WP/20/83

IMF Working Paper

Synergies Between Monetary and Macroprudential Policies in Thailand

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INTERNATIONAL MONETARY FUND

 WP/20/83

IMF Working Paper

Asia and Pacific Department

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Authorized for distribution by Lamin Leigh

March 2020

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Abstract

A dynamic stochastic general equilibrium (DSGE) model tailored to the Thai economy is used to explore the performance of alternative monetary and macroprudential policy rules when faced with shocks that directly impact the financial cycle. In this context, the model shows that a monetary policy focused on its traditional inflation and output objectives accompanied by a well targeted counter-cyclical macroprudential policy yields better macroeconomic outcomes than a lean-against-the-wind monetary policy rule under a wide range of assumptions.

JEL Classification Numbers: E17, E58

Keywords: Macroprudential policies; Lean-against-the-wind monetary policy rule; Dynamic stochastic general equilibrium model; Thailand

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[1] The authors are grateful to Lamin Leigh, Ana Corbacho, Shanaka Jay Peiris, Miklos Vari, Pawel Zabczyk, the 2018 IMF Article IV mission team to Thailand, and seminar participants at the Bank of Thailand for helpful comments and discussions. The views expressed herein are those of the authors and should not be attributed to the IMF, its Executive Board, or its management.

I. INTRODUCTION

Over the last decade, Thailand has seen a significant increase in household debt. At the same time, low interest rates in advanced economies and a strong external position have contributed to exchange rate appreciation and a drop in the inflation rate below the target range. In this context, a key objective of the Thai monetary authorities is to lift inflation back to target without unduly stimulating household debt and housing prices.

Macroprudential measures can be a useful complement to monetary policy in addressing potential pockets of vulnerability to financial stability. While monetary policy provides only one instrument (interest rate), counter-cyclical macroprudential tools could provide a useful complement, especially when real and financial cycles do not coincide. The Thai authorities already implemented three main macroprudential measures: (i) limits on loan-to-value ratio in the property market, (ii) limits on credit card and personal loans, and (iii) dynamic loan loss provisioning.[2] Recent empirical studies suggest that some of these measures have been effective in stabilizing credit cycles.[3] However, it remains an open question which type of policy combination of monetary and macroprudential policies would be most effective in dealing with both real and financial cycles. For instance, there have been active debates on whether monetary policy should address financial stability or focus on inflation and output stability. The type of macroprudential policy measures could also make a substantial difference in the outcome.

Using a dynamic stochastic general equilibrium (DSGE) model tailored to the Thai economy, this paper sheds light on (i) the combination of monetary and macroprudential policies that would be most effective for Thailand in dealing with both real and financial cycles and (ii) the appropriate choice of macroprudential tool in such policy combination. The model analysis aims to explore various conditions under which the use of macroprudential measures can (or cannot) improve macroeconomic outcomes within a plausible range of parameters and assumptions. Since there are a growing number of DSGE models that incorporate macroprudential measures in a variety of ways and different models focus on different aspects of financial frictions and economic environment, choosing a relevant model and tailoring it to the current context of the Thai economy is crucial. It is also important to note that quantitative implications may be highly dependent on model specifications and calibrations.

Our results show that well-targeted macroprudential measures can provide a useful complement to monetary policy in the context of asynchronous real and financial cycles as observed since 2016 in Thailand.[4] Active use of targeted macroprudential measures is likely

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[2] Bank of Thailand (2017) provides an overview of Thailand's macroprudential framework.

[3] Pongsaparn et al. (2017) shows that the Bank of Thailand's measures on LTV ratio were effective in moderating housing credit growth. In the global context, a cross-country panel regression analysis of the effects of macroprudential measures on household credit growth across advanced and emerging market economies, including Thailand, is reported in the October 2017 GFSR Chapter 2, Box 2.5 (IMF, 2017).

[4] During this period, inflation has been weak while pockets of financial risk have kept the authorities concerned.

to achieve better macroeconomic outcomes by allowing monetary policy to focus on inflation and output stabilization while effectively containing financial risks from rising housing loans. A broader or mistargeted macroprudential measure, however, may perform worse than a lean-against-the-wind monetary policy rule in some cases.

The remainder of the paper proceeds as follows. Section II briefly reviews the literature on DSGE model analysis of monetary and macroprudential policies. Section III describes the key features of our model, while the full description of the model is provided in Appendix. Section IV presents the results. Section V concludes.

II. LITERATURE

Monetary policy rules that react to financial stability concerns have been studied extensively in recent DSGE models. Standard monetary policy rules that react to inflation and output could lead to growing financial risks under financial frictions (such as collateral borrowing constraints), in which case a monetary policy that also targets financial stability by "leaning against the wind" could be welfare improving. DSGE models compare this benefit with the cost from short-term deviations from inflation and output targets and the corresponding welfare losses. While some models strongly support the case for leaning against the wind (e.g., Gambacorta and Signoretti 2014), other models show that the implied deviations from standard policy rules are quantitatively small (e.g., Curdia and Woodford 2010). Moreover, the case for leaning against the wind may be even weaker in small open economies, where the impact of such policy on international capital flows may exacerbate macroeconomic and financial stability concerns.

More recent DSGE models, including ours, incorporate various types of macroprudential policy and study its relationship with monetary policy. These models typically find that monetary and macroprudential policies are complements rather than substitutes, in the sense that it is optimal to use these policies together rather than use only one policy instrument to achieve financial stability and the inflation target (e.g., Angelini et al. 2014). Macroprudential policy could help alleviate tensions between macroeconomic and financial stability objectives when real and financial cycles are not synchronized. However, these results may change depending on the types of macroprudential policy considered in the models. We simulate the impact of complementing the monetary policy rate with counter-cyclical LTVs and capital requirements on macro stability and housing credit, and derive lessons for Thailand.

In general, the relationship between monetary and macroprudential policies is highly dependent on the nature of shocks and financial frictions.[5] Many recent models suggest that it is optimal to mainly use macroprudential policies in a wake of financial shock that leads to financial stability concerns. By contrast, in response to a (positive) productivity shock, limiting credit by tightening macroprudential policies may be misguided and runs counter to accommodative monetary policy for supporting inflation. The latter conclusion, however,

[5] IMF (2012) discusses this issue extensively.

could be reversed if lending by individual banks endogenously affects overall financial riskiness even in the case of a non-financial (productivity) shock, which could make tight macroprudential policies optimal.

III. MODEL

We use a New Keynesian DSGE model for small open economies with price rigidities and financial frictions. To tailor to the Thai economy, the model incorporates a fully specified banking sector, household and corporate debt, and external borrowing.[6] In particular, the model generates rich dynamics of household debt, which is one of the key features of Thai economy as mentioned in the introduction. The banking sector, which intermediates funds from patient households to impatient households and entrepreneurs, also plays a crucial role in financial cycles and policy transmission in Thai economy.[7]

The model has more than 50 equations with more than 80 parameters, as fully described in Appendix. These parameters are calibrated based on data, previous studies, or judgment. The brief descriptions of private economic agents, namely households, entrepreneurs, and banks, are as follows (Figure 1 depicts the relationships between agents in this economy).

- There are two types of households, patient (with a lower intertemporal discount rate) and impatient,[8] who both derive utility from consumption, leisure, and housing. In equilibrium, the patient households save part of their income, which is invested in domestic bank deposits and foreign bonds. Impatient households end up borrowing to consume and purchase houses.

- Entrepreneurs borrow from domestic banks and from abroad to purchase capital. They also hire labor and produce goods that are then sold to retailers who subsequently sell to the consumers, capital producers, and foreign markets in a monopolistically competitive environment.

- Banks can lend to the government, entrepreneurs, or households. Interest rates are sticky because banks face quadratic costs associated with changes in interest rates. At the same time, bank borrowing is subject to macroprudential measures.

Monetary and macroprudential policies are described by policy reaction functions. Two separate policy functions are incorporated: one for the monetary policy interest rate that follows a Taylor rule; and the other for a macroprudential policy measure, specifically either a cap on household loan-to-value (LTV) ratio or a minimum bank capital adequacy ratio

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[6] The framework of Anand, Delloro, and Peiris (2014) is extended to incorporate housing sector and household debt, following Gerali et al. (2010).

[7] The banking sector in the model encompasses all types of financial intermediaries (including Specialized Financial Institutions) and does not distinguish different mandates and business models among them.

[8] "Impatient households" can also be interpreted as liquidity-constrained households in this model.

(CAR). For each policy reaction function, we consider two variants. The two variants of the Taylor rule are as follows:

a. Standard Taylor rule—focused on inflation and output gap

$$i = \alpha_1 \times inflation\ gap + \alpha_2 \times output\ gap$$

where *i* is the policy interest rate, *inflation gap* is the difference between actual inflation and the target, and *output gap* is the difference between actual and potential output.

b. Modified Taylor rule—focused on inflation, output, and credit gaps

$$i = \alpha_1 \times inflation\ gap + \alpha_2 \times output\ gap + \alpha_3 \times credit\ gap$$

where *credit gap* is the difference between the actual stock of household credit and its steady-state level.[9]

The two variants for a macroprudential measure are as follows:

a. Constant LTV (or CAR) rule: The cap on LTV applied to household credit (or the minimum CAR applied to bank credit) is kept constant.

b. Countercyclical LTV (or CAR) rule: The cap on LTV applied to household credit decreases (or the minimum CAR applied to bank credit increases) as the stock of household (or bank) credit increases relative to its steady-state value.

