ratio, respectively.

2.6 Housing Market We assume that the housing supply is exogenously given by $\bar{H}$, normalized to 1. Then the housing market clearing condition is:

$$\bar{H} = H_t^s + H_t^b + H_t^e. \tag{2.21}$$

2.7 Exogenous Shocks We have five non-financial shocks: aggregate spending (ε_t^c), MEI (ε_t^k), TFP (ε_t^z), markup ($\theta_{p,t}$), and monetary policy (ϵ_t^R) shocks. Moreover, we have five financial shocks: housing demand (ε_t^h), two default (ε_t^b, ε_t^e), and two LTV (ε_t^{lb}, ε_t^{le}) shocks. Apart from the monetary policy shock, the shock processes are:

$$\log(1+\theta_{p,t}) = (1-\rho_p)\log(1+\theta_p) + \rho_p \log(1+\theta_{p,t-1}) + \epsilon_t^p, \tag{2.22}$$

$$\log \varepsilon_t^x = \rho_x \log \varepsilon_{t-1}^x + \epsilon_t^x \quad \text{for} \quad x \in \{c, k, z, h, lb, le\}, \tag{2.23}$$

$$\varepsilon_t^x = \rho_x \varepsilon_{t-1}^x + \epsilon_t^x \quad \text{for} \quad x \in \{b, e\}, \tag{2.24}$$

where ϵ_t^x is the i.i.d. disturbance that is normally distributed with mean 0 and variance σ_x^2, for $x \in \{p, c, k, z, h, lb, le, b, e\}$.

3 Estimation and Impulse Responses

We solve and estimate the log-linearized model's parameters using a Bayesian method.

3.1 Data and Calibration We estimate the model using ten observables: real consumption, real nonresidential fixed investment, losses on loans to businesses, losses on loans to households, loans to businesses, loans to households, real house prices, total factor productivity, the growth rate of the GDP deflator, and the federal funds rate. The last two series are demeaned. The remaining series are retrieved from Iacoviello (2015). We estimate the model using U.S. quarterly data from 1985Q1 to 2010Q4.

The following set of parameters are fixed during the estimation. The patient households' discount factor, β_s, the impatient households' discount factor, β_b, the entrepreneurs' discount factor, β_e, and the discount factor of banks, β_r, are fixed at 0.9925, 0.94, 0.94, and 0.945, respectively. The housing preference parameters, ν_s^h and ν_b^h, and labor disutility parameters, ν_s^n and ν_b^n, are 0.075 and 2, respectively. The capital depreciation rate, δ, the total capital share in production, α, and the housing share in production, ν, are 0.035, 0.35, and 0.04, respectively. These values are taken from Iacoviello (2015). The steady state markup, θ_p, is fixed at 0.1. We set the steady state LTV ratio on housing, γ_0^{Hb}, LTV ratio on capital, γ_0^{Kb}, fraction of the wage bill that must be paid in advance, γ^{Ne}, equal to 0.7, 0.9, and 0.7, respectively. The steady state minimum capital requirements, η_0^b and η_0^e, are fixed to 0.08. Finally, the model we estimate assumes no systematic response of monetary policy, LTV ratios, and minimum capital requirements to the loan-to-GDP ratios (i.e., $\gamma_L = \gamma_1^{Hb} = \gamma_1^{He} = \eta_1^b = \eta_1^e = 0$).

3.2 Priors, Posteriors, and Variance Decomposition The priors on the parameters that we estimate are fairly diffuse and broadly in line with those adopted in previous studies, such as Justiniano, Primiceri, and Tambalotti (2010), Iacoviello (2015), and Gelain, Lansing, and Natvik (2018). Tables 3.1 and 3.2 report the prior and posterior distributions of the model's structural parameters and parameters governing shock processes. As in Iacoviello (2015), we find substantially more persistence in the households and entrepreneurs' borrowing than in the banks' equity. The high persistence of the borrowing arises from the well-known observation that credit tends to lag non-financial variables such as output and inflation. Moreover, estimates of the degree of habits, investment adjustment costs, price stickiness, indexation, and coefficients of monetary policy rules are fairly in line with those presented in Justiniano, Primiceri, and Tambalotti (2010) and Christiano, Motto, and Rostagno (2014). The inverse of Frisch elasticity of labor supply is estimated to be very similar to the one estimated by Gelain, Lansing, and

Table 3.1: Prior and Posterior Dist. of Structural Parameters

Parameter	Description	Prior dist.			Posterior dist.		
		Distribution	Mean	SD	Mean	5%	95%
h	Consumption habits	Beta	0.6	0.1	0.75	0.68	0.83
φ	Inv. Frisch elasticity	Gamma	0.5	0.1	0.26	0.16	0.35
κ_{d^r}	Deposit adj. cost, bank	Gamma	0.25	0.125	0.25	0.06	0.44
κ_{d^s}	Deposit adj. cost, pat. H	Gamma	0.25	0.125	0.24	0.07	0.39
$\kappa_{l^{er}}$	Loan to ent. adj. cost, bank	Gamma	0.25	0.125	0.28	0.07	0.48
κ_{l^e}	Loan to ent. adj. cost, ent.	Gamma	0.25	0.125	0.25	0.06	0.44
$\kappa_{l^{br}}$	Loan to imp. H adj. cost, bank	Gamma	0.25	0.125	0.27	0.07	0.47
κ_{l^b}	Loan to imp. H adj.cost, imp. H	Gamma	0.25	0.125	0.26	0.06	0.46
s_s	Investment adj. cost, pat. H	Gamma	4	1	5.91	4.06	7.79
s_e	Investment adj. cost, ent.	Gamma	4	1	4.73	3.08	6.32
ρ_r	Persist. of bank equity	Beta	0.25	0.1	0.24	0.08	0.40
ρ_e	Persist. of deleveraging, ent.	Beta	0.25	0.1	0.85	0.81	0.89
ρ_b	Persist. of deleveraging, imp. H	Beta	0.25	0.1	0.81	0.75	0.87
ψ_s	Capital utilization cost, pat. H	Beta	0.5	0.15	0.60	0.40	0.81
ψ_e	Capital utilization cost, ent.	Beta	0.5	0.15	0.60	0.39	0.83
ω_n	Labor share of pat. H	Beta	0.7	0.1	0.83	0.78	0.88
ω_k	Capital share of ent.	Beta	0.5	0.1	0.46	0.38	0.55
ξ_p	Calvo price	Beta	0.5	0.1	0.90	0.86	0.93
ι_p	Price indexation	Beta	0.5	0.15	0.18	0.07	0.28
ρ_R	Taylor rule: smoothing	Beta	0.6	0.2	0.63	0.57	0.70
γ_π	Taylor rule: inflation	Norm	1.7	0.3	1.84	1.53	2.13
γ_{GDP}	Taylor rule: GDP	Norm	0.4	0.3	1.12	0.79	1.44

Note: The posterior distribution is constructed from the random-walk Metropolis–Hastings algorithm with a single chain, keeping 250,000 draws after a burn-in period of size 250,000.

Natvik (2018), whose model embeds collateral constraint, persistence in borrowing, and New Keynesian features.

Although we build on the model of Iacoviello (2015), we cannot directly compare our estimates of the shocks processes to his because his model does not incorporate sticky prices, a monetary policy shock, and a markup shock. To understand how the presence of these elements alters the relative roles of the different shocks in our model, we report the variance decomposition for selected variables in Table 3.3. The table shows that financial shocks, in combination, explain about 26% of the variance of GDP.[5] Moreover, they drive at least 80% of the variation in the financial variables such as loans to entrepreneurs and households, and losses on loans to entrepreneurs and households, and house prices. The large role of financial shocks in explaining financial and non-financial variables provides a rationale for investigating

[5] GDP is the sum of aggregate consumption, C_t, and aggregate investment, I_t.

