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Monetary Policy and Financial Stability*

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Abstract

The 2008 Global Financial Crisis called into question the narrow focus on price stability of inflation targeting regimes. This paper studies the relationship between price stability and financial stability by analyzing alternative monetary policy regimes for an economy that experiences endogenous financial crises due to excessive household sector leverage. We reach four conclusions. First, a central bank can improve both price stability and financial stability by adopting an aggressive inflation targeting regime, in the absence of the zero lower bound (ZLB) constraint on nominal interest rates. Second, in the presence of the ZLB constraint, an aggressive inflation targeting regime may undermine both price stability and financial stability. Third, an aggressive price-level targeting regime can improve both price stability and financial stability, regardless of the presence of the ZLB constraint. Finally, a leaning against the wind policy can be detrimental to both price stability and financial stability when the credit cycle is driven by countercyclical household sector leverage. In this environment, leaning with credit spreads can be more effective.

JEL Classification: E32, E52, G01
Keywords: Inflation targeting, financial crises, zero lower bound

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1 Introduction

After the 2008 Global Financial Crisis (GFC), a number of commentators concluded that it was the narrow focus on price stability of inflation targeting (IT) frameworks that made monetary authorities of advanced economies complacent about the financial imbalances that resulted in a near meltdown of the global financial system during the GFC (see, for example, Grauwe (2007), Leijonhufvud (2008), and Giavazzi and Giovannini (2010)). An implicit assumption underlying IT is that "the low and predictable inflation delivered by IT would promote financial robustness" (Kuttner, 2013). The GFC casts doubts on such optimism.

In this paper, we study monetary policy strategies for an economy that suffers from endogenous financial crises. In particular, we analyze monetary policy rules that can reduce both the probability and depth of financial crises. We then assess the costs of implementing such strategies in terms of sacrificing the traditional mandate of price stability.

To study the relationship between price stability and financial stability, we build a structural model of endogenous financial crises with nominal rigidities and a zero lower bound (ZLB) constraint on the policy interest rate. The endogenous financial crises mechanism in our model builds upon Kumhof et al. (2015) (KRW thereafter). In particular, borrowers compare the present values of expected utility under a default scenario with those in a non-default scenario in each period. A financial crisis occurs when the gains from default surpass the costs of default. Since the cost of default is random in this framework, the probability of financial crises is well-defined and evolves over time according to the evolution of the endogenous states of the economy, among which leverage is the most important.[1] While the endogenous financial crisis mechanism in KRW is very useful, their model cannot be used for monetary policy analysis, as it is an endowment economy with neither nominal frictions nor ZLB constraint on the policy rate.[2] To study the relationship between monetary policy and financial stability, we endogenize the production and income distribution of the KRW model, and introduce nominal rigidities and the ZLB constraint on the policy interest rate. As will be shown, the presence of the ZLB constraint fundamentally changes the conclusions about the nature of the trade-off between price stability and financial stability.

An important contribution of our paper is to study alternative monetary policy regimes within a structural model of endogenous financial crises in an economy with nominal rigidities. Related papers in the literature that study how to mitigate the effects of a financial crisis if one occurs include Del Negro et al. (2017), Cúrdia and Woodford (2011, 2016), and Gertler and Karadi (2011). However, these papers model financial crises as exogenous events, for which a probability distribution is not well defined. Therefore, such an approach does not allow one to think about "the terms of the trade-off between inflation (or output) and the likelihood of a crisis...(and)...the magnitude of the impact of the policy rate on financial fragility" (Kuttner, 2013). Two notable exceptions are Woodford (2012) and Ajello et al. (2019). These two papers assume that the probability of financial

[1] We use leverage and leverage ratio interchangeably to refer to the debt-to-income ratio.

[2] KRW use their model to show that the rise of income inequality since 1980s led to the rise of household sector leverage and, consequently, to the rise of the probability of default.

crises is an increasing function of household leverage, but the functional forms are constructed in reduced-form ways.

The analysis in our paper is a conditional one, as it focuses on two specific types of shocks that disrupt credit market equilibrium: a credit demand shock and a credit supply shock.[3] Credit market disruptions are the most important drivers of the probability of financial crises in our model.

To implement a credit demand shock, we use the risk premium shock of Smets and Wouters (2007). This shock has been widely used in the business cycle literature to model aggregate demand fluctuations. In a downturn caused by a risk premium shock, borrowers smooth out consumption by increasing debt issuance. Thus, the risk premium shock works as a credit demand shifter.

To implement a credit supply shock, we use a shock to creditors' preferences. In particular, our model assumes that creditors earn direct utility from holding privately issued bonds ("bond-in-the-utility"preferences). A shock to the marginal utility of holding bonds works as a credit supply shifter. For instance, a positive shock that increases the willingness to lend leads to a supply-driven boom in the credit market: the increase in credit supply lowers borrowing costs, leading to a consumption boom.

As both types of shocks change the credit market equilibrium over time, the manner in which the probability of financial crises evolves crucially depends on the monetary policy strategy followed by the monetary authority. This important feature allows us to explore "the terms of the trade-off between inflation (or output) and the likelihood of a crisis."