In our results presented in the next section, the performance of policy combinations is evaluated in terms of the volatilities of inflation, output gap, and housing loans in response to specific types of shocks. This measure approximates welfare loss in the model with price rigidities and financial friction, where inflation stability and financial stability should improve welfare. We compare the following three combinations of policy rules: (i) a standard Taylor rule with a constant LTV (or CAR) rule, (ii) a standard Taylor rule with a counter-cyclical LTV (or CAR) rule, and (iii) a modified Taylor rule with a constant LTV (or CAR) rule.[10] As relevant types of shocks faced by the Thai economy, we consider a negative world interest rate shock (monetary easing in advanced economies) and a positive shock to domestic housing demand.

IV. Results

Benchmark results

[9] Using some alternative financial gaps, including a house price gap, does not change the results substantively.

[10] Another possible combination of policy rules, namely a modified Taylor rule with a counter-cyclical LTV rule, is examined in Corbacho et al. (2018). Its outcomes fall in the middle of those of (ii) and (iii).

Figure 2 shows the impulse responses of nominal interest rate (policy rate), housing loans, inflation, and output to a minus one percentage point shock to the world interest rate. All responses are expressed as percentage deviations from their steady state values. The shock causes appreciation pressure of the domestic currency and triggers domestic monetary easing, which can lead to housing market overheating. The growth of housing loans is contained to a similar extent under both the counter-cyclical cap on LTV ratio and the modified Taylor rule.[11] However, the negative impact of the shock on inflation and output gap is much larger under the modified Taylor rule than the counter-cyclical LTV rule.[12] Therefore, the counter-cyclical LTV rule performs better in terms of stabilizing inflation, output, and housing loans.

A similar result is obtained in the responses to a positive housing demand shock (Figure 3). With the counter-cyclical LTV rule, the growth of housing loans is contained without raising the nominal interest rate. By contrast, raising the interest rate following the modified Taylor rule causes a substantial decline in inflation and output gap while insufficiently containing growth in housing loans.

Considering all scenarios together, results suggest that better outcomes in growth, inflation, and financial stability can be achieved with monetary policy focused on inflation and output gap and macroprudential policy targeting the specific source of financial instability. Asking monetary policy to do too much (that is, to also target financial stability) comes at the cost of suboptimal inflation and growth.

Robustness checks on monetary policy transmission

We check the robustness of the above results by changing key parameters. Figure 4 shows the impulse responses to a negative world interest rate shock (the same as in Figure 2) in the case where inflation is less sensitive to output volatility (i.e., the Philips Curve is flatter) compared with the benchmark case above.[13] The performance of the modified Taylor rule in terms of stabilizing inflation gets closer to, but does not get better than, that of the counter-cyclical LTV rule.[14] In this case, while the cost of the modified Taylor rule is small in terms of additional deviations from the inflation target, its benefit in terms of financial stability may also be small and, as a result, does not exceed that of the counter-cyclical LTV rule. More surprisingly, in response to a positive housing demand shock (Figure 5), the difference in the performance of the modified Taylor rule and the counter-cyclical LTV rule becomes

[11] For illustrative purpose, we set some large values to the parameters of the policy responses to credit gaps in the counter-cyclical LTV rule and the modified Taylor rule.

[12] Although the nominal rate drops by more under the modified Taylor Rule than under the other policy rules, this barely compensates for the larger decline in inflation. As a result, the reduction in the real interest rate is relatively small under the modified Taylor rule.

[13] The parameter α in the equation (34) of Appendix is changed from 0.5 (benchmark case) to 0.8 (flattened Philips Curve case).

[14] In this case, the model cannot be solved under the policy combination of a standard Taylor rule with a constant LTV rule.

larger (the former is much worse), rather than smaller, compared with the benchmark case. In the case of a flatter Philips curve, stabilizing housing loans by the modified Taylor rule comes at a huge cost in terms of the output gap.

These results imply that the limited effectiveness of monetary policy on inflation does not necessarily justify the use of monetary policy for broader objectives including financial stability. Similarly, we confirm that some impairment of the monetary policy transmission in the banking sector (e.g. lower pass-through to the loan interest rate) does not change the result that the counter-cyclical LTV rule performs better than the modified Taylor rule.

Robustness checks on alternative macroprudential measures

Next, we check the robustness of the results when an alternative macroprudential measure is used. Specifically, we consider a case where a targeted macroprudential measure such as the household LTV cap is not available and instead a broader measure such as counter-cyclical bank minimum capital adequacy ratio (CAR) is used.

In response to a negative world interest rate shock (Figure 6), the counter-cyclical CAR ‘overkills’ the growth of housing loans while stabilizing corporate loans, which leads to a more severe reduction in output gap compared with the modified Taylor rule. Therefore, the counter-cyclical CAR rule performs worse than the modified Taylor rule. In response to a positive housing demand shock (Figure 7), the counter-cyclical CAR rule does not necessarily overkill the growth of housing loans, but it may overkill corporate loans and thus reduces output much more severely than the modified Taylor rule. Which rule performs better in terms of output, inflation, and financial stabilization is less clear (depending on the relative importance among these objectives). These results imply that the appropriateness of monetary policy reaction to financial stability concerns depends on the availability of targeted macroprudential measures as well as the nature of shocks faced by the economy.

V. CONCLUSION

We have found that well-targeted macroprudential measures can provide a useful complement to monetary policy in the current context of the Thai economy. Active use of targeted macroprudential measures, to the extent it is available, is likely to achieve better macroeconomic outcomes by allowing monetary policy to focus on inflation and output stabilization while effectively containing financial risks.

Our findings, however, should be interpreted in context. For instance, a number of factors may limit availability of targeted macroprudential measures, including reliable data, resources for implementation, and jurisdictional constraints. At the same time, cases of weak effectiveness or leakage of macroprudential measures are relatively uncertain and untested. It is also important to note that different types of shocks from those considered in this paper—shocks to the world interest rate and domestic housing demand—may change the above conclusion. Further analysis of various types of macroprudential measures in response to various types of shocks would be an important direction for future work.

Appendix: Full description of the model

1 Households

The economy is populated by two groups of households (patient *P* and impatient *I*) as well as entrepreneurs (*E*). Each group of households is assumed to be comprised of a unit mass of identical and infinitely-lived households indexed by j. The key difference between the two groups is the degree of impatience: the discount factor of patient household (β_P) is higher than that of impatient households (β_I). The heterogeneity in discount factors determines the direction of financial flows in equilibrium: patient households purchase a positive amount of deposits and do not borrow, while impatient households (as well as entrepreneurs) borrow a positive amount of loans.

1.1 Patient Households

The representative patient household *j* maximizes expected lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} {\beta_P}^t \left[\frac{(1-b)(C_t^P(j) - bC_{t-1}^P)^{1-\sigma}}{1-\sigma} + \frac{\phi_h e_t^h \left(h_t^P(j)\right)^{1-\sigma_h}}{1-\sigma_h} - \frac{\phi_n L_t^P(j)^{1+\phi}}{1+\phi} \right]$$

subject to its budget constraint

$$\begin{aligned} C_t^P(j) + q_t^h\left(h_t^P(j) - h_{t-1}^P(j)\right) + D_t(j) + \epsilon_t B_{t+1}^f(j) = w_t^P L_t^P(j) + \epsilon_t \left(\frac{1+i_{t-1}^d}{\pi_t}\right) D_{t-1}(j) \\ + \epsilon_t \left(\frac{1+i_{t-1}^f}{\pi_t^*}\right) B_t^f(j) + \int_0^1 \pi_t^r(s) ds \\ + \int_0^1 (1-w^b) \pi_{t-1}^B(i) di \end{aligned}$$

wherein resources are spent on consumption C_t^P, housing investment $(h_t^P - h_{t-1}^P)$, making new deposits D_t, and purchase of foreign denominated bonds B_{t+1}^f that can be priced at domestic currency using the real exchange rate ϵ_t. Domestic and international inflation are denoted by π_t and π_t^*, respectively. Sources of income include real wage earnings w_t^P, interest earnings on previous period holdings of foreign bonds (at a rate i_t^f) and deposits (at a rate i_t^d), and profits from retail firms and banks, denoted by $\pi_t^r(s)$ and $\pi_t^B(i)$, respectively. Patient households are assumed to own retail firms, indexed by s, and banks, indexed by i. In the utility function, e_t^h represents a shock to the housing demand. The first-order conditions of the optimization problem are given by

$$\lambda_t^P = (1-b)(C_t^P(j) - bC_{t-1}^P)^{-\sigma} \tag{1}$$

$$\phi_h e_t^h \left(h_t^P(j)\right)^{-\sigma_h} - \lambda_t^P q_t^h + \beta_P \mathbb{E}_t[\lambda_{t+1}^P q_{t+1}^h] = 0 \tag{2}$$

$$\lambda_t^P w_t^P = \phi_n (1-b) L_t^P(j)^{\phi} \tag{3}$$

$$\lambda_t^P = \beta_P \mathbb{E}_t \left[\lambda_{t+1}^P \left(\frac{1 + i_t^d}{\pi_{t+1}} \right) \right] \tag{4}$$

$$\lambda_t^P = \beta_P \mathbb{E}_t \left[\lambda_{t+1}^P \left(\frac{1 + i_t^f}{\pi_{t+1}^*} \right) \left(\frac{\epsilon_{t+1}}{\epsilon_t} \right) \right] \tag{5}$$

where λ_t^P is Lagrange multiplier on the budget constraint. Combining equations (4) and (5) gives the uncovered interest parity condition.