Table 3.2: Prior and Posterior Dist. of Shock Processes

Parameter	Description	Prior dist.			Posterior dist.		
		Distribution	Mean	SD	Mean	5%	95%
ρ_C	Auto. agg. spending	Beta	0.6	0.2	0.77	0.69	0.86
ρ_H	Auto. housing demand	Beta	0.6	0.2	0.99	0.98	1.00
ρ_K	Auto. MEI	Beta	0.6	0.2	0.63	0.54	0.72
ρ_Z	Auto. TFP	Beta	0.6	0.2	0.91	0.85	0.96
ρ_p	Auto. markup	Beta	0.6	0.2	0.79	0.68	0.90
ρ_b	Auto. imp. H default	Beta	0.6	0.2	0.99	0.97	1.00
ρ_e	Auto. ent. default	Beta	0.6	0.2	0.93	0.89	0.97
ρ_{lb}	Auto. imp. H LTV	Beta	0.6	0.2	0.97	0.95	0.99
ρ_{le}	Auto. ent. LTV	Beta	0.6	0.2	0.89	0.84	0.95
$100\sigma_C$	Std. agg. spending	Inv. Gamma	0.5	1	3.21	2.39	3.97
$100\sigma_H$	Std. housing demand	Inv. Gamma	0.5	1	4.91	2.93	6.83
$100\sigma_K$	Std. MEI	Inv. Gamma	0.5	1	6.56	4.73	8.32
$100\sigma_Z$	Std. TFP	Inv. Gamma	0.5	1	0.67	0.59	0.74
$100\sigma_R$	Std. monetary policy	Inv. Gamma	0.15	1	0.92	0.74	1.09
$100\sigma_p$	Std. markup	Inv. Gamma	0.15	1	4.93	1.68	8.89
$100\sigma_b$	Std. imp. H default	Inv. Gamma	0.25	1	0.12	0.11	0.13
$100\sigma_e$	Std. ent. default	Inv. Gamma	0.25	1	0.11	0.10	0.12
$100\sigma_{lb}$	Std. imp. H LTV	Inv. Gamma	0.25	1	2.56	1.67	3.42
$100\sigma_{le}$	Std. ent. LTV	Inv. Gamma	0.25	1	6.50	3.81	9.00

Note: The posterior distribution is constructed from the random-walk Metropolis–Hastings algorithm with a single chain, keeping 250,000 draws after a burn-in period of size 250,000.

the extent to which policies that aim to stabilize financial variables matters for business cycles. In addition, the monetary policy shock explains a large portion of variations in real variables such as GDP and consumption, indicating the importance of incorporating monetary policy into the model. In the next subsection, we study how various policies that are proposed to curb credit shape the aggregate dynamics by showing impulse responses.

3.3 Impulse Response Functions Throughout our analysis, we compare three model economies with different types of policies that are designed to moderate credit cycles against our baseline economy. The baseline economy corresponds to the model with the estimated monetary policy rule and with no systematic response of LTV ratios and minimum capital requirements. The first policy we consider is the estimated monetary policy rule augmented with the loan-to-GDP ratio so that the policy rate responds positively to an increase in the loan-to-GDP ratio ($\gamma_L = 0.05$). This policy is a leaning-against-the-wind (LAW) monetary policy. The second policy is a countercyclical capital requirement (CCR) policy, which forces the minimum ratio of the bank's equity to assets to increase by 0.25% when the loan-to-GDP

Table 3.3: Posterior Variance Decomposition

Shock/series	GDP	C	I	LE	LH	H. Price	LLE	LLH	Infl.	FFR
Agg. spending	8.64	27.62	1.16	1.45	1.71	0.54	0.00	0.00	9.74	12.24
Housing demand	2.02	2.22	1.09	0.87	58.47	85.79	0.00	0.00	1.17	0.69
MEI	18.61	15.54	34.12	2.39	1.11	3.03	0.00	0.00	10.43	17.99
TFP	3.18	3.02	1.88	0.23	0.15	0.46	0.00	0.00	2.56	0.11
Mon. policy	26.65	23.57	17.67	7.00	2.79	3.74	0.00	0.00	19.96	53.37
Markup	17.37	14.86	12.17	1.43	1.21	2.63	0.00	0.00	44.06	2.73
Imp. H default	4.81	5.07	2.37	1.38	6.46	0.76	0.00	100	0.45	0.02
Ent. default	0.00	0.00	0.01	0.00	0.03	0.00	100	0.00	0.01	0.00
Imp. H LTV	0.00	0.00	0.01	0.00	26.75	0.01	0.00	0.00	0.01	0.00
Ent. LTV	18.70	8.09	29.51	85.24	1.34	3.04	0.00	0.00	11.61	12.84

Note: Decomposition computed at the posterior mean for selected variables. LE is loans to entrepreneurs, LH loans to households, $H.Price$ house price, LLE losses on loans to entrepreneurs, LLH losses on loans to households, $Infl.$ inflation, and FFR the federal funds rate.

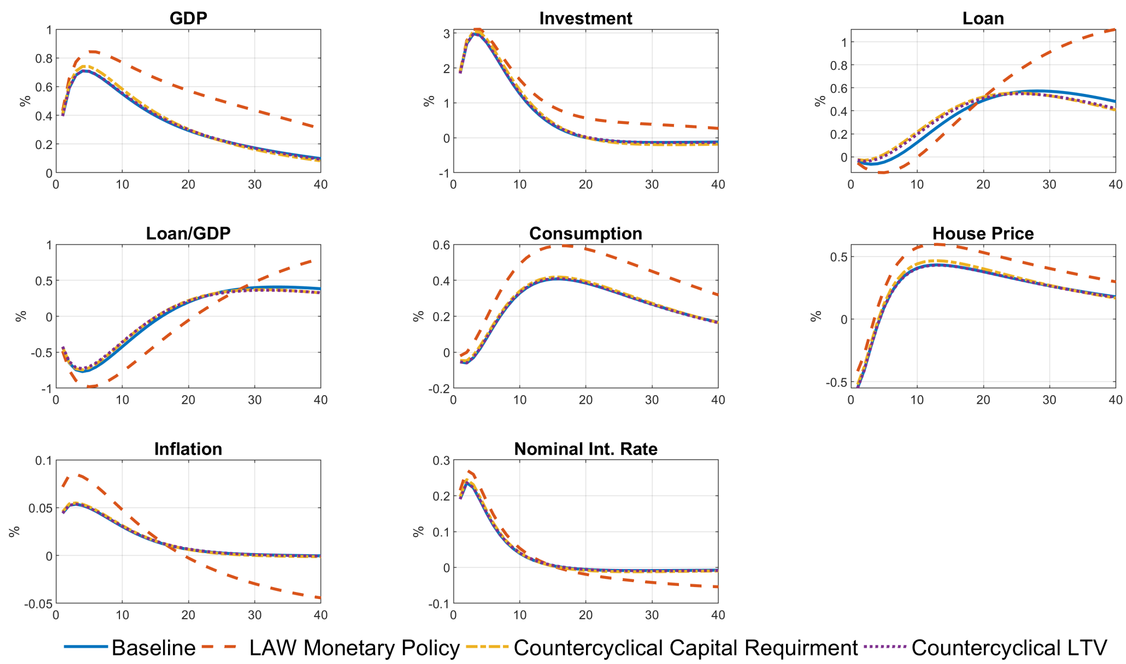
ratio increases by 1% ($\eta_b^1 = \eta_e^1 = 0.25$). The third policy implements countercyclical loan-to-value (LTV) limits, in which the LTV ratio cap decreases by 0.25% in response to a 1% increase in the loan-to-GDP ratio ($\gamma_1^{Hb} = \gamma_1^{Eb} = 0.25$). The latter two policies are often known as macroprudential policies.