Our main findings are fourfold. First, we find that, in the absence of the ZLB constraint on nominal interest rates, the economy can achieve both price stability and financial stability by simply adopting a very aggressive form of IT.[4] The most important driver of financial crises in our framework is borrowers' debt burden, as measured by their debt-to-income ratio. In the model, borrowers' income moves faster than the stock of debt, making the debt-to-income ratio countercyclical.[5] Hence, a policy rule that minimizes the cyclical swings of nominal income also tends to minimize fluctuations in the debt-to-income ratio and the probability of financial crises. In addition, a hawkish IT regime (that is, a monetary policy regime where the interest rate responds strongly to inflation) is not only hawkish against upside risks to inflation, but also against downside risks to inflation. This means that, in the absence of the ZLB constraint, a hawkish IT regime provides a stabilization function during financial crises.

Second, the presence of the ZLB constraint overturns our first result. In particular, implementing a hawkish IT regime may undermine both price stability and financial stability when the ZLB constraint is imposed. The intuition for this result is as follows. The ZLB constraint clearly

[3]Our paper does not attempt to provide the most realistic representation of the economy by specifying and estimating a full set of structural shocks as in the quantitative macroeconomic literature studying business cycle fluctuations. We leave this next step for future research.

[4]We define "financial stability" as the product of the probability of financial crises and the 20-year cumulative output loss conditional upon a financial crisis.

[5]This is in line with Gelain et al. (2017). In contrast, Woodford (2012) assumes that borrowers' leverage is procyclical. His conclusion regarding the trade-off between price stability and financial stability largely hinges on this assumed procyclicality. Section 5 provides a detailed comparison of our results with the ones in Woodford (2012).

limits how aggressive an IT central bank can be in response to downside risks to inflation, without limiting the aggressiveness of response to upside risks to inflation. This asymmetry means that the combination of a binding ZLB and a hawkish IT monetary policy regime makes the distribution of inflation outcomes left-skewed.[6] This creates a deflation bias which, through the Fisher's debt-deflation channel, elevates borrowers' real debt burden and, consequently, the probability of financial crises. In addition, inflation volatility is larger: the increase in inflation volatility on the downside, due to the binding ZLB constraint and more frequent financial crises, is far greater than the reduction in inflation volatility on the upside. Finally, a binding ZLB means that the benefit of aggressive easing during financial crises cannot be obtained by a hawkish IT regime.

The deflation bias of IT in the presence of the ZLB constraint is already well known in the literature. Our contribution is to quantify the detrimental effects of the deflation bias on financial stability by developing a quantitative model of nominal debt and financial crises. In particular, our analysis shows the possibility that the more hawkish the central bank is against inflation, the greater inflation volatility as well as the greater financial instability it may face. This is in contrast to the consensus view summarized by Clarida et al. (1999, 2000).[7]

The first two findings suggest that the criticism against an IT regime based on the narrow focus on inflation stabilization and the oversight of financial imbalances is somewhat misleading. In particular, our results indicate that the low and predictable inflation delivered by an IT regime could indeed promote financial stability in the absence of the ZLB constraint. Our results suggest that the existing IT literature underestimated the probability of hitting the ZLB and the ramifications thereof for financial stability, and lacked discussions on how to overcome the limitations of an IT regime in this regard. In our baseline calibration, which assumes only a moderate frequency of binding ZLB constraint (4 percent of the time) and also a moderate probability of financial crises (4 percent in annual frequency), the deflation bias and its effect on real debt burden are sizable. The deflation bias amounts to -1.3 percentage points in annual frequency and the debt-to-income rate is 0.6 percentage points higher on average, when compared with an economy without imposing the ZLB and without financial crises. This leads us to our third finding.

Third, a hawkish price-level targeting (PLT) regime always succeeds in securing both price stability and financial stability even in the presence of the ZLB constraint.[8] The reason why an

[6]Note that occasional financial crises also contribute to the negative skewness in inflation. However, the main mechanism that makes a hawkish IT regime impair both price stability and financial stability is the ZLB constraint.

[7]Our conclusion also contrasts with Nakata and Schmidt (2019), who show that appointing Rogoff (1985)'s conservative central banker is optimal not only against the deflation bias due to the lack of commitment, but also against the deflation bias due to the liquidity trap. We view that the difference is largely due to the presence of a financial crisis channel and its interaction with the liquidity trap in our model, which are not present in the canonical New Keynesian framework of Nakata and Schmidt (2019). We show that a monetary policy tightening away from the ZLB constraint stabilizes inflation only at the cost of elevating the debt-to-income ratio of borrowers and the probability of financial crises. Rogoff (1985)'s conservative central banker in Nakata and Schmidt (2019)'s framework also stabilizes inflation away from the ZLB, but without the costs of jeopardizing financial stability.

[8]Other papers that study an interest-rate feedback rule with makeup features in the presence of the zero lower bound constraint include: Reifschneider and Williams (2000), Kiley and Roberts (2017), Bernanke et al. (2019), and Mertens and Williams (2019). These papers, however, do not model financial crises and thus abstract from studying the trade-off between price stability and financial stability.