$$\mathbb{E}_t \left(\frac{\epsilon_{t+1}}{\epsilon_t} \right) = \mathbb{E}_t \left[\frac{1 + i_t^d}{1 + i_t^f} \frac{\pi_{t+1}^*}{\pi_{t+1}} \right]$$

1.2 Impatient Households

The representative impatient household *j* maximizes expected lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} {\beta_I}^t \left[\frac{(1-b)(C_t^I(j) - bC_{t-1}^I)^{1-\sigma}}{1-\sigma} + \frac{\phi_h e_t^h \left(h_t^I(j) \right)^{1-\sigma_h}}{1-\sigma_h} - \frac{\phi_n L_t^I(j)^{1+\phi}}{1+\phi} \right]$$

subject to its budget constraint

$$C_t^I(j) + q_t^h \left(h_t^I(j) - h_{t-1}^I(j) \right) - \left(\frac{1 + i_{t-1}^{lH}}{\pi_{t-1}} \right) B_{t-1}^H(j) = w_t^I L_t^I(j) + B_t^H(j)$$

wherein resources are spent on consumption C_t^I, housing investment $(h_t^P - h_{t-1}^P)$, and gross reimbursement of borrowing B_{t-1}^H with a net interest rate of i_{t-1}^{lH}. Impatient households are assumed to borrow exclusively from domestic banks (foreign borrowing is prohibitively costly). In addition, impatient households face a borrowing constraint: the expected value of their housing stock must guarantee repayment of debt and interests.

$$\left(1 + i_t^{lH}\right) B_t^H(j) = m_t \mathbb{E}_t[\pi_{t+1} q_{t+1}^h h_t^I(j)]$$

The first-order conditions of the optimization problem are given by

$$\lambda_t^I = (1-b)(C_t^I(j) - bC_{t-1}^I)^{-\sigma} \tag{6}$$

$$\phi_h e_t^h \left(h_t^I(j) \right)^{-\sigma_h} - \lambda_t^I q_t^h + \beta_I \mathbb{E}_t[\lambda_{t+1}^I q_{t+1}^h] - s_t m_t \mathbb{E}_t[\pi_{t+1} q_{t+1}^h]\text{=}0 \tag{7}$$

$$\lambda_t^I w_t^I = \phi_n (1-b) {L_t^I}^{\phi} \tag{8}$$

(9)

$$\lambda_t^I = \beta_I \mathbb{E}_t \left[\lambda_{t+1}^I \left(\frac{1 + i_t^{lH}}{\pi_{t+1}} \right) \right] + s_t \left(1 + i_t^{lH}\right)$$

where λ_t^P and s_t are Lagrange multipliers on the budget constraint and the borrowing constraint, respectively.

1.3 Aggregation

The aggregated consumption bundle $C_t \equiv C_t^P + C_t^I$ consists of domestically produced goods $C_{H,t}$ and imported foreign goods $C_{F,t}$, and is given by a CES aggregator function

$$C_t = \left[\gamma^{\frac{1}{\vartheta}} \left(C_{H,t}\right)^{\frac{\vartheta-1}{\vartheta}} + (1-\gamma)\left(C_{F,t}\right)^{\frac{\vartheta-1}{\vartheta}} \right]^{\frac{\vartheta}{\vartheta-1}}$$

where ϑ is the elasticity of substitution between domestic and foreign goods and γ refers to the home bias. Each group of households minimizes consumption expenditure $P_t C_t = P_{H,t} C_{H,t} + P_{F,t} C_{F,t}$. It gives the demand function for domestic and imported consumption goods, as well as the consumer price index, respectively.

$$C_{H,t} = \gamma \left(\frac{P_{H,t}}{P_t} \right)^{-\vartheta} C_t \tag{10}$$

$$C_{F,t} = (1-\gamma) \left(\frac{P_{F,t}}{P_t} \right)^{-\vartheta} C_t \tag{11}$$

$$P_t = \gamma \left(P_{H,t}\right)^{1-\vartheta} + (1-\gamma)\left(P_{F,t}\right)^{1-\vartheta} \tag{12}$$

1.4 Deposit/Loan Demand

Patient households determine how much to deposit in retail banks by maximizing the interest payments from deposits

$$\int_0^1 i_t^d(i) D_t(i)\, di$$

subject to the deposit and deposit rate aggregator functions, respectively given by

$$D_t = \left[\int_0^1 D_t(i)^{\frac{1+\varepsilon^d}{\varepsilon^d}}\, di \right]^{\frac{\varepsilon^d}{1+\varepsilon^d}}$$

$$i_t^d = \left[\int_0^1 i_t^d(i)^{1+\varepsilon^d}\, di \right]^{\frac{1}{1+\varepsilon^d}}$$

The first order condition gives the ith retail bank's deposit demand function.

$$D_t(i) = \left[\frac{i_t^d(i)}{i_t^d}\right]^{\varepsilon^d} D_t \tag{13}$$

Similarly, impatient households decide how many loans to make by minimizing interest payments from loans

$$\int_0^1 i_t^{lH}(i) B_t^H(i)\, di$$

subject to an analogous loan and lending rate aggregator functions. Similar to the deposit demand of patient households, loan demand by impatient households will take a functional form of

$$B_t^H(i) = \left[\frac{i_t^{lH}(i)}{i_t^{lH}}\right]^{-\varepsilon^{lH}} B_t^H \tag{14}$$

2 Entrepreneurs

Entrepreneurs purchase capital K_{t+1} for the subsequent time period at price q_t. They finance capital acquisition partly through their net worth n_t and partly through borrowing. Total borrowing B_t^E of the entrepreneur satisfies the following balance sheet identity

$$B_t^E = q_t K_t - n_t \tag{15}$$

A proportion of total borrowing $L_t^d = \varpi B_t^E$ comes from domestic banks at a nominal rate of i_t^{lE} and the remaining proportion $L_t^f = (1-\varpi) B_t^E$ comes from foreign borrowing. We assume that the rate charged for foreign borrowing is the same for foreign-denominated bonds held by patient households. The real costs of domestic and foreign loans are respectively given by

$$\varpi \mathbb{E}_t \left[\frac{1 + i_t^{lE}}{\pi_{t+1}}\right]$$

$$(1-\varpi) \mathbb{E}_t \left[\frac{1 + i_t^f}{\pi_t^*} \frac{\epsilon_{t+1}}{\epsilon_t}\right]$$

Entrepreneurs decide how many domestic loans to make by minimizing interest payments from said loans

$$\int_0^1 i_t^{lE}(i) L_t^d(i)\, di$$

subject to an analogous loan and lending rate aggregator functions. Similar to impatient households, loan demand by entrepreneurs will take a functional form of

$$L_t^d(i) = \left[\frac{i_t^{lE}(i)}{i_t^{lE}}\right]^{-\varepsilon^{lE}} L_t^d \tag{16}$$

We assume that there exists an agency problem between foreign banks and entrepreneurs, which makes foreign external finance more expensive than internal funds. The entrepreneur's marginal external financing cost $\mathbb{E}_t f_{t+1}$ is given by

$$\mathbb{E}_t f_{t+1} = (1+\Gamma_t)\left[\varpi \mathbb{E}_t\left[\frac{1+i_t^l}{\pi_{t+1}}\right] + \Theta\left(\frac{n_{t+1}}{q_t K_{t+1}}\right)(1-\varpi)\mathbb{E}_t\left[\frac{1+i_t^f}{\pi_{t+1}^*}\frac{\epsilon_{t+1}}{\epsilon_t}\right]\right] \tag{17}$$

where Γ_t is a shock to the cost of borrowing. We specify the external finance premium as

$$\Theta\left(\frac{n_{t+1}}{q_t K_{t+1}}\right) = \left(\frac{n_{t+1}}{q_t K_{t+1}}\right)^{-\eta} \tag{18}$$

At the end of the period, entrepreneurs lease their undepreciated capital to capital goods producers. The expected marginal real return on capital yields the expected gross return

$$\mathbb{E}_t R_{t+1}^k = \mathbb{E}_t\left[\frac{r_{t+1}^k + (1-\delta)q_{t+1}}{q_t}\right] \tag{19}$$

The optimal loan contract condition between banks and entrepreneurs is given by

$$\mathbb{E}_t f_{t+1} = (1+\Gamma_t)\Theta\left(\frac{n_{t+1}}{q_t K_{t+1}}\right)\left[\varpi \mathbb{E}_t\left(\frac{1+i_t^l}{\pi_{t+1}}\right) + (1-\varpi)\mathbb{E}_t\left(\frac{1+i_t^f}{\pi_t^*}\frac{\epsilon_{t+1}}{\epsilon_t}\right)\right] \tag{20}$$

which states that the marginal return of capital should equal its marginal cost. The net worth of an individual entrepreneur V_t is given by

$$V_t = R_t^k q_{t-1} K_t - f_t B_t^E \tag{21}$$

We assume that a proportion ν of entrepreneurs survive until the next period. A fraction $1-\nu$ of entrepreneurs exits the economy and is similarly replaced by new entrepreneurs. We further assume that the new entrepreneurs receive an exogenous transfer H from the exiting entrepreneurs. The transfer of resources is necessary to ensure that all entrepreneurs have sufficient funds to borrow and settle their loans. Aggregate entrepreneurial net worth evolves according to

$$n_t = \nu V_t + (1-\nu)H - \varepsilon_t^n \tag{22}$$

where ε_t^n is a zero mean i.i.d. shock to net worth.