We present impulse responses to the MEI and entrepreneurial LTV shocks. As indicated in Table 3.3, the former is one of the non-financial shocks that are largely responsible for the variance of GDP, and the latter is the most important financial shock in explaining GDP fluctuations. Accordingly, understanding the effect of leaning-against-the-wind policies in response to these shocks would give a sense of whether the stabilization effect of such policies depends on the nature of shocks.

Figure 3.1 shows the impulse responses of selected variables to a positive MEI shock. Let us start with the baseline model. Given the amount of investment, as more capital is produced, aggregate investment, the sum of investment made by patient households and entrepreneurs, increases. The increased stock of capital allows entrepreneurs to take out more loans. However, the loan-to-GDP ratio falls during the initial periods. This is because capital is a stock variable that evolves slowly, and thus loans to entrepreneurs increase gradually as well. As GDP, a flow variable, increases more than the increase in loans, the loan-to-GDP ratio falls initially and starts to rise when capital is sufficiently accumulated. The expansion in aggregate demand fuels inflationary pressure, resulting in a rise in the nominal interest rates. House prices drop initially, as patient households substitute away from purchasing houses to investment in physical capital.

Under the LAW monetary policy, a fall in the loan-to-GDP ratio works to reduce the nominal interest

Figure 3.1: Impulse Responses to Positive Unit Standard Deviation Marginal Efficiency of Investment Shock

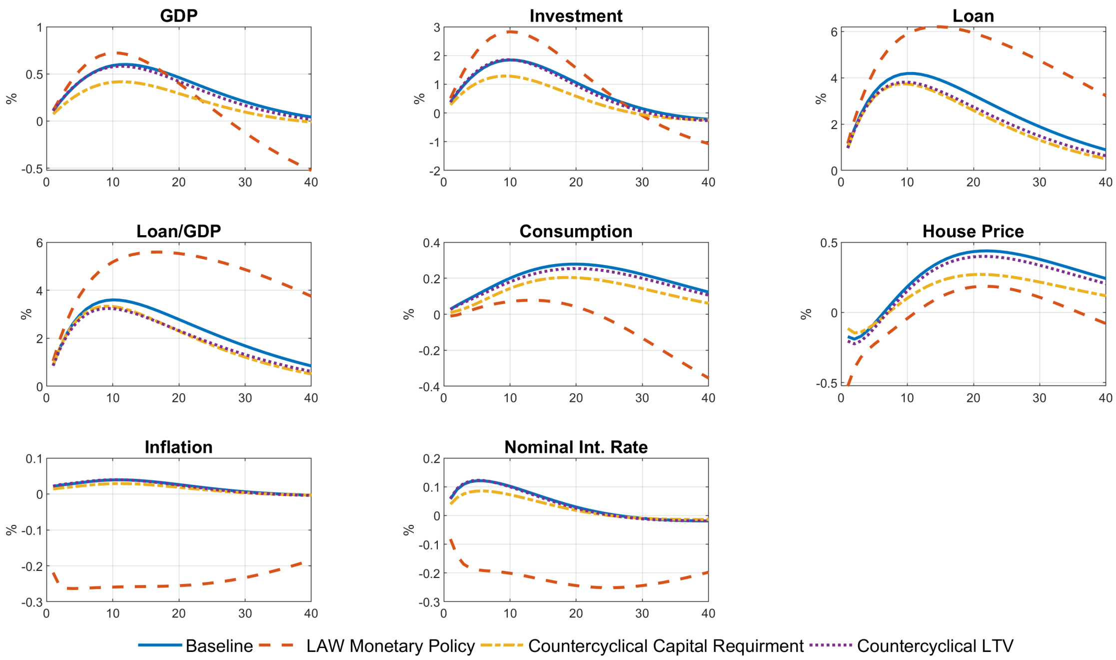


Note: The nominal interest rate is the policy rate determined by the monetary policy rule.

rate. This makes investment and consumption more expansionary relative to the baseline model. The increase in aggregate demand increases inflation further, contributing to a rise in the nominal interest rate. This inflationary pressure is powerful enough to overturn the direct effect of a fall in the loan-to-GDP ratio on the nominal interest rate. Therefore, the nominal interest rate increases more relative to the baseline. Interestingly, despite one's expectation that a positive coefficient on the loan-to-GDP ratio in the monetary policy rule would dampen the variations in the loan-to-GDP ratio, it actually makes the loan-to-GDP ratio more volatile. This observation arises from the more expansionary GDP and higher inflationary pressure under a LAW monetary policy. As higher inflation works to lower real loans through Fisherian debt deflation, an increase in GDP leads to a further fall in the loan-to-GDP ratio. However, under the two macroprudential policies, the responses of all variables are indistinguishable from those in the baseline model.

The dynamics in response to the MEI shock suggest important policy implications. First, a central bank should not increase the nominal interest rate when there is a boom in the loan-to-GDP ratio. Doing so would only raise the volatility of the aggregate demand components and inflation rates. Second,

Figure 3.2: Impulse Responses to Positive Unit Standard Deviation Entrepreneurial LTV Shock



countercyclical LTV and CCR policies have a limited role in managing aggregate demand in response to major non-financial shocks. In Appendix A, we present impulse responses to markup and monetary policy shocks, which are other important non-financial shocks in explaining GDP fluctuations in our model. We draw a similar conclusion as the one drawn from the responses to the MEI shock. A systematic increase in the monetary policy rate to a higher loan-to-GDP ratio magnifies the volatility of GDP, inflation, and the loan-to-GDP ratio. Moreover, countercyclical LTV and CCR policies have no meaningful effect in altering the aggregate demand components and inflation.

Figure 3.2 shows the impulse responses of selected variables to a positive entrepreneurial LTV shock. Starting from the baseline model, an exogenous increase in the entrepreneurial LTV ratio directly increases loans to entrepreneurs. Entrepreneurs' increased consumption and investment increase the income of all agents, and so aggregate consumption, aggregate investment, the inflation rate, and the nominal interest rate also increase. When the LAW monetary policy is in place, a rise in the loan-to-GDP ratio works to increase the nominal interest rate even more, increasing the real interest rate. The significant rise in the real interest rate contracts the aggregate demand, creating a strong deflationary pressure. This deflationary pressure is powerful enough to counteract the initial rise in the nominal interest rate that arises from the higher loan-to-GDP ratio. Therefore, the nominal interest rate eventually falls. Lastly, the loan-to-GDP ratio is more volatile than it is in the baseline as real loans are higher than they are in the baseline due to a fall in inflation.

Turning to the effect of macroprudential policies, notice that the CCR policy is effective in stabilizing the loan-to-GDP ratio, aggregate demand components, and inflation. Although entrepreneurs can borrow more due to a positive LTV ratio shock, the CCR policy moderates the supply of credit as banks are required to hold more equity relative to their assets. Such a policy makes the entrepreneurial LTV shock less expansionary. As in the case of the MEI shock, we find that the countercyclical LTV policy does not alter the dynamics meaningfully relative to the baseline.

