

Online Annex 2.2. Theoretical Modeling Framework

1. The chapter uses a nonlinear dynamic stochastic general equilibrium (DSGE) model with occasionally binding housing collateral constraint, as in Guerrieri and Iacoviello (2017). For simplicity, the model ignores interactions with the corporate sector and focuses on the household sector, distinguishing between two types of households with different discount factors: borrowers and lenders. Households maximize their utility by choosing consumption, leisure, and housing, subject to budget and collateral constraints. Housing is the only collateral for borrowing, and house prices are determined by a standard forward-looking asset pricing formula. The collateral constraint is not always binding but occasionally binding, depending on house prices, income, and debt level. Other parts of the model are in line with a standard dynamic stochastic general equilibrium model with Euler equations for each type of households, a new Keynesian Phillips curve, and a monetary policy rule.

2. The model successfully replicates housing crises. The blue line in panel 1 of Annex Figure 2.2.1 shows the ergodic distribution of output gaps (that is, the gap from the steady-state level) in the baseline simulation, indicating that the model replicates huge declines in output during a housing crisis. In the model, housing crises are described as a vicious cycle of real economy and house price declines, due to the binding collateral constraint: when the level of household debt is high, further borrowing by households in response to an income decline makes the collateral constraint bind. Then, households start "fire sales" of their houses (an alternative interpretation may be as foreclosures) because they cannot borrow, leading to a decline in house prices and further tightening the collateral constraint. Given that the binding collateral constraint forces households to reduce their consumption, it decreases aggregate demand, output, wages, and household income, thus leading to another round of deteriorating conditions within the vicious cycle (see Annex Figure 2.2.1).

3. The model also replicates a positive association between the initial level of household debt and the probability of crisis. Panel 2 of Annex Figure 2.2.1 presents scatter plots of house price growth in period t (the vertical axis) against the debt-to-GDP ratios in period $t-1$ (the horizontal axis). The three lines are the estimated 5th, 50th, and 95th percentile. The figure indicates that while higher debt-to-GDP ratios have no effects (or slightly positive effects) on median growth of house prices, they significantly increase the probability of housing crises, which is consistent with this chapter's empirical analysis using a quantile regression. The model, therefore, gives some theoretical foundations as to why debt-to-GDP ratios can be used as an early warning indicator.

4. Three policy measures to mitigate the adverse effects of a housing crisis are examined in the policy exercises. The first one is macroprudential measures. Macroprudential measures are modeled as a Pigouvian tax on debt following the previous literature (see, for example, Bianchi and Mendoza 2018). While the macroprudential measures rule to internalize the pecuniary externality is a complicated and nonlinear function of state variables, the macroprudential measures rule can be well approximated by a linear function of household debt (that is, high taxes on debt when the

debt level is high).¹ The second policy measure is monetary policy augmented by a response to household debt. Under this monetary policy rule, nominal interest rates are positively associated with a household debt level, implying that the central bank increases interest rates in a run-up period while it lowers interest rates in response to deleveraging. The third policy measure is the monetary policy rule augmented by the response to credit spreads, as discussed in Cúrdia and Woodford (2011). The credit spread in the model is defined by the gap between secured and unsecured lending. Given that the spread is negligible in normal time, the central bank behaves differently from the baseline case only in a crisis by lowering interest rates in response to higher credit spread in a crisis.

5. Macroprudential measures lower the probability of crises and mitigate the negative effects of crises. The green line in panel 1 of Annex Figure 2.2.1 shows the ergodic distribution of the output gap with macroprudential measures. The figure shows that, compared with the baseline case without macroprudential measures (the blue line), macroprudential measures significantly decrease the volatility of the output gap, particularly by shrinking the negative tails of the distribution. This result suggests that macroprudential measures are effective in preventing or mitigating a housing crisis. Panel 3 more precisely shows the policy effects during crisis periods (defined as those with declines in output of more than 3 percent). Panels 3A and 3B show that macroprudential measures mitigate the decline both in output growth and house price growth during a crisis, suggesting that macroprudential measures mitigate the negative effects of housing crisis on the real economy by somewhat preventing the tightening of collateral constraint due to the decline in house prices. Panel 3D shows that the average level of household debt is significantly lower than in the baseline case, implying that household debt would be lower not only during the run-up periods but even in normal times if policymakers commit to activate macroprudential measures in response to overborrowing.

6. Monetary policy responding to household debt mitigates the negative effects of housing crisis, but its policy effect is insignificant, relative to macroprudential measures. In this exercise, the monetary policy rule is augmented by a response to household debt, and the parameters are calibrated so that the steady-state debt level is at the same level as in the economy with macroprudential measures (Annex Figure 2.2.1, panel 3D). The results show that while monetary policy responding to household debt slightly mitigates the adverse effects on output growth in a crisis (panel 3A), it does not have any effects on house price growth in a crisis, in contrast to MPMs (panel 3B). The declines in nominal interest rates in a crisis are larger than the baseline case (panel 3C), reflecting the central bank respond to deleveraging in a crisis by lowering nominal interest rates. Hence, the augmented monetary policy rule does not have effects on house prices and only slightly mitigates the adverse effects on output growth by: (1) subduing debt accumulation before a crisis, and (2) lowering nominal interest rates in response to deleveraging.

¹Note that other macroprudential measures, including caps on loan-to-value ratios and surcharges on lending rates for household debt are mathematically equivalent to macroprudential measures, using taxes on debt in the model.