Entrepreneurs exiting the economy consume and transfer some funds to new entrepreneurs. Thus, the consumption of entrepreneurs, denoted by C_t^e, is given by

$$C_t^e = (1-\nu)(V_t - H) \tag{23}$$

3 Capital Producers

Capital producers combine the existing capital stock leased from entrepreneurs to transform gross investment I_t into new capital. We assume that the production of new capital entails a quadratic adjustment costs. Capital accumulation in the economy is given by a linear technology

$$K_{t+1} = (1-\delta)K_t + \varsigma_{I,t+1}I_{t+1} - \frac{\zeta}{2}\left(\frac{I_{t+1}}{K_t} - \delta\right)^2 K_t \tag{24}$$

where $\varsigma_{I,t}$ is a shock to the marginal efficiency of investment. Gross investment consists of domestic and foreign final goods, denoted respectively as $I_{H,t}$ and $I_{F,t}$. We further assume that it has the same aggregation function as the consumption bundle.

$$I_t = \left[\gamma^{\frac{1}{\vartheta}}\left(I_{H,t}\right)^{\frac{\vartheta-1}{\vartheta}} + (1-\gamma)\left(I_{F,t}\right)^{\frac{\vartheta-1}{\vartheta}}\right]^{\frac{\vartheta}{\vartheta-1}}$$

Minimizing the capital producers' investment expenditure $P_tI_t = P_{H,t}I_{H,t} + P_{F,t}I_{F,t}$ gives the demand function for domestic and imported investment goods, respectively

$$I_{H,t} = \gamma\left(\frac{P_{H,t}}{P_t}\right)^{-\vartheta} I_t \tag{25}$$

$$I_{F,t} = (1-\gamma)\left(\frac{P_{F,t}}{P_t}\right)^{-\vartheta} I_t \tag{26}$$

Capital producing firms seek to maximize expected profits

$$\mathbb{E}_t\left[q_t\left[\varsigma_{I,t}I_t - \frac{\zeta}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t\right] - I_t\right]$$

The first-order condition gives the capital supply equation

$$q_t\left[\varsigma_{I,t} - \zeta\left(\frac{I_t}{K_{t-1}} - \delta\right)\right] = 1 \tag{27}$$

4 Wholesale sector

The wholesale sector in the economy is assumed to be a perfectly competitive market. It is composed of the economy's entrepreneurs that combine labor provided by each group of households and capital purchased from capital-producing firms, in order to produce wholesale goods Y_t through a CRS Cobb-Douglas production function.

$$Y_t = \theta_t K_{t-1}^{\psi}[(L_t^P)^{\mu}(L_t^I)^{1-\mu}]^{1-\psi} \tag{28}$$

where θ_t is a shock to total factor productivity. Entrepreneurs determine how much labor and capital to employ by maximizing profits subject to the production function

$$w_t^P = \mu(1-\psi)mc_t \frac{Y_t}{L_t^P} \tag{29}$$

$$w_t^I = (1-\mu)(1-\psi)mc_t \frac{Y_t}{L_t^I} \tag{30}$$

$$r_t^k = \psi mc_t \frac{Y_t}{K_{t-1}} \tag{31}$$

where mc_t is the real marginal cost of production.

5 Retail sector

The retail sector of the economy is assumed to be monopolistically competitive and is composed of a continuum of retailers with a unit mass. Retailers purchase wholesale goods and differentiate them at no cost, to produce domestic goods Q_t^d and export goods Q_t^x. Final domestic goods from the retail sector is a composite of individual retail goods

$$Q_t^d = \left[\int_0^1 Q_t^d(s)^{\frac{v-1}{v}} ds\right]^{\frac{v}{v-1}}$$

with corresponding demand function facing each retailer

$$Q_t^d(s) = \left[\frac{P_{H,t}(s)}{P_{H,t}}\right]^{-v} Q_t^d$$

For simplicity, we assume that the aggregate export demand function is given by

$$Q_t^x = \left(\frac{P_{X,t}}{P_t^*}\right)^{-\vartheta_x} Y_t^* \tag{32}$$

where variables with asterisks indicate their exogenous counterpart. We also assume that the law of one price holds in the export market, so that $P_{x,t} = e_t P_{H,t}$.

To incorporate nominal rigidity in the model, we assume that in each period, only a fraction $1-\alpha$ of firms can change their prices. All other firms can only index their prices to the previous price set. Retailers seek to maximize expected profits

$$\mathbb{E}_t \sum_{t=0}^{\infty} (\alpha\beta)^s \lambda_{t+s} \left[\left(\frac{P_{H,t+s}}{P_{t+s}} \right)^{1-v} Y_{t+s} - mc_{t+s} \left(\frac{P_{H,t+s}}{P_{t+s}} \right)^{-v} Y_{t+s} \right] \tag{33}$$

where λ_{t+s} is the stochastic discount factor derived from patient household utility maximization. Profit maximization yields the New Keynesian Phillips Curve

$$P_{H,t} = (1-\alpha)\left(P_{H,t}\right)^{1-v} + \alpha\left(P_{H,t-1}\right)^{1-v} \tag{34}$$

We assume that the price of imported goods is set in the similar way.

6 Banking sector

The banking sector operates in a monopolistically competitive environment where it sets the deposit and lending rates, correspondingly. It is divided into a wholesale and retail branch. The retail branch consists of deposit and loan banks. We incorporate nominal rigidities in interest rate setting by assuming that deposit and loan banks face quadratic adjustment costs when setting their respective rates.

6.1 Retail branch

Each deposit bank collects deposits $D_t(i)$ from patient households and passes it onto the wholesale branch, which pays them a wholesale deposit rate i_t^s. The representative deposit bank determines the retail deposit rate i_t^d by maximizing its expected profit function

$$\mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left[i_t^s D_t(i) - i_t^d(i) D_t(i) - \frac{\phi_{i^d}}{2} \left(\frac{i_t^d(i)}{i_{t-1}^d(i)} - 1 \right)^2 D_t \right]$$

subject to deposit demand of patient households given in equation (13). In a symmetric equilibrium, the first-order condition gives the optimal retail deposit rate

$$\frac{1+\varepsilon^d}{\varepsilon^d} i_t^d = i_t^s - \frac{\phi_{i^d}}{\varepsilon^d} \left(\frac{i_t^d}{i_{t-1}^d} - 1 \right) \frac{i_t^d}{i_{t-1}^d} + \beta \frac{\phi_{i^d}}{\varepsilon^d} \mathbb{E}_t \left[\left(\frac{i_{t+1}^d}{i_t^d} - 1 \right) \frac{i_{t+1}^d}{i_t^d} \frac{D_{t+1}}{D_t} \right] \tag{35}$$

Each loan bank obtains wholesale loans $L_t^d(i)$ from the wholesale branch at the rate i_t^b. The retail loan rates i_t^{lH} and i_t^{lE} are determined from the expected profit maximization of the representative loan bank, given by

$$\mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \Bigg[i_t^{lH}(i) B_t^H(i) + i_t^{lE}(i) L_t^d(i) - i_t^b(i) \left(B_t^H(i) + L_t^d(i) \right) \\ - \frac{\phi_{i^{lH}}}{2} \left(\frac{i_t^{lH}(i)}{i_{t-1}^{lH}(i)} - 1 \right)^2 B_t^H - \frac{\phi_{i^{lE}}}{2} \left(\frac{i_t^{lE}(i)}{i_{t-1}^{lE}(i)} - 1 \right)^2 L_t^d \Bigg]$$

subject to the loan demand of impatient households and entrepreneurs given in equations (14) and (16). Similarly, in symmetric equilibria, the optimal retail loan rates for impatient households and entrepreneurs are

$$i_t^{lH} = \frac{\varepsilon^{lH}}{\varepsilon^{lH}-1} i_t^b - \frac{\phi_{i^{lH}}}{\varepsilon^{lH}-1}\left(\frac{i_t^{lH}}{i_{t-1}^{lH}}-1\right)\frac{i_t^{lH}}{i_{t-1}^{lH}} + \beta\frac{\phi_{i^{lH}}}{\varepsilon^{lH}-1}\mathbb{E}_t\left[\left(\frac{i_{t+1}^{lH}}{i_t^{lH}}-1\right)\frac{i_{t+1}^{lH}}{i_t^{lH}}\frac{B_{t+1}^H}{B_t^H}\right] \tag{36}$$

$$i_t^{lE} = \frac{\varepsilon^{lE}}{\varepsilon^{lE}-1} i_t^b - \frac{\phi_{i^{lE}}}{\varepsilon^{lE}-1}\left(\frac{i_t^{lE}}{i_{t-1}^{lE}}-1\right)\frac{i_t^{lE}}{i_{t-1}^{lE}} + \beta\frac{\phi_{i^{lE}}}{\varepsilon^{lE}-1}\mathbb{E}_t\left[\left(\frac{i_{t+1}^{lE}}{i_t^{lE}}-1\right)\frac{i_{t+1}^{lE}}{i_t^{lE}}\frac{L_{t+1}^d}{L_t^d}\right] \tag{37}$$