Our result that the LAW monetary policy results in more volatile aggregate demand and inflation in response to both financial and non-financial shocks is in line with that in Gelain, Lansing, and Natvik (2018). Like us, they demonstrate that a monetary policy that has a positive coefficient on the debt-to-GDP ratio raises the volatility of inflation. The key logic behind their argument is that, during the period of high inflation caused by an expansionary shock, the debt-to GDP ratio falls due to Fisherian debt deflation. As a result, the nominal interest falls, and so the economy becomes very expansionary. An expansion associated with a reduced debt-to-GDP ratio is also observed in our model after a positive MEI shock, confirming their logic.

In sum, the LAW monetary policy generates more volatile business cycles in response to the MEI, markup, monetary policy, and entrepreneurial LTV shocks, while the CCR policy somewhat stabilizes business cycles after an entrepreneurial LTV shock. In contrast, the countercyclical LTV policy has a negligible effect in stabilizing the economy in response to the MEI, markup, monetary policy, and entrepreneurial LTV shocks.

4 Leaning-Against-the-Wind Policies and Business Cycles

It is natural to ask the effectiveness of policies that lean against credit cycles when the economy is subject to all shocks. This question is important given that any policy's goal is to minimize the cost of business cycles, which are driven by multiple shocks. In this section, we evaluate the effectiveness of policies that we analyzed in the previous section when all shocks are operative. We then derive the optimal (in the sense of a simple rule) policy and evaluate its effectiveness by applying it to historical U.S. data.

Table 4.1: Relative Standard Deviation of Key Variables

	std(GDP)	std(C)	std(π)	std(l)	std(l/GDP)	std(p^H)
LAW monetary policy	1.701	1.604	4.166	1.928	2.138	1.045
CCR	0.966	0.991	0.977	0.851	0.872	0.986
Countercyclical LTV	0.991	0.992	1.002	0.884	0.869	0.993
CCR (aggressive)	0.957	0.992	0.964	0.740	0.778	0.980

Note: Standard deviations under each policy are computed relative to those from the baseline economy, in which leaning-against-the-wind policies are absent. The last row corresponds to the aggressive countercyclical capital requirement (CCR) policy ($\eta_b^1 = \eta_e^1 = 0.5$).

4.1 Unconditional Volatility

In this subsection, we compare the unconditional volatility of selected financial and non-financial variables under three policies from the previous section. We report the standard deviations of the selected variables relative to those in the baseline model, in which leaning-against-the-wind policies are absent. The results are reported in Table 4.1.

Our main results can be summarized as follows. A LAW monetary policy makes GDP, consumption, inflation, loans, loan-to-GDP ratios, and house prices more volatile relative to the baseline. This outcome is not surprising, given that the LAW monetary policy magnifies the volatility of these variables in response to the MEI, markup, monetary policy, and entrepreneurial LTV shocks, which explain most of the GDP fluctuations. Therefore, it is recommended that central banks not respond positively to a higher loan-to-GDP ratio. Turning to macroprudential policies, countercyclical LTV limits do not change the volatility of key macro variables, consistent with impulses responses shown in the previous section. CCR policies are the most effective in reducing the volatility of aggregate demand, inflation, and financial variables. The stabilizing property is more pronounced when the capital regulation is more countercyclical (the last row).

It is worth comparing our results to those presented in Ingholt (2020). He argues that countercyclical LTV limits are not effective in moderating booms while they are effective in moderating recessions. The key feature in his model that leads to this argument is that the LTV constraint does not bind in expansions, whereas it often binds in contractions. We find that countercyclical LTV limits are not effective in stabilizing aggregate demand, even if LTV constraints always bind in our model. Our result stems from the fact that business cycles are driven more by changes in loans to entrepreneurs than by changes in loans to households. As shown in Table 3.3, the entrepreneurial LTV shock, which explains most of the fluctuations in loans to entrepreneurs, largely contributes to aggregate demand fluctuations, while the housing demand shock, which is most responsible for driving loans to households, contributes only a little. Therefore, the stabilization effect of countercyclical LTV limits, which mostly curb loans to households, is limited. However, in a model in which there are financial frictions only on households such as the model of Ingholt (2020), we expect the housing demand shock to have a larger role in the variance of GDP as aggregate consumption is tied more closely to GDP. In this case, countercyclical LTV limits can be more effective.

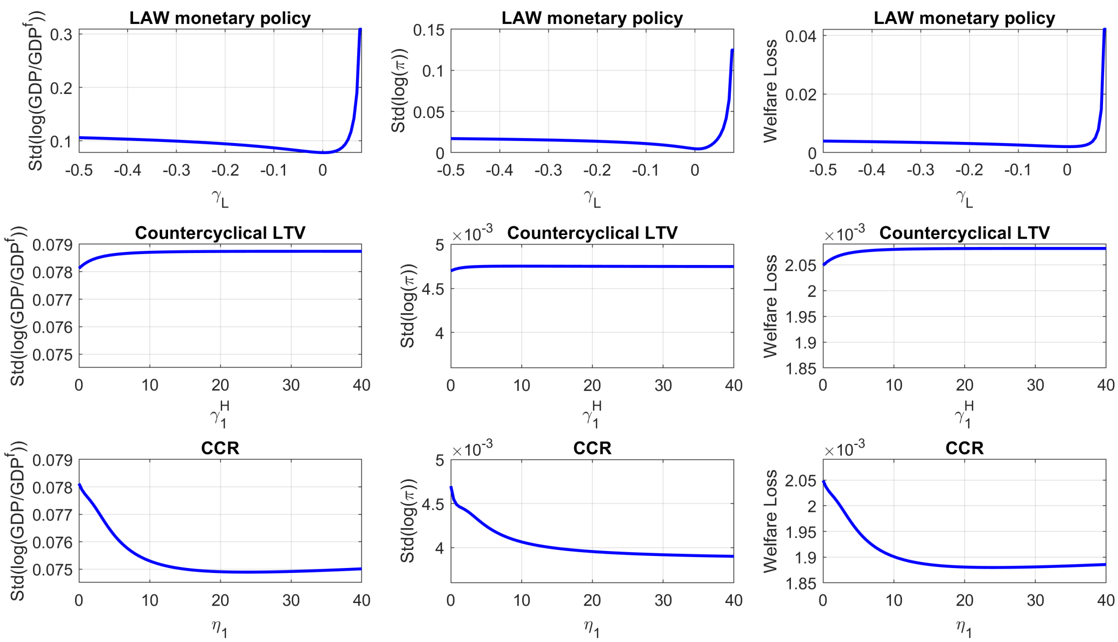
One might wonder how the effectiveness of LAW monetary policy would change if we assume a fixed-rate debt contract, as in Ingholt (2020). If the nominal interest rates born by impatient households and entrepreneurs are nearly invariant, the destabilizing effect of LAW monetary policy would be smaller than under adjustable-rate contracts, which we assume in our model. However, incorporating fixed-rate contracts into our model is non-trivial, as the interest rates faced by the two debtors are endogenously determined by the bank's balance sheet position.[6]

4.2 Optimal Leaning-Against-the-Wind Policy Although Table 4.1 shows that the CCR policy is the most effective leaning-against-the-wind policy in stabilizing GDP fluctuations, a common measure of business cycles, GDP volatility in the sticky-price economy does not necessarily represent the welfare cost of business cycles. What matters for the welfare cost of business cycles is the extent to which GDP deviates from its efficient path, as stabilization policy can only play a useful role in this case. In this subsection, we define a metric that measures the welfare cost of business cycles and derive the coefficients of the leaning-against-the-wind policy that minimizes such costs. We then evaluate the effectiveness of the welfare-maximizing policy by comparing the counterfactual evolution of the aggregate demand components to the actual one.