IT regime fails to achieve price stability and financial stability is due to its "bygones-be-bygones" principle. In particular, the misses in hitting the inflation target during binding ZLB episodes are never made up for once the economy gets out of the ZLB constraint. As a result, the distribution of inflation is left-skewed, creating deflation bias, and thus elevating borrowers' real debt burden. In contrast, a PLT regime promises to overshoot the inflation target during binding ZLB episodes, thereby making the real interest rate lower immediately. Thus, a PLT regime corrects for the left-skewed distribution of inflation and stabilizes borrowers' real debt burden. The more hawkish the central bank is in implementing the PLT, the greater the enhancement for both price stability and financial stability, regardless of the presence of the liquidity trap. There is nothing new in the argument that PLT can outperform IT in the presence of the ZLB constraint. Our contribution is to show that a PLT regime can also contribute to financial stability.[9]

Fourth, supplementing an IT or PLT framework with a "leaning against the wind" policy may undermine both price stability and financial stability if monetary policy actions intended to stabilize borrowers' debt-to-income ratio affect borrowers' income faster than their stock of debt.[10] In particular, if the debt-to-income ratio is countercyclical, which is more likely if income goes down faster than debt during a downturn, a leaning against the wind policy implements a *procyclical* monetary policy. This policy amplifies booms and busts, undermining its traditional stabilization goals. Such a possibility is shown by Svensson (2013) in a reduced form model. Our contribution is to quantify such an outcome in an optimization-based general equilibrium model.

Our analysis also shows that such a policy may face indeterminacy if monetary policy tightening leads to a greater increase in the debt-to-income ratio, which requires even stronger tightening. Thus, this policy may have an unintended consequence of elevating the debt-to-income ratio and the probability of financial crises. We find that this problem becomes much more severe when the debt contract is in longer maturities and the refinancing ratio is lower, in line with Gelain et al. (2017). Additionally, we find that easing monetary policy in response to a credit crunch, reflected in spikes in credit spreads, works better in lowering the probability of financial crises. However, this may require sacrificing price stability in the presence of the ZLB constraint, especially when such a policy is implemented in the context of an IT regime. Instead, complementing a PLT regime with a credit spreads rule does not face such a trade-off between price stability and financial stability.[11]

The analysis of this paper is conditional on the assumption that there are no regulatory authorities implementing macroprudential policies independent of the monetary authority. Thus, our results concern the study of monetary policy strategies that safeguard price stability and financial

[9] While this paper focuses on shocks that disrupt credit market equilibrium, this result is robust to alternative shocks, including technology shocks and shocks to workers' bargaining power. See Cairó and Sim (2018).

[10] "Leaning against the wind" policy is to modify the traditional interest rule with a positive coefficient assigned to private sector's leverage, such as debt-to-GDP ratio.

[11] Note that the PLT framework considered in this paper is the limit point of various forms of Average Inflation Targeting (AIT). In general, provided that AIT concerns past misses in hitting the inflation target far back enough, AIT and PLT share similar features. For example, both prescribe inflation to overshoot the central bank's target to make up for cumulative past inflation misses due to the binding ZLB constraint and financial crises. Also, both approaches help the central bank align the unconditional inflation expectations of the public to its inflation target.

stability in the absence of macroprudential policy tools.[12]

The rest of the paper is organized as follows. Section 2 develops the model, which is calibrated in Section 3. Section 4 describes the main model properties. Section 5 studies the relationship between price stability and financial stability under alternative monetary policy regimes. Section 6 concludes.

2 Model

The model economy features two groups of agents: agent K, who plays the role of shareholders-creditors, denoted by superscript K, and agent W, who plays the role of workers-debtors, denoted by superscript W. Each group contains a continuum of agents and forms a large family that shares the budget and consumption. The population shares of shareholders and workers are denoted by χ and $1-\chi$, respectively.

We assume a segmented asset market structure, where agent K owns production firms and accumulates physical capital. Agent K also accumulates private bonds and government bonds. Agent W does not participate in capital markets and the only instrument available to smooth consumption is borrowing from the private bond market. In equilibrium, agent K lends money to agent W.

2.1 Agent W

Preferences of agent W are:

$$U_t^W = \mathbb{E}_t \sum_{t=0}^{\infty} (\beta^W)^t \left\{ \frac{(c_t^W - s c_{t-1}^W)^{1-1/\sigma_c}}{1-1/\sigma_c} \right\}, \tag{1}$$

where β^W is the discount factor, c_t^W denotes per capita consumption level of agent W, s is the degree of external habit formation, and σ_c is the elasticity of intertemporal substitution. c_t^W is a Dixit-Stiglitz aggregator of a variety of consumption goods with elasticity of substitution $\gamma \in (1, \infty)$.

Agent W earns wage income by providing labor when employed and searches for a job and earns unemployment benefits when unemployed. The only financial instrument that agent W can use to smooth consumption is the issuance of defaultable discount bonds. Per capita private bond issuance of agent W is denoted by b_t and the price of the discount bond by q_t^B. If borrowers do not default, the bond delivers a real return of $\mathbb{E}_t[1/\pi_{t+1}]$ to lenders in the next period, where π_t is the gross inflation rate. If borrowers default, lenders get back only $(1-h)\mathbb{E}_t[1/\pi_{t+1}]$, where h is the haircut associated with the default. Thus, the actual payment can be denoted as:

$$l_t = (1 - h\delta_t^B) \frac{b_{t-1}}{\pi_t}, \tag{2}$$

[12] As a result, we do not address the coordination issue between monetary and regulatory authorities (see De Paoli and Paustian (2017) for a study on the coordination issue).

where $\delta_t^B \in \{0,1\}$ is the default indicator that takes 1 upon default and 0 otherwise.

Default involves pecuniary and non-pecuniary costs, the latter in terms of a loss in borrowers' utility. The size of the pecuniary default cost is given by a fraction ν_t of aggregate output y_t, which follows:

$$\nu_t = \rho_\nu \nu_{t-1} + \gamma_\nu \delta_t^B. \tag{3}$$

The effect of a default is given by γ_ν on impact, while ρ_ν governs the decay rate in the absence of further defaults.