6.2 Wholesale branch

The wholesale branch takes the deposits from the deposit bank. We assume that the wholesale branch meets the cash reserve ratio (CRR) and the statutory liquidity ratio (SLR) imposed by the central bank. The latter can be thought of as an exogenously determined share of deposits in government securities. The central bank varies these requirements to control credit supply by changing the availability of resources with which the banks can use to make loans. Let α_t^s and α_t^d denote the CRR and SLR, respectively. The wholesale branch keeps $\alpha_t^s D_t(i)$ in the form of cash, and $\alpha_t^d D_t(i)$ in the form of government securities which earns an interest of i_t^t.

The wholesale branch combines bank capital $Z_t(i)$ with the remaining deposit $\left(1-\alpha_t^s-\alpha_t^d\right)D_t(i)$ to make wholesale loans $B_t^H(i)$ and $L_t^d(i)$. Since the wholesale branch can finance their loans using either deposits or bank capital, they have to obey the balance sheet identity, given by

$$\left(1-\alpha_t^s-\alpha_t^d\right)D_t + Z_t = B_t^H + L_t^d \tag{38}$$

We assume that there exists an exogenously given capital-to-assets (leverage) ratio κ_t for banks. The bank pays a quadratic cost whenever the capital-to-asset ratio moves away from κ_t. This modeling choice provides bank capital a key role in providing the conditions of credit supply.

Bank capital is accumulated each period out of retained earnings according to

$$Z_t = (1-\delta^b)Z_{t-1} + \omega^b \Pi_{t-1}^B - \varepsilon_t^B \tag{39}$$

where $1-\omega^b$ summarizes the dividend policy of the bank, δ^b measures the resources used in managing bank capital and conducting overall banking activity, and ε_t^B is a mean zero shock to the bank capital. The dividend policy is assumed to be exogenously fixed, so that bank capital is not a choice variable for the bank.

The problem for the wholesale branch is to choose loans and deposits so as to maximize profits subject to the balance sheet identity.

$$\mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left[i_t^b \left(B_t^H(i) + L_t^d(i) \right) - i_t^t(i) \alpha_t^d D_t(i) - i_t^s D_t(i) - Z_t(i) \right.$$
$$\left. - \frac{\phi_z}{2} \left(\frac{Z_t(i)}{B_t^H(i) + L_t^d(i)} - \kappa_t \right)^2 Z_t(i) \right]$$

The solution yields an optimality condition that links the spread between wholesale loan and deposit rates to the degree of the bank's leverage position.

$$i_t^b = \frac{i_t^s}{1 - \alpha_t^s - \alpha_t^d} - \phi_z \left(\frac{Z_t(i)}{B_t^H(i) + L_t^d(i)} - \kappa_t \right) \left(\frac{Z_t(i)}{B_t^H(i) + L_t^d(i)} \right)^2 - \frac{\alpha_t^d}{1 - \alpha_t^s - \alpha_t^d} i_t^t$$

We assume that banks can invest excess liquidity in the SDA facility of the central bank, from which they get remunerated at rate i_t^{SDA}. Assuming that there exists no arbitrage between the SDA facility and the deposit market, we have $i_t^s = i_t^{SDA}$. Additionally, invoking the policy rate–SDA rate identity implies that $i_t^{SDA} = i_t$. After imposing a symmetric equilibrium, we have

$$i_t^b = \frac{i_t}{1 - \alpha_t^s - \alpha_t^d} - \phi_z \left(\frac{Z_t}{B_t^H + L_t^d} - \kappa_t \right) \left(\frac{Z_t}{B_t^H + L_t^d} \right)^2 - \frac{\alpha_t^d}{1 - \alpha_t^s - \alpha_t^d} i_t^t \tag{40}$$

which links the wholesale loan rate to the central bank policy rate and T-bill rate, as well as to the leverage of the banking sector. Overall, profits of banks are the sum of earnings from the wholesale and retail branches. After deleting intra-group transactions, bank profits is given by

$$\begin{aligned} \Pi_t^B = i_t^{lH} B_t^H + i_t^{lE} L_t^d + i_t^t \alpha_t^d D_t - i_t^d D_t - \frac{\phi_{i^{lH}}}{2} \left(\frac{i_t^{lH}}{i_{t-1}^{lH}} - 1 \right)^2 B_t^H \\ - \frac{\phi_{i^{lE}}}{2} \left(\frac{i_t^{lE}}{i_{t-1}^{lE}} - 1 \right)^2 L_t^d - \frac{\phi_{i^d}}{2} \left(\frac{i_t^d}{i_{t-1}^d} - 1 \right)^2 D_t \\ - \frac{\phi_z}{2} \left(\frac{Z_t}{B_t^H + L_t^d} - \kappa_t \right)^2 Z_t \end{aligned} \tag{41}$$

7 Public sector

Government spending and the government security rate is assumed to be determined exogenously. The central bank sets the policy rate using a Taylor-type rule

$$i_t = \gamma_i i_{t-1} + (1 - \gamma_i) i + \gamma_\pi (\pi_t - \pi) + \gamma_Y (Y_t - Y) + \varepsilon_t^i \tag{42}$$

while it sets the cash reserve ratio and statutory liquidity ratio according to

$$\alpha_t^s = (1 - \rho_{\alpha s}) \alpha^s + \rho_{\alpha s} \alpha_{t-1}^s + \gamma_\pi (\pi_t - \pi) + \gamma_Y (Y_t - Y) + \varepsilon_t^{\alpha s} \tag{43}$$

$$\alpha_t^d = (1-\rho_{\alpha d})\alpha^d + \rho_{\alpha d}\alpha_{t-1}^d + \varepsilon_t^{\alpha d} \tag{44}$$

The central bank exercises macroprudential regulation on the banking sector by setting the capital adequacy ratio requirement using the following rule.

$$\kappa_t = (1-\rho_\kappa)\kappa + (1-\rho_\kappa)\chi_\kappa\left(B_t^H + L_t^d - B^H - L\right) + \rho_\kappa \kappa_{t-1} \tag{45}$$

This macroprudential policy rule is analogous to the Basel III counter-cyclical capital buffer – capital requirement of banks is increased when economic conditions are good, and is relaxed during downturns. Similarly, we assume that the LTV ratio for impatient households is determined by the following rule.

$$m_t = (1-\rho_m)m + (1-\rho_m)(B_t^H - B^H) + \rho_m m_{t-1} \tag{46}$$

8 Market Clearing Conditions

Households, exiting entrepreneurs, capital producers, government, and the rest of the world buy final goods from retailers. The economy-wide resource constraint is given by

$$Y_t = Q_t^d + Q_t^x \tag{47}$$

where $Q_t^d = C_{H,t} + C_{H,t}^e + I_{H,t} + G_t$. The national income accounting equation is given by

$$ZZ_t = C_t + C_t^e + I_t + \left(\frac{P_{H,t}}{P_t}\right)G_t + \left(\frac{P_{X,t}}{P_t^*}\right)\epsilon_t Q_t^x - \left(\frac{P_{F,t}}{P_t}\right)Q_t^m \tag{48}$$

Note that the aggregated housing stock is fixed: $h = h_t^P + h_t^I$, therefore housing investment is not included in the aggregate demand. The model allows for non-zero holdings of foreign currency denominated bonds by patient households and foreign currency denominated debt by entrepreneurs. The balance of payments equation is

$$\left(\frac{P_{X,t}}{P_t^*}\right)\epsilon_t Q_t^x - \left(\frac{P_{F,t}}{P_t}\right)Q_t^m + i_t^f\left(B_t^f + L_t^f\right) = \left(B_{t+1}^f + L_{t+1}^f\right) - \left(B_t^f + L_t^f\right) \tag{49}$$

where the left-hand side is the current account and the right-hand side is the capital account. In order to close the small open economy model, we specify a foreign debt elastic risk premium whereby holders of foreign debt are assumed to face an interest rate that is increasing the country's net foreign debt

$$1 + i_t^f = (1 + i_t^*) - \chi\left[\left(B_t^f + L_t^f\right) - (B^f + L^f)\right] \tag{50}$$

where χ is the degree of capital mobility.