Because it is no longer clear what the efficient allocation in the model with financial frictions is, we summarize the degree of inefficient business cycles by the distance between the actual GDP and the potential GDP. Potential GDP is defined as the level of GDP that would be observed if markups were constant at their steady state level, and prices are flexible, following Justiniano, Primiceri, and Tambalotti (2013). Moreover, because our model features many agents with different discount factors, it is no longer clear which agent's utility function should be used to represent the economy's welfare. Therefore, as in Gelain, Lansing, and Natvik (2018), we assume that the policymaker's objective is to minimize the

[6] In Ingholt (2020), there are no banks, and hence the nominal interest rates faced by debtors are purely determined by the monetary policy rate. In this environment, the near fixed-interest rates can be introduced by parameterizing the degree of pass-through from the policy rate to the lending rate.

Figure 4.1: Welfare under Different Leaning-Against-the-Wind Policies



Note: The top panels plot the standard deviation of the GDP gap, the standard deviation of the inflation rate, and welfare losses for different loan-to-GDP coefficients in the monetary policy rule (γ_L). The middle panels plot the standard deviation of the GDP gap, the standard deviation of the inflation rate, and welfare losses for different loan-to-GDP coefficients in the LTV policy rule (γ_1^H). The bottom panels plot the standard deviation of the GDP gap, the standard deviation of the inflation rate, and welfare losses for different loan-to-GDP coefficients in the capital requirement policy rule (η_1). Welfare losses are in terms of $(1/2)var(\log(GDP_t/GDP_t^f)) + (1/2)var(\log(\pi_t))$.

average welfare loss per period given by:

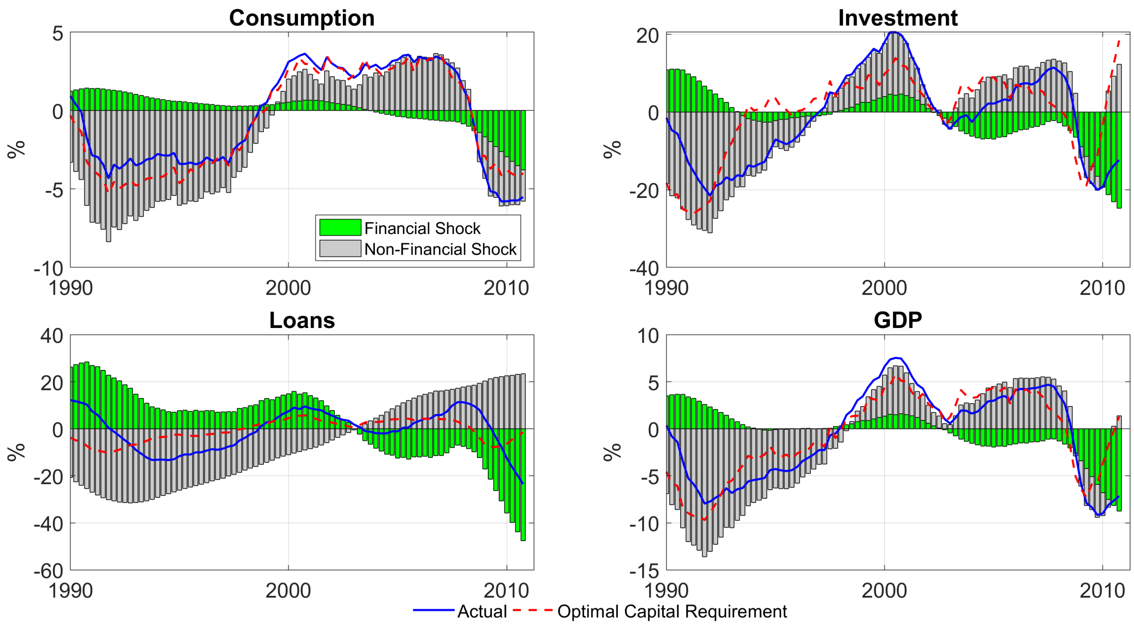
$$\Gamma_{GDP} \cdot var(\log(GDP_t/GDP_t^f)) + (1-\Gamma_{GDP}) \cdot var(\log(\pi_t)), \tag{4.1}$$

where Γ_{GDP} is the policymaker's weight on stabilizing the GDP gap, and GDP_t^f is potential GDP. We set $\Gamma_{GDP} = 1/2$.[7]

Figure 4.1 illustrates how the welfare losses, the volatility of the GDP gap, and the inflation change as we change the coefficient on the loan-to-GDP ratio for each leaning-against-the-wind policy. The top three panels in the figure show that a positive coefficient on the loan-to-GDP ratio in the monetary policy rule raises the volatility of the GDP gap and inflation, increasing the welfare costs. The increased inflation volatility associated with a positive coefficient is consistent with the impulse responses shown

[7]The purpose of adopting this value is to ensure the existence of the global minimum of the welfare loss function. A significantly low Γ_{GDP} that leads to very high optimal η_1 barely changes the result shown in Figure 4.1.

Figure 4.2: Actual and Counterfactual Historical Path



Note: The actual historical path (solid line) is the data. The counterfactual historical path (dashed line) is plotted under the optimal capital requirement policy ($\eta_1 = 24$). Green and grey bars represent the contribution of financial shocks (housing demand, default, and LTV shocks) and non-financial shocks (aggregate spending, MEI, TFP, monetary policy, and markup shocks), respectively.

in the previous section. Interestingly, a negative loan-to-GDP coefficient also increases the welfare losses and the variance of the GDP gap and inflation. As shown in the previous section, the aggregate demand components increase further after a positive MEI shock, when the loan-to-GDP coefficient is positive. However, the aggregate demand components fall after a positive entrepreneurial LTV shock if the monetary policy rate reacts positively to the loan-to-GDP ratio. If the coefficient is negative, the result would be the opposite: the aggregate demand components are stabilized after a positive MEI shock, but further increase in response to a positive entrepreneurial LTV shock. It turns out that the destabilizing effect dominates the stabilizing effect, raising the volatility of inflation and the GDP gap in the aggregate. Therefore, it is optimal for the monetary authority not to respond to variation in the loan-to-GDP ratio.

The bottom six panels in Figure 4.1 represent the effectiveness of countercyclical LTV limits and CCR policies as a function of coefficients on the loan-to-GDP ratio in these policies. Here, we assume $\gamma_1^{Hb} = \gamma_1^{He} = \gamma_1^{H}$ and $\eta_1^b = \eta_1^e = \eta_1$. We find that the countercylicality of LTV ratios, measured by γ_1^{H}, is almost irrelevant with respect to reducing the volatility of the GDP gap and inflation and, thus, the welfare cost of business cycles. This outcome confirms the pattern shown in Table 4.1, which illustrates that countercyclical LTV limits have essentially no effect on reducing variation in inflation and GDP. However, increasing the countercyclicality of the bank capital requirement, measured by η_1, tends to be effective in reducing the volatility of the GDP gap and inflation with the welfare loss minimized at $\eta_1 = 24$. Therefore, the optimal leaning-against-the-wind policy is the CCR policy rule, with the coefficient on the loan-to-GDP ratio being 24. This policy requires the bank's equity-to-asset ratio to increase by 24% when the loan-to-GDP ratio increases by 1%.