The per capita budget constraint for agent W can be expressed as:[13]

$$c_t^W = q_t^B b_t - l_t + \frac{1}{1-\chi}\left[\int_0^1 w_t(i)n_t(i)di + (1-\chi-n_t)b^U - \nu_t y_t\right], \tag{4}$$

where $w_t(i)n_t(i)$ is the wage income of workers employed by firm i, and b^U denotes unemployment benefits. The first-order conditions (FOCs) of agent W are given by $\Lambda_t^W = (c_t^W - sc_{t-1}^W)^{-1/\sigma_c}$, and

$$q_t^B = \beta^W \mathbb{E}_t\left[\frac{\Lambda_{t+1}^W}{\Lambda_t^W}(1-hp_{t+1}^\delta)\frac{1}{\pi_{t+1}}\right], \tag{5}$$

where Λ_t^W is the shadow value of the budget constraint, and $p_{t+1}^\delta \equiv \mathbb{E}_{t+1}[\delta_{t+1}^B]$ is the probability of default.

2.2 Agent K

We denote per capita consumption level of agent K by c_t^K, per capita government bond holdings by b_t^G, and per capita holdings of private bonds by $b_t(1-\chi)/\chi$. Agent K maximizes the following intertemporal utility function:

$$U_t^K = \mathbb{E}_t \sum_{t=0}^{\infty} (\beta^K)^t \left\{\frac{(c_t^K - sc_{t-1}^K)^{1-1/\sigma_c}}{1-1/\sigma_c} + \psi_t^B \frac{[1+b_t(1-\chi)/\chi]^{1-1/\sigma_b}}{1-1/\sigma_b} + \psi^G \frac{(1+b_t^G)^{1-1/\sigma_g}}{1-1/\sigma_g}\right\}, \tag{6}$$

where β^K is the discount factor. ψ_t^B and ψ^G are strictly positive weights on utilities from bond holdings. σ_b and σ_g determine how fast the marginal utilities of financial asset holdings decline. As indicated by the time subscript in ψ_t^B, we allow for a preference shock so that the marginal utility from holding private bonds is perturbed by a random shock. The process for ψ_t^B is assumed to be AR(1):

$$\log(\psi_t^B) = (1-\rho_\psi)\log(\psi^B) + \rho_\psi \log(\psi_{t-1}^B) + \sigma_\psi \epsilon_{\psi,t}, \quad \epsilon_{\psi,t} \sim N(0,1).$$

The per capita budget constraint for agent K is expressed as:

$$c_t^K = \frac{b_{t-1}^G}{\pi_t} - \frac{b_t^G}{1+i_t} + (l_t - q_t^B b_t)\frac{1-\chi}{\chi} + \frac{1}{\chi}\{r_t k_{t-1} + \Pi_t - T_t - q_t^K[k_t - (1-\delta)k_{t-1}] + \nu_t y_t\}, \tag{7}$$

[13]We assume that wage income and unemployment benefits are evenly shared by members of agent W. This allows for a symmetric equilibrium in which all members of agent W make identical consumption and borrowing/default decisions.

where i_t is the nominal interest rate controlled by the monetary authority, r_t is the rental rate of capital, k_t/χ is per capita capital stock, δ is the depreciation rate of capital, q_t^K is the relative price of capital, Π_t/χ is the per capita profit of intermediate-goods firms, and T_t/χ is the per capita lump sum tax.

As indicated by the last term in equation (7), we assume that the pecuniary default cost of agent W is transferred to agent K in a lump-sum fashion. Hence the transfer of default costs can be viewed as debt restructuring. Default provides a large one-time release in agent W's budget, but generates a persistent cost. The FOCs of agent K are

$$q_t^B = \beta^K \mathbb{E}_t \left[\frac{\Lambda_{t+1}^K}{\Lambda_t^K} (1 - hp_{t+1}^\delta) \frac{1}{\pi_{t+1}} \right] + \frac{\psi_t^B}{\Lambda_t^K} \left[1 + b_t \left(\frac{1-\chi}{\chi} \right) \right]^{-1/\sigma_b}, \tag{8}$$

$$1 = \beta^K \mathbb{E}_t \left[\frac{\Lambda_{t+1}^K}{\Lambda_t^K} \left(\frac{r_{t+1} + (1-\delta) q_{t+1}^K}{q_t^K} \right) \right], \tag{9}$$

$$\frac{1}{1+i_t} = \beta^K \mathbb{E}_t \left[\frac{\Lambda_{t+1}^K}{\Lambda_t^K} \frac{\phi_t}{\pi_{t+1}} \right] + \frac{\psi^G}{\Lambda_t^K} (1 + b_t^G)^{-1/\sigma_g}, \tag{10}$$

where $\Lambda_t^K = (c_t^K - sc_{t-1}^K)^{-1/\sigma_c}$. Following Smets and Wouters (2007), ϕ_t is a risk-premium shock that drives a wedge between the interest rate controlled by the central bank and the return on assets held by agent K, and follows an AR(1) process:

$$\log \phi_t = \rho_\phi \log \phi_{t-1} + \epsilon_{\phi,t}, \quad \epsilon_{\phi,t} \sim N(-0.5\sigma_\phi^2, \sigma_\phi^2).$$