9 Specification of the stochastic processes

The model includes thirteen structural shocks: shocks to technology (θ_t), investment efficiency $(\varsigma_{I,t})$, and housing demand (e_t^h), two financial shocks to the entrepreneur's cost of borrowing (Γ_t) and net worth (ε_t^n), a shock to bank capital (ε_t^B), two foreign shocks to world interest rate (i_t^*) and foreign demand (Y_t^*), a government spending shock (G_t), a shock to CRR (α_t^s), a shock to SLR (α_t^d), a shock to the T-bill rate (i_t^t), and a shock to monetary policy (ε_t^i). Aside from the monetary policy shock and net worth shock, which are zero mean i.i.d. shocks with standard deviations σ_i and σ_{nw} respectively, the other structural shocks follow an AR (1) process of the form:

$$x_t = (1-\rho_x)x + \rho_x x_{t-1} + \varepsilon_t^x$$

where $x_t = \{\theta_t, \varsigma_{I,t}, e_t^h, \Gamma_t, i_t^*, Y_t^*, G_t, \alpha_t^s, \alpha_t^d, i_t^t\}$, $x \geq 0$ is the steady state of x_t, $\rho_x \in (-1,1)$, and ε_t^x is normally distributed with zero mean and standard deviation σ_{xt}.

10 Key parameter values

The following parameters are calibrated based on data, previous studies, or judgment. Some parameter values are determined endogenously in the steady-state equilibrium.

σ = 2; relative risk aversion with respect to consumption
σ_h = 1; relative risk aversion with respect to housing
b = 0.7; consumption habit persistence
ϕ = 2; Frisch elasticity on labor supply

η = 0.05; external finance premium for entrepreneurs
δ = 0.025; capital depreciation ratio
ζ = 10; cost of capital adjustment
ψ = 0.33; capital share in production function

α = 0.5; Calvo pricing share
ν = 5; elasticity of substitution between domestic goods

ω^b = 0.8; fraction of bank profits used to accumulate bank capital
ϕ_{i^d} = 0.01; deposit rate adjustment cost parameter
$\phi_{i^{lH}}$ = 0.01; adjustment cost of loan rate for households
$\phi_{i^{lE}}$ = 0.01; adjustment cost of loan rate for entrepreneurs

Figure 1: Model overview

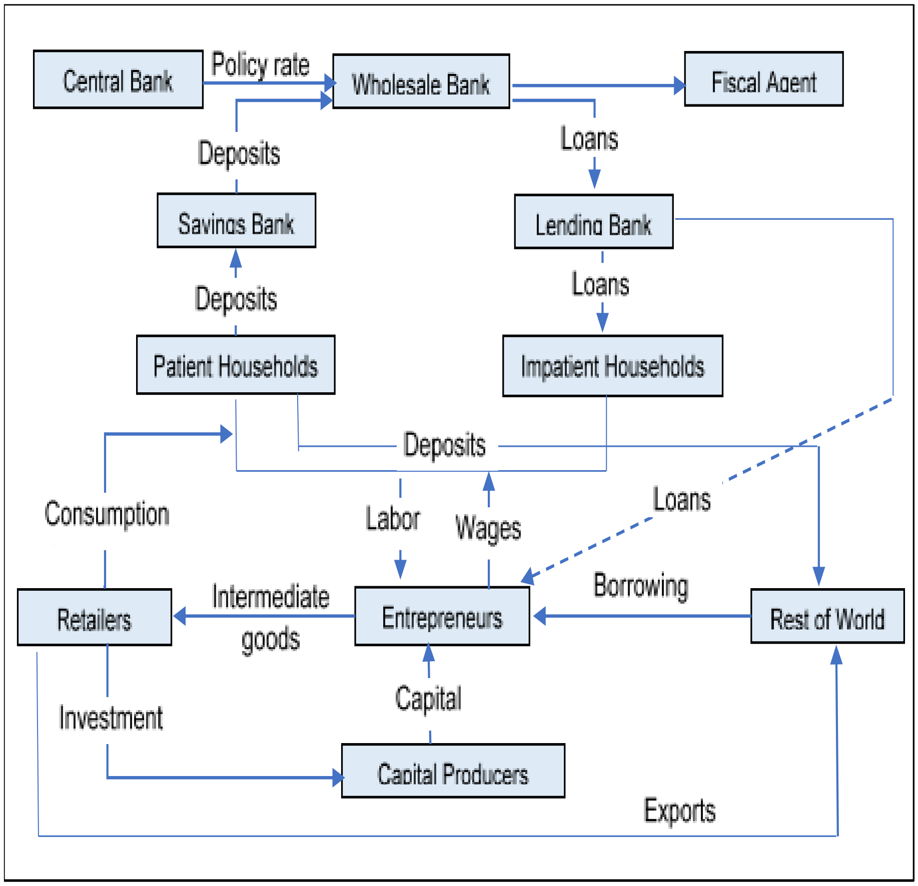


Figure 2: Responses to a negative world interest rate shock (Benchmark case)

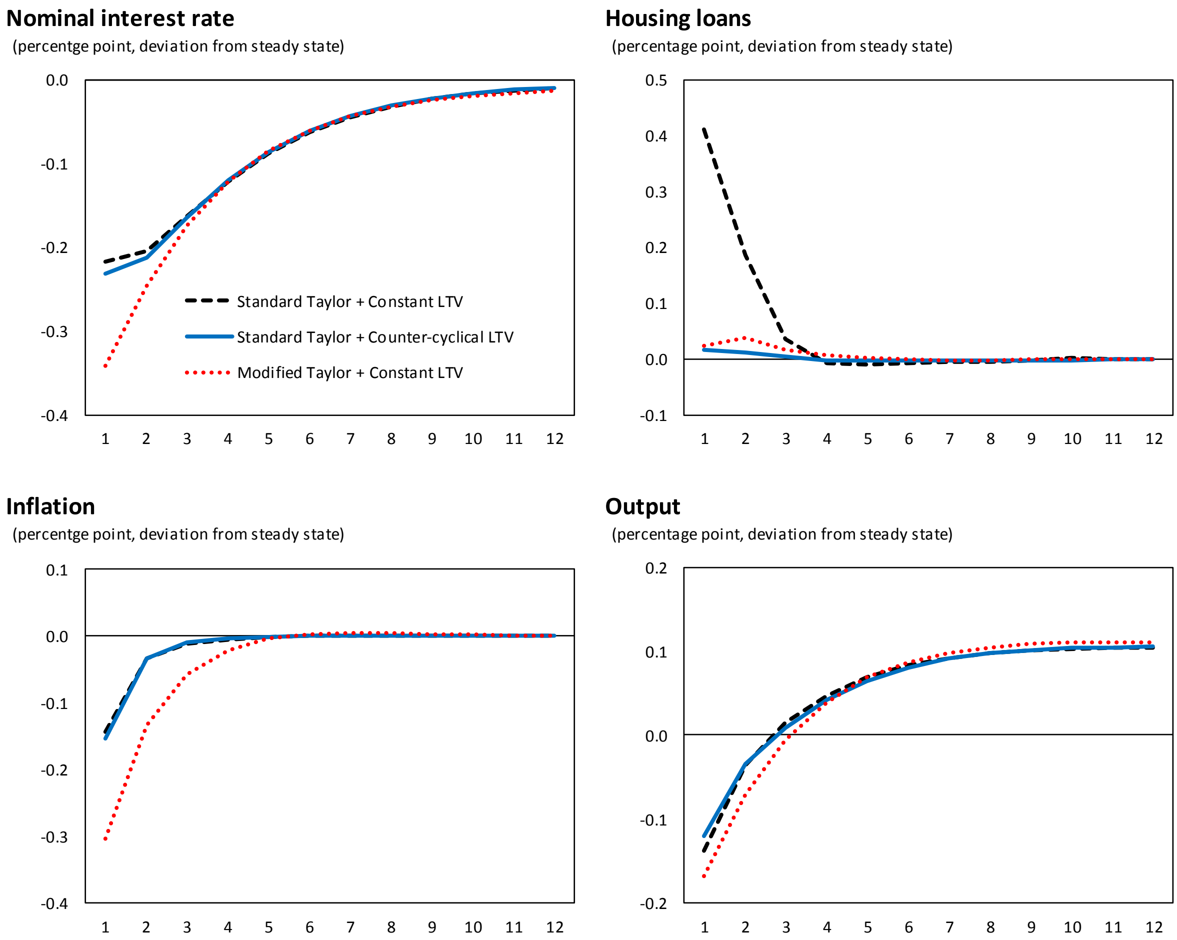


Figure 3: Responses to a positive housing demand shock (Benchmark case)