Although we have derived the optimal CCR policy, one might wonder whether the policy's effectiveness can be detected in U.S. business cycles. Identifying the periods in which the optimal CCR policy is effective guides policymakers in planning when to use such a policy. To study the effect of the optimal CCR policy over the U.S. business cycles, we use our estimated model and U.S. aggregate data to uncover the historical aggregate shocks. We then feed these aggregate shocks to a model in which the optimal CCR policy is present to generate counterfactual paths of aggregate consumption, aggregate investment, aggregate loans, and GDP. Figure 4.2 depicts the data (solid line) and the counterfactual path (dashed line).

The optimal CCR policy reduces the variation of the aggregate loans relative to the historical benchmark in most periods. It does so by limiting bank's ability to expand loans during credit booms and by encouraging banks to make loans during credit busts. However, the variation of GDP and its components are reduced only for a limited number of periods. In particular, variation is reduced during 1998-2003 and after 2008. A notable feature of these two periods is that the relative contribution of financial shocks to GDP and its components, measured by the size of the green bars, is larger than other periods. This outcome can be understood from the fact that the CCR policy reduces the variation of the aggregate demand components in response to the entrepreneurial LTV shock, shown in Figure 3.2. Given that the entrepreneurial LTV shock is the most important financial shock in terms of explaining GDP fluctuations, it is not surprising that the policy is effective when financial shocks play a relatively large role. For the remaining periods, non-financial shocks are much more dominant, as noted by the size of the grey bars. During these periods, the optimal CCR policy does not moderate GDP and its components. This pattern is consistent with the impulse responses to the MEI, monetary policy, and markup shocks, which are the most important non-financial shocks that drive most of the GDP fluctuations.

One might wonder why the contribution of financial shocks in shaping the GDP boom during 2004-2007 is irrelevant, whereas Iacoviello (2015) finds they are important during the same period. This discrepancy stems from the New Keynesian ingredients, which Iacoviello (2015) does not have. Without these ingredients, the MEI, markup, and monetary policy shocks have an insignificant role in driving aggregate fluctuations, and therefore financial shocks become much more important. However, in our model, the MEI, markup, and monetary policy shocks are estimated to be very important in driving business cycles, and so the relative contribution of financial shocks significantly declines.

Our analysis suggests that the relevant variable for implementing a CCR policy is not credit swings *per se*. Rather, policymakers who intend to impose a CCR regulation should pay attention to credit swings that are likely to be driven by financial shocks.

5 Conclusion

This paper evaluates the effect of widely proposed leaning-against-the-wind policies in stabilizing business cycles using an estimated New Keynesian model augmented with a financial sector. We find that a LAW monetary policy rule with a positive response to the loan-to-GDP ratio is not recommended since it destabilizes economic fluctuations. In addition, a countercyclical LTV policy has almost no effect in reducing the volatility of inflation and GDP despite its effectiveness in reducing loan variation. We find that a CCR policy is the most desirable leaning-against-the-wind policy in stabilizing GDP, inflation, and loans. We then derive the optimal capital requirement rule and assess whether its stabilizing effect would have been quantitatively relevant during 1990-2010. We find that this policy was more effective in periods in which financial shocks played a large role.

Future work can incorporate a monetary policy rule that takes into account of the zero lower bound and then estimate the model using the data that covers more recent periods. Using this laboratory model, one can investigate how the effectiveness of different policies would change compared to the results shown in the current paper, which does not allow the zero lower bound on nominal interest rates.

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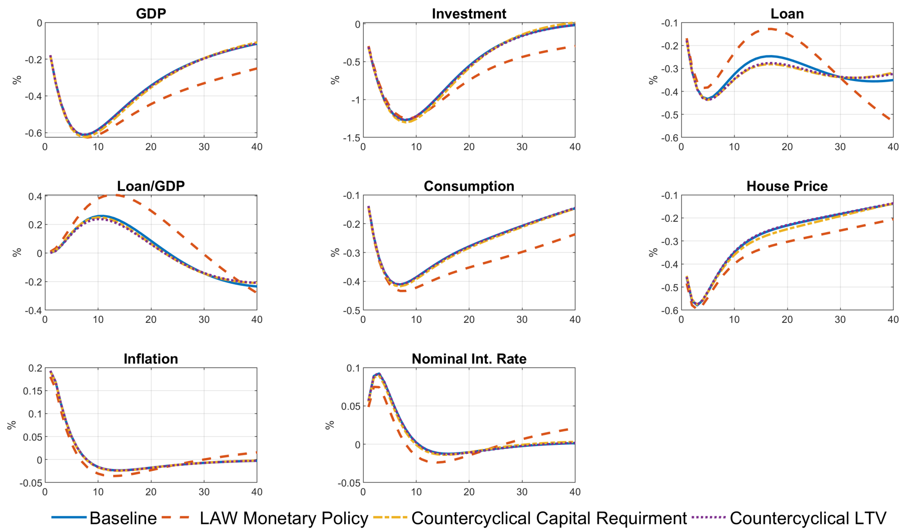
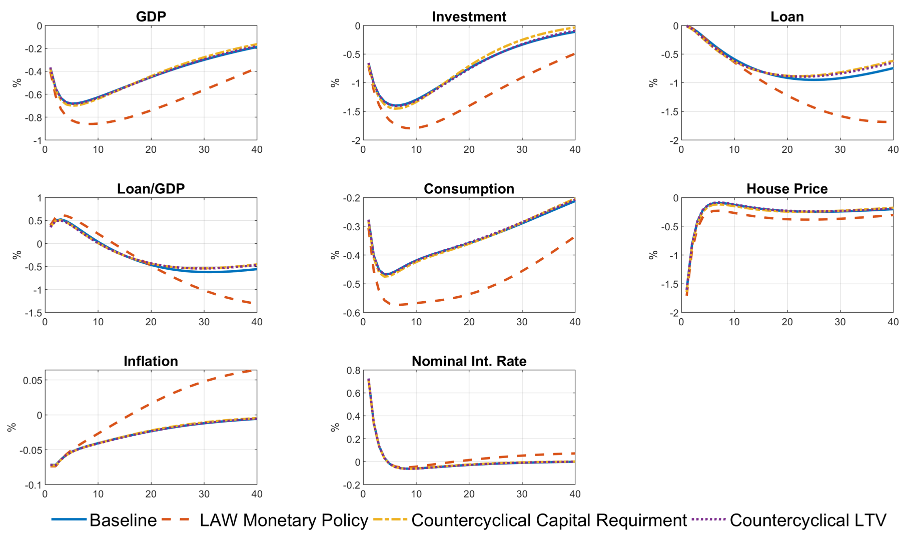
A Appendix. Impulse Responses to Other Shocks