2.3 Financial Crises

A default occurs when the borrowers' utility gain from defaulting is greater than the utility cost of default $\epsilon_{\delta,t}$, which follows an iid process with its cumulative distribution function denoted by $\Xi(\cdot)$. Formally, a default occurs when $\epsilon_{\delta,t} < U_t^D - U_t^N$, where U_t^D and U_t^N denote agent W's values of default and non-default, respectively, defined as:

$$U_t^D((1-h)b_{t-1}/\pi_t, \nu_{t-1}) \equiv \frac{(c_t^D - sc_{t-1}^W)^{1-1/\sigma_c}}{1 - 1/\sigma_c} + \beta^W \mathbb{E}_t [U_{t+1}^W (l_{t+1}, \rho_\nu \nu_{t-1} + \gamma_\nu)], \tag{11}$$

$$U_t^N(b_{t-1}/\pi_t, \nu_{t-1}) \equiv \frac{(c_t^N - sc_{t-1}^W)^{1-1/\sigma_c}}{1 - 1/\sigma_c} + \beta^W \mathbb{E}_t [U_{t+1}^W (l_{t+1}, \rho_\nu \nu_{t-1})], \tag{12}$$

where U_{t+1}^W corresponds to equation (1). We define $c_t^D \equiv c_t^W(\delta_t^B = 1)$ and $c_t^N \equiv c_t^W(\delta_t^B = 0)$ as the consumption levels conditional on default and non-default decisions, respectively.

The probability of default is then given by

$$p_t^\delta \equiv \text{prob}(\delta_t^B = 1) = \Xi(U_t^D - U_t^N). \tag{13}$$

The utility cost of default $\epsilon_{\delta,t}$ is assumed to follow a modified logistic distribution as in KRW:

$$\Xi(\epsilon_{\delta,t}) = \left\{ \begin{array}{cc} \dfrac{\varrho}{1+\exp(-\varsigma\epsilon_{\delta,t})} & \text{if } \epsilon_{\delta,t} < \infty \\ 1 & \text{if } \epsilon_{\delta,t} = \infty \end{array} \right\}, \tag{14}$$

where $0 < \varrho < 1$. The parameters ϱ, ς, γ_ν, and ρ_ν are calibrated to match the empirical evidence on financial crises.

All individuals take the macroeconomic variables as given while making their individual default decision. The bond market is characterized as a competitive equilibrium with a continuum of agents and "the actions of a single individual are negligible" (Aumann, 1975). In our symmetric default or non-default equilibrium, every individual makes an identical choice, believing that their actions will not affect macroeconomic outcomes. However, with everyone making the same choice, default decisions impact the economy in equilibrium. It is for the same reason that neither the borrower's efficiency condition nor the lender's efficiency condition (equations (5) and (8), respectively) incorporate the effect of increasing debt on the probability of default or the bond price. In other words, both agents behave as if $\partial p^{\delta}_{t+1}/\partial b_t = \partial q^{B}_t/\partial b_t = 0$ because they view their individual actions inconsequential for the competitive equilibrium in the debt market: they are price takers.

2.4 Monopolistic Competitors

The activities of monopolistic competitors are standard and the description thereof is kept brief. There exists a continuum of monopolistic competitors indexed by $i \in [0,1]$, producing an intermediate consumption good using capital $k_t(i)$ and labor $n_t(i)$. The production technology is given by:

$$y_t(i) = k_{t-1}(i)^{\alpha} n_t(i)^{1-\alpha}. \tag{15}$$

Firm i faces a downward sloping demand curve, $y_t(i) = (P_t(i)/P_t)^{-\gamma}\, y_t$, where P_t is the aggregate price index. Firms make three decisions: a pricing decision subject to infrequent price adjustments, a vacancy posting and hiring decision in a frictional labor market, and a capital rental decision.

We assume that firms set prices according to a variant of the formalism proposed by Calvo (1983) to allow for indexation. In particular, each firm has a constant probability $1-\varphi$ to reset its price in any given period, which is independent across firms and time. Firms that cannot reset their price in a given period partially index their price to lagged inflation. Thus, the price of firm i in period t is

$$P_t(i) = \begin{cases} P^*_t & \text{with probability } 1-\varphi \\ P_{t-1}(i)\pi^{\varepsilon}_{t-1} & \text{with probability } \varphi \end{cases},$$

where P^*_t is the reset price, $\pi_t = P_t/P_{t-1}$ is the inflation rate, and ε is the degree of indexation.

At the end of period $t-1$, a fraction ρ of workers is exogenously separated from the firm. Then, aggregate shocks realize, and firms make pricing decisions determining the production scale. Firms then post vacancies $v_t(i)$ at a flow vacancy posting cost ξ per period. Vacancies are filled with probability $q(\theta_t) = m(v_t, u_t)/v_t = (\zeta v_t^\epsilon u_t^{1-\epsilon})/v_t = \zeta\theta_t^{\epsilon-1}$, where $\theta_t \equiv v_t/u_t$ is labor market tightness and ζ is the matching function efficiency. Firms consider the flow probability as given when choosing vacancy posting. Then, firms make the capital rental decision.