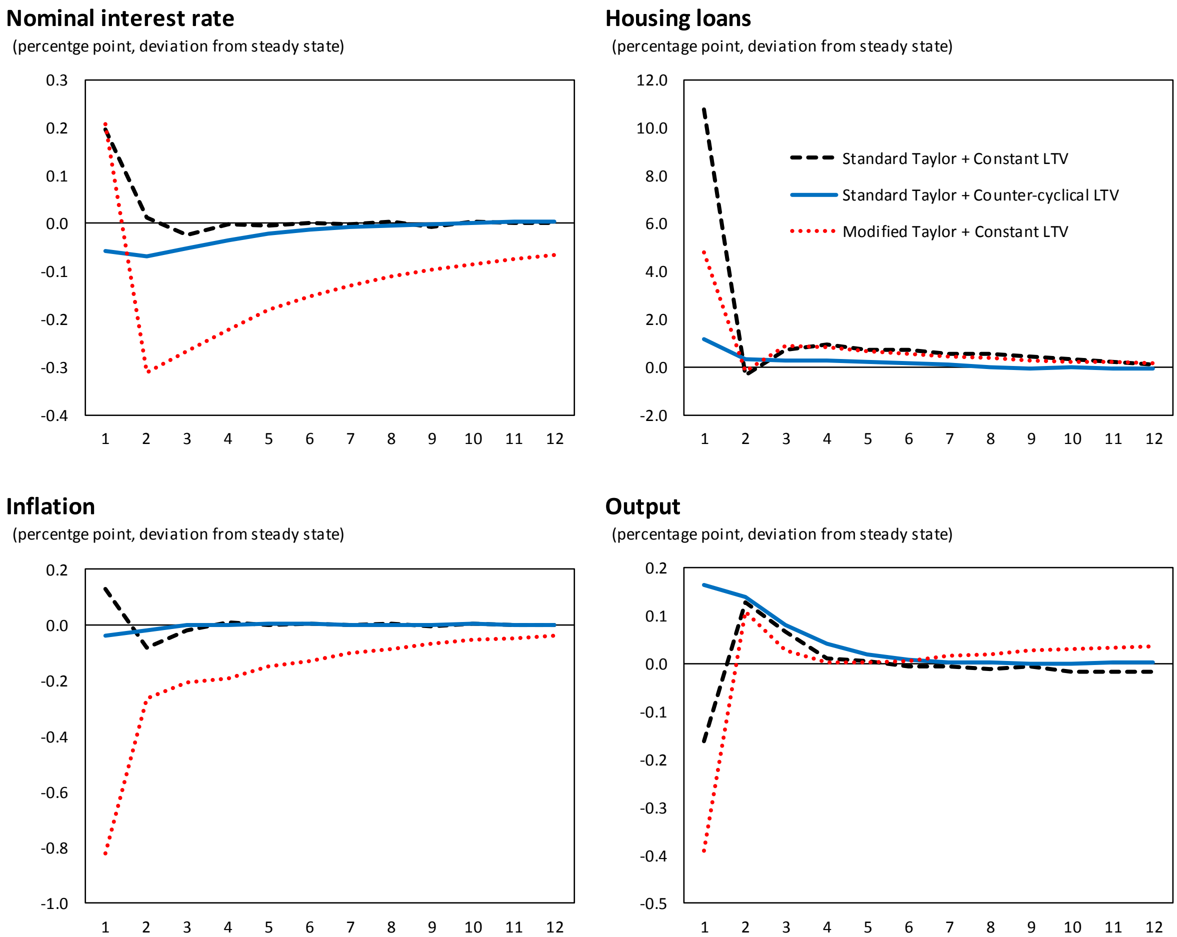


Figure 4: Responses to a negative world interest rate shock (Flattened Philips Curve case)

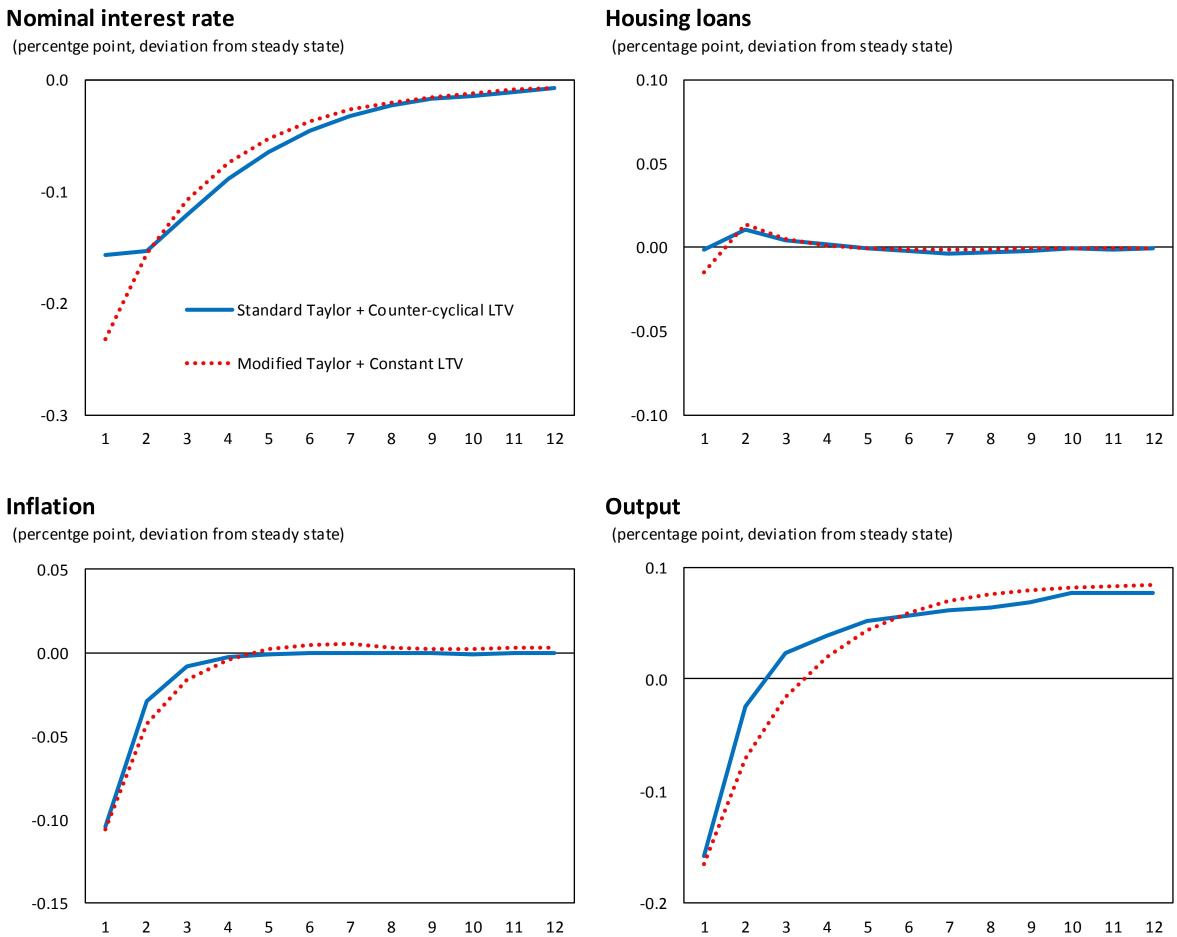


Figure 5: Responses to a positive housing demand shock (Flattened Philips Curve case)