Figure A.1: Impulse Response Functions



(a) Impulse Responses to Positive Unit Standard Deviation Markup Shock



(b) Impulse Responses to Positive Unit Standard Deviation Monetary Policy Shock

B Supplementary Online Appendix: Not for Publication

B.1 Equilibrium Conditions

B.1.1 Patient Household

$$[C_t^s] \qquad \lambda_t^s = \frac{\varepsilon_t^c}{C_t^s - hC_{t-1}^s} - h\beta_s \mathbb{E}_t \left[\frac{\varepsilon_{t+1}^c}{C_{t+1}^s - hC_t^s}\right] \tag{B.1}$$

$$[K_t^s] \qquad q_t^s = \beta_s \mathbb{E}_t \frac{\lambda_{t+1}^s}{\lambda_t^s}[(1-\delta)q_{t+1}^s + r_{t+1}^{ks} u_{k,t+1}^s - \Psi_s(u_{k,t+1}^s)] \tag{B.2}$$

$$[u_{k,t}^s] \qquad \Psi_s'(u_{k,t}^s) = r_t^{ks} \tag{B.3}$$

$$[I_t^s] \qquad 1 = q_t^s \varepsilon_t^k \left[1 - \frac{s_s}{2}\left(\frac{I_t^s}{I_{t-1}^s} - 1\right)^2 - s_s \left(\frac{I_t^s}{I_{t-1}^s}\right)\left(\frac{I_t^s}{I_{t-1}^s} - 1\right)\right] \tag{B.4}$$

$$+ s_s \beta_s \mathbb{E}_t \frac{\lambda_{t+1}^s}{\lambda_t^s} q_{t+1}^s \varepsilon_{t+1}^k \left(\frac{I_{t+1}^s}{I_t^s}\right)^2 \left(\frac{I_{t+1}^s}{I_t^s} - 1\right)$$

$$[q_t^s] \qquad K_t^s = \varepsilon_t^k I_t^s \left[1 - \frac{s_s}{2}\left(\frac{I_t^s}{I_{t-1}^s} - 1\right)^2\right] + (1-\delta)K_{t-1}^s \tag{B.5}$$

$$[H_t^s] \qquad p_t^H = \frac{\varepsilon_t^c \varepsilon_t^h \nu_h^s}{H_t^s \lambda_t^s} + \beta_s \mathbb{E}_t \left[\frac{\lambda_{t+1}^s}{\lambda_t^s} p_{t+1}^H\right] \tag{B.6}$$

$$[N_t^s] \qquad w_t^s = \frac{\nu_n^s (N_t^s)^\varphi}{\lambda_t^s} \tag{B.7}$$

$$[d_t] \qquad 1 + \frac{\partial AC_{d^s}(d_t)}{\partial d_t} = \beta_s \mathbb{E}_t \left[\frac{\lambda_{t+1}^s}{\lambda_t^s} \frac{r_t^d}{\pi_{t+1}}\right] \tag{B.8}$$

$$[\lambda_t^s] \qquad C_t^s + I_t^s + p_t^H \left(H_t^s - H_{t-1}^s\right) + d_t + AC_{d^s}(d_t) = w_t^s N_t^s + \frac{r_{t-1}^d}{\pi_t} d_{t-1} + r_t^{ks} u_{k,t}^s K_{t-1}^s \tag{B.9}$$

$$- \Psi_s(u_{k,t}^s) K_{t-1}^s + Div_t,$$

where λ_t^s and q_t^s are the Lagrangian multipliers associated with the budget constraint and the capital accumulation process, respectively.

B.1.2 Impatient Household

$$[C_t^b] \qquad \lambda_t^b = \frac{\varepsilon_t^c}{C_t^b - hC_{t-1}^b} - h\beta_b \mathbb{E}_t \left[\frac{\varepsilon_{t+1}^c}{C_{t+1}^b - hC_t^b}\right] \tag{B.10}$$

$$[H_t^b] \qquad p_t^H = \frac{\varepsilon_t^c \varepsilon_t^h \nu_h^b}{H_t^b \lambda_t^b} + \beta_b \mathbb{E}_t \left[\frac{\lambda_{t+1}^b}{\lambda_t^b} p_{t+1}^H\right] + \mu_t^b (1-\rho_b) \gamma_t^{Hb} \mathbb{E}_t \left[\frac{p_{t+1}^H}{r_t^b / \pi_{t+1}}\right] \tag{B.11}$$

$$[N_t^b] \qquad w_t^b = \frac{\nu_n^b (N_t^b)^\varphi}{\lambda_t^b} \tag{B.12}$$

$$[l_t^b] \qquad 1 - \frac{\partial AC_{l^b}(l_t^b)}{\partial l_t^b} = \mu_t^b + \beta_b \mathbb{E}_t \left[\frac{\lambda_{t+1}^b}{\lambda_t^b} \left(\frac{r_t^b}{\pi_{t+1}} - \rho_b \frac{\mu_{t+1}^b}{\pi_{t+1}} \right) \right] \tag{B.13}$$

$$[\lambda_t^s] \qquad C_t^b + p_t^H \left[H_t^b - H_{t-1}^b \right] + \frac{r_{t-1}^b}{\pi_t} l_{t-1}^b + AC_{l^b}(l_t^b) = w_t^b N_t^b + l_t^b + \varepsilon_t^b \tag{B.14}$$

$$[\mu_t^b] \qquad l_t^b = \rho_b \frac{l_{t-1}^b}{\pi_t} + (1-\rho_b) \left[\gamma_t^{Hb} \mathbb{E}_t \frac{p_{t+1}^H H_t^b}{r_t^b / \pi_{t+1}} \right], \tag{B.15}$$

where λ_t^b and μ_t^b are the Lagrangian multipliers associated with the budget constraint and the borrowing constraint, respectively.

B.1.3 Entrepreneur

$$[C_t^e] \qquad \lambda_t^e = \frac{1}{C_t^e - hC_{t-1}^e} - \beta_e \mathbb{E}_t \frac{h}{C_{t+1}^e - hC_t^e} \tag{B.16}$$

$$[K_t^e] \qquad q_t^e = \mu_t^e (1-\rho_e) \gamma_t^{Ke} + \beta_e \mathbb{E}_t \frac{\lambda_{t+1}^e}{\lambda_t^e} [(1-\delta) q_{t+1}^e + r_{t+1}^{ke} u_{k,t+1}^e - \Psi_e(u_{k,t+1}^e)] \tag{B.17}$$

$$[u_{k,t}^e] \qquad \Psi_e'(u_{k,t}^e) = r_t^{ke} \tag{B.18}$$

$$[I_t^e] \qquad 1 = q_t^e \varepsilon_t^k \left[1 - \frac{s_e}{2} \left(\frac{I_t^e}{I_{t-1}^e} - 1 \right)^2 - s_e \left(\frac{I_t^e}{I_{t-1}^e} \right) \left(\frac{I_t^e}{I_{t-1}^e} - 1 \right) \right] + s_e \beta_e \mathbb{E}_t \frac{\lambda_{t+1}^e}{\lambda_t^e} q_{t+1}^e \varepsilon_{t+1}^k \left(\frac{I_{t+1}^e}{I_t^e} \right)^2 \left(\frac{I_{t+1}^e}{I_t^e} - 1 \right) \tag{B.19}$$

$$[q_t^e] \qquad K_t^e = \varepsilon_t^k I_t^e \left[1 - \frac{s_e}{2} \left(\frac{I_t^e}{I_{t-1}^e} - 1 \right)^2 \right] + (1-\delta) K_{t-1}^e \tag{B.20}$$

$$[H_t^e] \qquad p_t^H = \beta_e \mathbb{E}_t \left[\frac{\lambda_{t+1}^e}{\lambda_t^e} p_{t+1}^H (1 + r_{t+1}^H) \right] + \mu_t^e (1-\rho_e) \gamma_t^{He} \frac{p_{t+1}^H}{r_{t+1}^e / \pi_{t+1}} \tag{B.21}$$

$$[N_t^s] \qquad (1 + (1-\rho_e)\gamma_t^{Ne} \mu_t^e) w_t^s N_t^s = (1-\alpha-\nu)\omega_n p_t^X Y_t \tag{B.22}$$