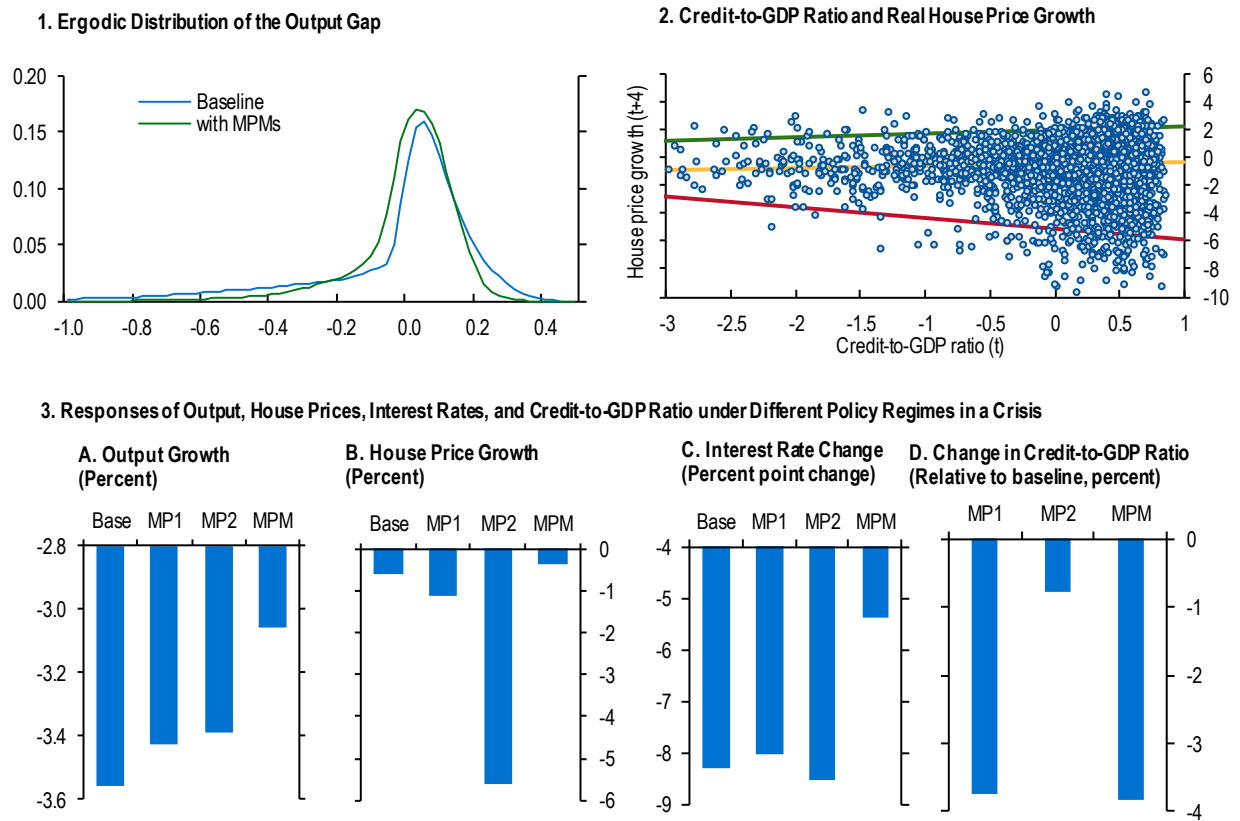
The results suggest that monetary policy may be a too blunt a tool for crisis management, as argued by Bernanke (2011).^{2,3}

7. Monetary policy responding to the credit spread also mitigates the negative effects of housing crises, but its policy effect is also limited and assumes considerable room for policy reactions. As in the previous case, Annex Figure 2.2.1 (panel 3) shows that monetary policy responding to credit spreads slightly mitigates the adverse effects on output growth in a crisis (panel 3A) but does not have any effects on house price growth in a crisis (panel 3B). Hence, monetary policy under this rule does not prevent a crisis itself but only mitigates its adverse effects on output growth in a crisis by lowering nominal interest rates and thus boosting aggregate demand. Furthermore, the declines in nominal interest rates in a crisis are very large (panel 3C), reflecting the central bank response to increases in credit spreads in a crisis by lowering nominal interest rates. Such a large decline of nominal interest rates in a crisis, however, may not be possible in some countries in a low interest rate environment, making the feasibility of this monetary policy rule somewhat doubtful.

²Surcharges on lending rates for household debt are equivalent to macroprudential measures, using taxes on debt in the model. Hence, the augmented monetary policy performs worse than macroprudential measures, only because the monetary policy influences not only lending rates but also other relevant interest rates including deposit rates.

³There are, however, several caveats. First, the exercise looks at a very specific form of monetary policy rule, namely the conventional Taylor rule augmented by a linear response to household debt. This does not mean that all monetary policy rules in a more general form may not work for crisis management. Second, in the midst of a crisis, monetary policy can respond more promptly than macroprudential measures, and may be more practically useful for policymakers.

Annex Figure 2.2.1. Impact of Monetary and Macroprudential Policies in the Theoretical Model



Source: IMF staff calculations.

Note: Panel 2 shows various associations between debt-to-GDP and house price growth for the lower 5th percentile (red line), 50th percentile (median, orange line) and 95th percentile (green line). In panel 3, output growth less than -3 percent in the baseline model is defined as a crisis period. Base = baseline specification; MP1 = monetary policy rule augmented by the response to household debt-to-GDP; MP2 = monetary policy rule augmented by the response to credit spreads; MPMs = macroprudential tax on credit-to-GDP ratio.

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