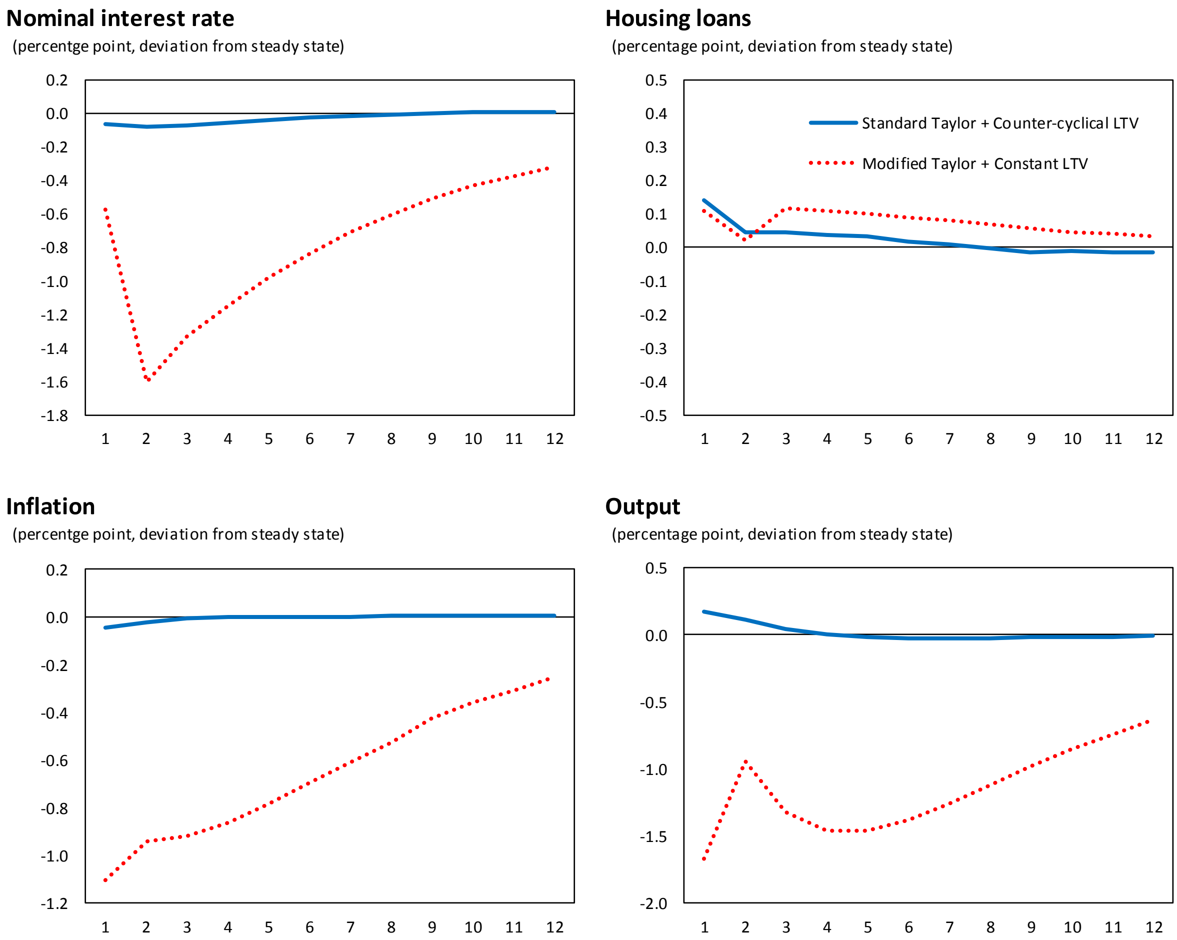


Figure 6: Responses to a negative world interest rate shock (with Capital adequacy ratio rules)

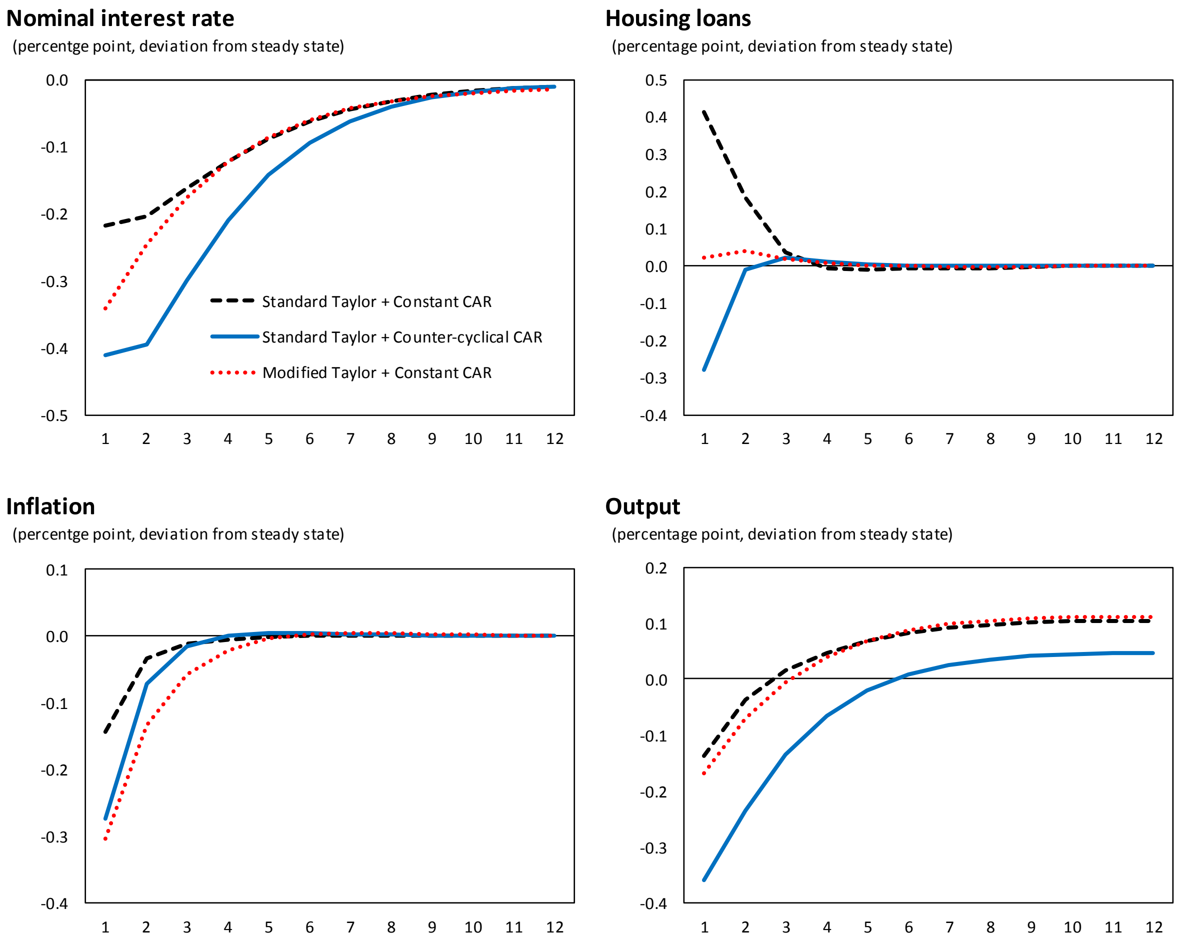
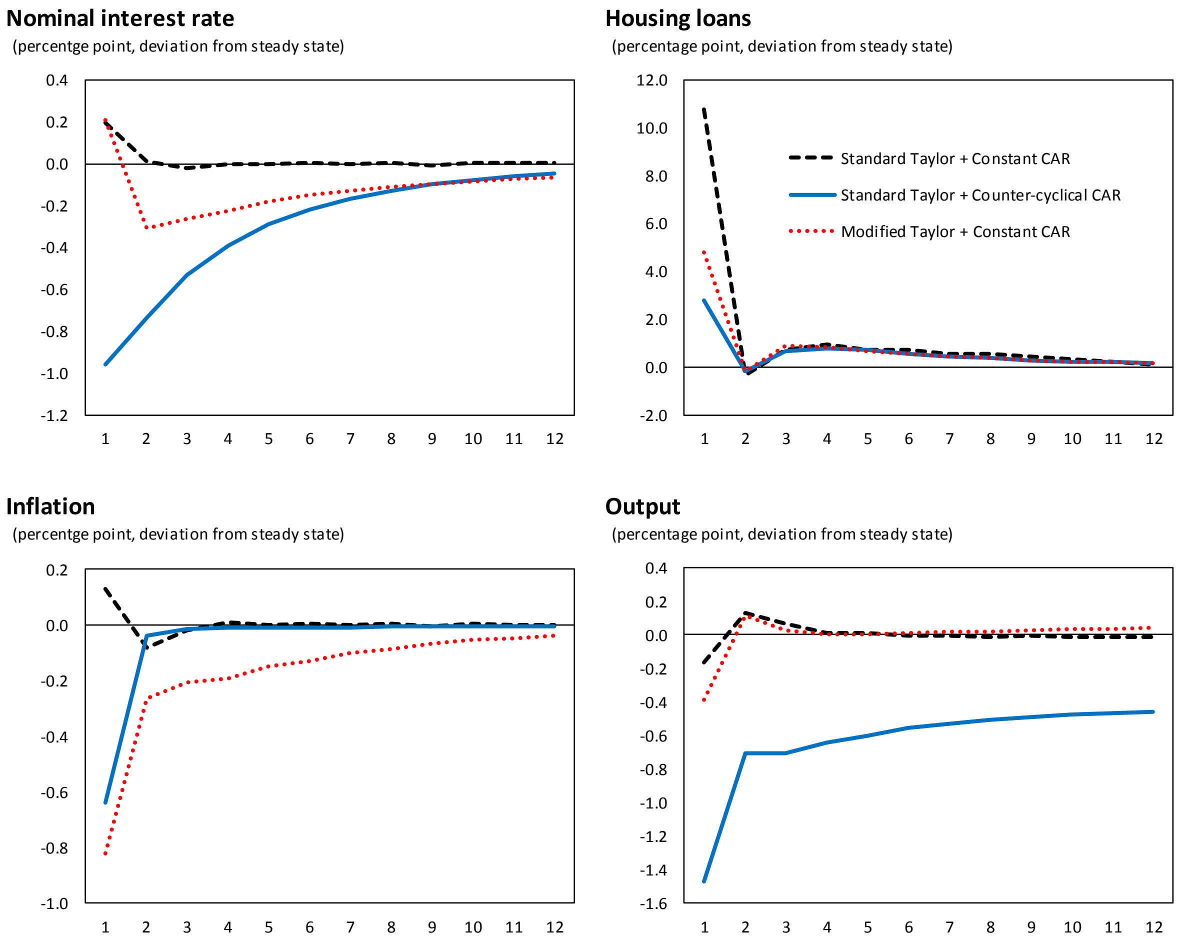


Figure 7: Responses to a positive housing demand shock (with Capital adequacy ratio rules)



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