$$[N_t^b] \qquad (1 + (1-\rho_e)\gamma_t^{Ne} \mu_t^e) w_t^b N_t^b = (1-\alpha-\nu)(1-\omega_n) p_t^X Y_t \tag{B.23}$$

$$[K_{t-1}^s] \qquad r_t^{ks} = \alpha \omega_k p_t^X Y_t / (u_{k,t}^s K_{t-1}^s) \tag{B.24}$$

$$[K_{t-1}^e] \qquad r_t^{ke} = \alpha (1-\omega_k) p_t^X Y_t / (u_{k,t}^e K_{t-1}^e) \tag{B.25}$$

$$[H_{t-1}^e] \qquad r_t^H = \nu \frac{p_t^X}{p_t^H} Y_t / H_{t-1}^e \tag{B.26}$$

$$[l_t^e] \qquad 1 - \frac{\partial AC_{l^e}(l_t^e)}{\partial l_t^e} = \mu_t^e + \beta_e \mathbb{E}_t \left[\frac{\lambda_{t+1}^e}{\lambda_t^e} \left(\frac{r_{t+1}^e}{\pi_{t+1}} - \rho_e \frac{\mu_{t+1}^e}{\pi_{t+1}} \right) \right] \tag{B.27}$$

$$[\lambda_t^e] \qquad C_t^e + I_t^e + p_t^H[H_t^e - H_{t-1}^e] + w_t^s N_t^s + w_t^b N_t^b + r_t^{ks} u_{k,t}^s K_{t-1}^s + \frac{r_t^e}{\pi_t} l_{t-1}^e + AC_{l^e}(l_t^e)$$

$$= p_t^X Y_t + l_t^e - \Psi_e(u_{k,t}^e) K_{t-1}^e + \varepsilon_t^e \tag{B.28}$$

$$[\mu_t^e] \qquad l_t^e = \rho_e \frac{l_{t-1}^e}{\pi_t} + (1-\rho_e)\left(\gamma_t^{He}\mathbb{E}_t \frac{p_{t+1}^H H_t^e}{r_{t+1}^e/\pi_{t+1}} + \gamma_t^{Ke} K_t^e - \gamma_t^{Ne}(w_t^s N_t^s + w_t^b N_t^b)\right) \tag{B.29}$$

$$v_t Y_t = \varepsilon_t^z \left(u_{k,t}^s K_{t-1}^s\right)^{\alpha\omega_k} \left(u_{k,t}^e K_{t-1}^e\right)^{\alpha(1-\omega_k)} \left(H_{t-1}^e\right)^{\nu} \left(N_t^s\right)^{(1-\alpha-\nu)\omega_n} \left(N_t^b\right)^{(1-\alpha-\nu)(1-\omega_n)}, \tag{B.30}$$

where λ_t^e, q_t^e, and μ_t^e are the Lagrangian multipliers associated with the budget constraint, the capital accumulation process, and the borrowing constraint, respectively. $v_t \equiv \int_0^1 \left(\frac{P_t(j)}{P_t}\right)^{-\frac{1+\theta_{p,t}}{\theta_{p,t}}} dj$ is a measure of price dispersion across intermediate goods firms.

B.1.4 Banks

$$[C_t^r] \quad \lambda_t^r = \frac{1}{C_t^r - hC_{t-1}^r} - \beta_r \mathbb{E}_t \frac{h}{C_{t+1}^r - hC_t^r} \tag{B.31}$$

$$[d_t] \qquad 1 - \frac{\partial AC_{d^r}(d_t)}{\partial d_t} = \mu_t^r + \beta_r \mathbb{E}_t\left[\frac{\lambda_{t+1}^r}{\lambda_t^r}(\frac{r_t^d}{\pi_{t+1}} - \rho_r \frac{\mu_{t+1}^r}{\pi_{t+1}})\right] \tag{B.32}$$

$$[l_t^b] \qquad 1 + \frac{\partial AC_{l^{br}}(l_t^b)}{\partial l_t^b} = \mu_t^r(1-(1-\rho_r)\eta_t^b) + \beta_r \mathbb{E}_t\left[\frac{\lambda_{t+1}^r}{\lambda_t^r}(\frac{r_t^b}{\pi_{t+1}} - \rho_r \frac{\mu_{t+1}^r}{\pi_{t+1}})\right] \tag{B.33}$$

$$[l_t^e] \qquad 1 + \frac{\partial AC_{l^{er}}(l_t^e)}{\partial l_t^e} = \mu_t^r(1-(1-\rho_r)\eta_t^e) + \beta_r \mathbb{E}_t\left[\frac{\lambda_{t+1}^r}{\lambda_t^r}(\frac{r_{t+1}^e}{\pi_{t+1}} - \rho_r \frac{\mu_{t+1}^r}{\pi_{t+1}})\right] \tag{B.34}$$

$$[\lambda_t^r] \quad C_t^r + l_t^b + l_t^e + \frac{r_{t-1}^d}{\pi_t} d_{t-1} + AC_{d^r}(d_t) + AC_{l^{er}}(l_t^e) + AC_{l^{br}}(l_t^b) = d_t + \frac{r_t^e}{\pi_t} l_{t-1}^e + \frac{r_{t-1}^b}{\pi_t} l_{t-1}^b - \varepsilon_t^b - \varepsilon_t^b \tag{B.35}$$

$$[\mu_t^r] \qquad l_t^b + l_t^e - d_t - \varepsilon_t^b - \varepsilon_t^e = \rho_r(\frac{l_{t-1}^b}{\pi_t} + \frac{l_{t-1}^e}{\pi_t} - \frac{d_{t-1}}{\pi_t} - \varepsilon_{t-1}^b - \varepsilon_{t-1}^e) + (1-\rho_r)[\eta_t^b l_t^b + \eta_t^e l_t^e - \varepsilon_t^b - \varepsilon_t^e], \tag{B.36}$$

where λ_t^r and μ_t^r are the Lagrangian multipliers associated with the budget constraint and the capital constraint, respectively.

B.1.5 Retailers

$$f_{1,t} = (1+\theta_{p,t})p_t^X + \xi_p \beta_s \mathbb{E}_t \frac{\lambda_{t+1}^s}{\lambda_t^s} f_{1,t+1} \tag{B.37}$$

$$f_{2,t} = 1 + \xi_p \beta_s \mathbb{E}_t \frac{\lambda_{t+1}^s}{\lambda_t^s} \frac{\pi_t^{\iota_p} \pi^{1-\iota_p}}{\pi_{t+1}} f_{2,t+1} \tag{B.38}$$

$$1 = (1-\xi_p)(\frac{f_{1,t}}{f_{2,t}})^{-\frac{1}{\theta_{p,t}}} + \xi_p \left(\frac{\pi_{t-1}^{\iota_p} \pi^{1-\iota_p}}{\pi_t} \right)^{-\frac{1}{\theta_{p,t}}} \tag{B.39}$$

$$v_t = (1-\xi_p)(\frac{f_{1,t}}{f_{2,t}})^{-\frac{1+\theta_{p,t}}{\theta_{p,t}}} + \xi_p \left(\frac{\pi_{t-1}^{\iota_p} \pi^{1-\iota_p}}{\pi_t} \right)^{-\frac{1+\theta_{p,t}}{\theta_{p,t}}} v_{t-1}. \tag{B.40}$$

Finally, we have the housing market clearing condition (2.21), the monetary policy rule (2.20), and the aggregate shock processes.