Optimal decisions for vacancy posting, hiring, and capital rental satisfy the following FOCs:

$$J_t(i) = \frac{\xi}{q(\theta_t)}, \tag{16}$$

$$J_t(i) = \sum_{s=t}^{\infty} \mathbb{E}_t \left\{ (1-\rho)^{t-s} m_{t,s}^K \left[\mu_s(i)(1-\alpha)\frac{y_s(i)}{n_s(i)} - w_s(i)) \right] \right\}, \tag{17}$$

$$r_t = \mu_t(i)\alpha \frac{y_t(i)}{k_{t-1}(i)}, \tag{18}$$

where $m_{t,s}^K \equiv (\beta^K)^{s-t}\Lambda_s^K/\Lambda_t^K$. The FOC for vacancy posting (16) equalizes the value of the job to the firm, denoted by $J_t(i)$, to the present value of the vacancy posting cost given the expected duration of the vacancy. The FOC for hiring (17) shows the economic content of the value of the job to the firm, which is the present value of the marginal productivity over the real wage.[14] Since capital rental is free of adjustment frictions, the FOC (18) equalizes the marginal cost of the rental to the marginal productivity of capital.[15]

It is assumed that vacancies posted at the beginning of the period can be filled in the same period before production takes place, and that recently separated workers can search and find a job in the same period. Thus, the law of motion for the firm's workforce is given by:

$$n_t(i) = (1-\rho)n_{t-1}(i) + q(\theta_t)v_t(i). \tag{19}$$

After the matching process is complete, the wage is determined through Nash wage bargaining: $w_t(i) = \arg\max_{w_t(i)} W_t(i)^\eta J_t(i)^{1-\eta}$, where η is the workers' bargaining power and $W_t(i)$ denotes workers' surplus value given by

$$W_t(i) = \sum_{s=t}^{\infty} \mathbb{E}_t\{(1-\rho)^{t-s} m_{t,s}^W [w_t(i) - \underline{w}_t]\}, \tag{20}$$

where $m_{t,s}^W \equiv (\beta^W)^{s-t}\Lambda_s^W/\Lambda_t^W$. $\underline{w}_t$ is the value of worker's outside option and is given by the sum of unemployment benefits and the expected value of finding a new job next period:

$$\underline{w}_t = b^U + (1-\rho)\mathbb{E}_t \left[m_{t,t+1}^W p(\theta_{t+1}) \int_0^1 \frac{v_{t+1}(j)}{v_{t+1}} W_{t+1}(j)dj \right], \tag{21}$$

where $p(\theta_t)$ is the job finding rate given by $m(v_t, u_t)/u_t = \zeta v_t^\epsilon u_t^{1-\epsilon}/u_t = \zeta\theta_t^\epsilon$ and $v_{t+1}(j)/v_{t+1}$ is

[14] We assume a convex adjustment cost for the real wage, the expression of which we omit to simplify the presentation. See Section 3 for details.

[15] We assume that aggregate investment is subject to a convex adjustment cost in order to make the investment response hump shaped. See Section 3 for details.

the probability of being matched with firm j conditional on finding a job.

2.5 Government

We assume a balanced budget each period. Government spending is financed by lump sum taxes on shareholders and is composed of two elements: unemployment benefits and interest expenses on government debt. The balanced budget constraint then implies:[16]

$$T_t = (1 - \chi - n_t)b^U + \chi \left(\frac{b_{t-1}^G}{\pi_t} - \frac{b_t^G}{1 + i_t} \right). \tag{22}$$

The monetary authority is assumed to follow an inflation targeting (IT) regime in our baseline economy, subject to the ZLB constraint on nominal interest rates:

$$i_t = \max \left\{ 0, i^* + \rho_\pi \left(\frac{\pi_t^Y - \pi^*}{4} \right) \right\}, \tag{23}$$

where i^* is the steady state nominal interest rate, $\pi_t^Y \equiv \pi_t \pi_{t-1} \pi_{t-2} \pi_{t-3}$ is the gross annual inflation rate, and π^* is the annual inflation target.[17]

3 Calibration

The model is calibrated at a quarterly frequency. Table 1 summarizes our choices for the structural parameters determining preferences and default, which closely follow the calibration strategy in KRW. Table 2 summarizes the parameters pertaining to the structure of production, labor markets, nominal rigidities, monetary policy, and exogenous shock processes. The population share of agent K is calibrated at 5 percent.

Preferences and Default: We use the same haircut due to default ($h = 0.1$) and the persistence of the default cost ($\rho_\nu = 0.65^{0.25}$) as in KRW. The output loss upon default is set to $\gamma_\nu = 0.045$. Given this choice, the cumulative output loss following a financial crisis is 18 percent. This value stands in between the 8 percent decline assumed in KRW, which was less than observed during the Great Recession, and the 26 percent output loss suffered by the U.S. economy from 2008 to 2016 relative to its potential as estimated by the CBO in 2017.[18]

Regarding the parameters of the modified logistic distribution of the utility cost of default, we calibrate $\varsigma = 18$ as in KRW and set $\varrho = 0.011$ to match a quarterly default probability of 1.1 percent, which is consistent with the empirical default probability computed by Schularick and Taylor (2012) on the eve of the Great Recession.

[16] $1 - \chi - n_t$ is the unemployment rate at the end of period. The unemployment rate that enters the matching function at the beginning of the period is given by $u_t = 1 - \chi - (1 - \rho)n_{t-1}$.

[17] The ZLB constraint is implemented by a set of anticipated news shocks to the monetary policy rate. See Holden (2019) to see the equivalence of occasionally binding constraints and the set of anticipated news shocks.

[18] Note that this output loss can be considered a conservative estimate, given the significant downward revisions to potential output undertaken by the CBO during the years after the Great Recession.

Table 1: Parameters for Preferences and Default

Parameter	Target/Source	Value
Population share of agent K	5 percent	$\chi = 0.05$
Haircut	KRW	$h = 0.1$
Persistence of default cost	KRW	$\rho_\nu = 0.65^{0.25}$
Impact default cost	Output loss during the Great Recession	$\gamma_\nu = 0.045$
Default cost parameter	KRW	$\varsigma = 18$
Default cost parameter	Empirical default probability	$\varrho = 0.011$
Steady state interest rate	Literature	$i^* = 0.005$
Utility weight on private bond	Debt-to-income ratio of bottom 95 percent income earners = 1.5	$\psi^B = 0.95$
Utility weight on government bond	Same as private bond	$\psi^G = 0.95$
Discount factor of agent W	Literature	$\beta^W = 0.99$
Discount factor of agent K	Income share of top 5 percent income earners = 0.36	$\beta^K = 0.89$
Wealth elasticity of shareholders	KRW	$\sigma_b = 1.09$
Wealth elasticity of shareholders	Annual nominal interest rate of 2 percent	$\sigma_g = 0.5$
Elasticity of intertemporal subs.	Literature	$\sigma_c = 1$
Elasticity of subs. between goods	Literature	$\gamma = 5$

The steady state risk-free interest rate is set to 0.5 percent quarterly. In contrast to KRW, in which the risky private bond is the only financial investment, in our model economy the risk-free bond is an important financial investment vehicle for monetary policy transmission. Once we calibrate σ_g, equation (10) and the target interest rate pin down the level of per capita government bond holdings.

We calibrate the steady state debt-to-income ratio of agent W to 1.5, which is close to the debt-to-income ratio of the bottom 95 percent income earners on the eve of the Great Recession. This choice leads us to set a utility weight on private bond holdings of agent K ($\psi^B = 0.95$). For the government bond holdings, we use the same utility weight ψ^G as with private bonds. We choose a slightly lower value of the discount factor for agent K than KRW so that there is a greater incentive to invest in financial assets, and be consistent with the calibrated debt-to-income ratio. However, we use the same wealth elasticity as in their analysis and set $\sigma_b = 1.09$. With these choices, the income share of agent K is 0.34 in the steady state, a similar value observed on the eve of the Great Recession for the top 5 percent income earners. Also, the marginal propensity to save (MPS) of agent K in our baseline economy equals 0.303, close to the value of 0.397 used in KRW for the top 5 percent income earners that matches empirical MPS.

We specify a log utility, $\sigma_c = 1$, and an elasticity of substitution between differentiated goods of $\gamma = 5$. We set the degree of habit formation equal to $s = 0.75$, a standard value in the literature.[19]

Production: The capital share of production equals $\alpha = 0.2$ to match a labor income share of 0.60 in steady state. The value for α is somewhat lower than the convention of $0.3 \sim 0.4$. However, a conventional calibration results in a too-low labor share in our environment given the existence

[19] See, for example, Smets and Wouters (2007), Gertler et al. (2008), and Furlanetto and Groshenny (2016).

Table 2: Parameters for Technology, Labor Markets, Nominal Rigidities and Shock Processes

Parameter	Target/Source	Value
Capital share of production	Labor income share = 0.60	$\alpha = 0.2$
Investment adjustment cost	Relative volatility of investment	$\kappa = 4$
Habit in consumption	Literature	$s = 0.75$
Depreciation rate	Literature	$\delta = 0.025$
Separation rate	CPS	$\rho = 0.37$
Matching efficiency	CPS, job finding rate	$\zeta = 0.91$
Matching function elasticity	Literature	$\epsilon = 0.5$
Worker's bargaining power	Literature	$\eta = 0.5$
Unemployment benefit	$b^U/w = 0.88$	$b^U = 0.5$
Vacancy posting cost	Literature	$\xi = 0.11$
Inflation indexation	Inflation volatility	$\varepsilon = 0.5$
Price stickiness	Inflation volatility	$\varphi = 0.92$
Real wage stickiness	Inflation volatility	$\vartheta = 25$
Taylor rule: Inflation gap	Literature	$\rho_\pi = 1.5$
Persistence of risk premium shock	Literature	$\rho_\phi = 0.95$
Persistence of credit supply shock	Literature	$\rho_\psi = 0.95$
Std. Dev. of risk premium shock	Output volatility	$\sigma_\phi = 0.0009$
Std. Dev. of credit supply shock	Output volatility	$\sigma_\phi = 0.0160$

of rents due to market power, which are divided into different agents according to their bargaining power. We set the investment adjustment cost coefficient to $\kappa = 4$, so that investment is three times more volatile than output as observed in the data. The depreciation rate of the capital stock is set to $\delta = 0.025$.

Labor Markets: The efficiency of the matching function is set to $\zeta = 0.91$ in order to hit a quarterly job finding rate of 85 percent as in the Current Population Survey (CPS). The gross separation rate is calibrated to $\rho = 0.37$ so that the quarterly net separation rate equals 5.6 percent as in the CPS. For the elasticity of the Cobb-Douglas matching function with respect to vacancies, we follow the evidence reported in Pissarides and Petrongolo (2001) and set $\epsilon = 0.5$. We follow much of the literature and set workers' bargaining power to $\eta = 0.5$. Unemployment benefits equal $b^U = 0.5$, which represent 83 percent of the equilibrium wage in steady state. Finally, we set the vacancy posting cost equal to $\xi = 0.11$, about 11 percent of labor productivity, essentially the same as in Hagedorn and Manovskii (2008) and very similar to other values used in the literature.

Price and Wage Rigidities: Regarding the degree of nominal rigidities, we choose a low value for the probability of resetting the price ($1 - \varphi = 0.08$) and a substantial degree of price indexation ($\varepsilon = 0.5$) to be consistent with the so-called flat Phillips curve. We assume that firms face a quadratic adjustment cost of changing the real wage: $(\vartheta/2)(w_t/w_{t-1} - 1)^2$, and set the real wage adjustment cost parameter $\vartheta = 50$. With these choices, inflation in the economy with financial crises and the ZLB constraint is as volatile as PCE price inflation in the post-1984 period (a standard deviation of one percent) for both types of exogenous shocks considered.

Monetary Policy Rule: We let the monetary policy rule react only to the inflation gap, given that the shocks considered in our analysis move inflation and output in the same direction. The inflation coefficient is set to $\rho_\pi = 1.5$ in the baseline calibration following Taylor (1999), but we study a range of values for ρ_π.[20] We assume zero trend inflation rate, thus the (gross) annual inflation target is set to $\pi^* = 1$.

Exogenous Shock Processes: The persistence parameters of the risk premium shock and the credit supply shock are chosen to be the same and equal $\rho_\phi = \rho_\psi = 0.95$. We choose the volatility of each exogenous shock so that each shock generates a one percent volatility in output without considering financial crises and ZLB constraint.

4 Model Properties

This section explores the properties of the model economy by analyzing impulse response functions (IRFs) to credit market shocks and financial crisis shock, and by presenting key business cycle statistics based on stochastic simulations. For these exercises, we use our baseline monetary policy rule (23) with $\rho_\pi = 1.5$.

4.1 Impulse Responses to Credit Market Shocks

This section analyzes how shocks to credit demand and supply affect the real economy, as well as financial stability using IRFs. Figure 1 shows the IRFs of a credit demand shock (blue solid) implemented by a positive risk premium shock of Smets and Wouters (2007), and the IRFs of a credit supply shock (red dashed) implemented by a positive shock to bond-in-the-utility preferences.[21] In these episodes, the ZLB constraint is imposed, but is not binding. While the probability of financial crises is strictly positive and time-varying, it is assumed that the random draws of utility cost are low enough for the economy to avoid financial crises throughout the exercises.[22]

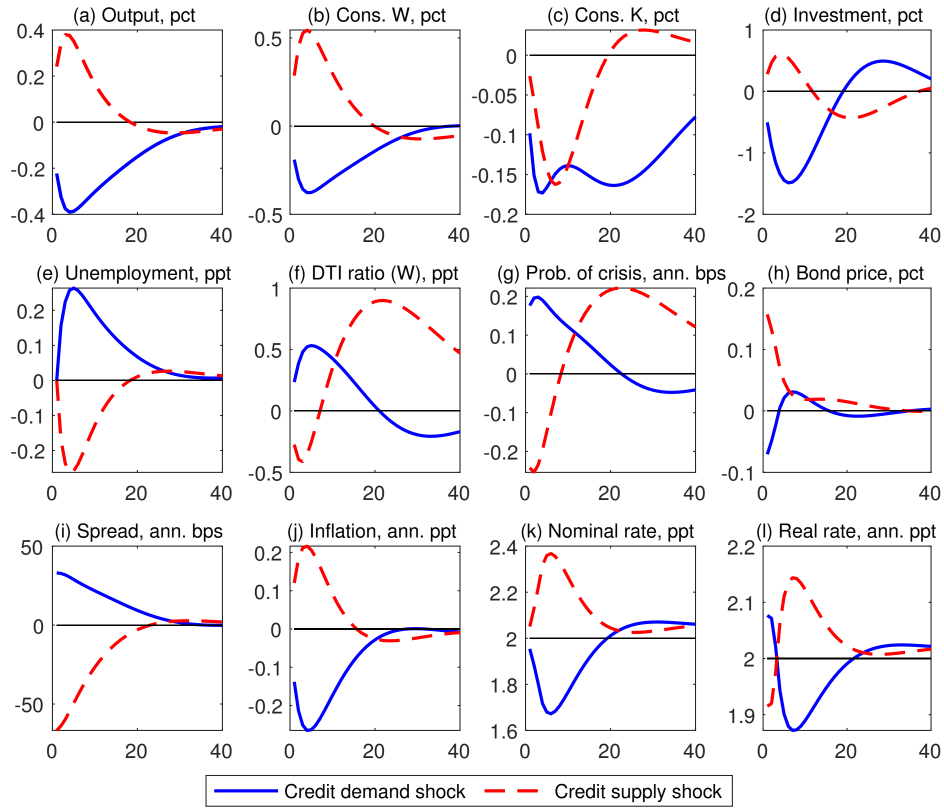
A positive risk premium shock works like a contractionary monetary policy shock: it contracts aggregate demand (panel (a)), as it raises the effective rate of return from the risk-free bond, depressing consumption demand (panels (b) and (c)). The fall in aggregate demand leads to higher unemployment (panel (e)) and lower labor earnings. Thus, agent W tries to smooth out consumption spending by issuing more debt. This causes the cost of borrowing to surge as shown by the plunge in the bond price (panel (h)) and also by the surge in credit spread $(1/q_t^B - (1 + i_t)$, panel (i)). Since borrowers' incomes fall while the debt burden increases, debt-to-income ratio rises (panel (f)), which then leads to a higher probability of financial crises (panel (g)). In this case, debt-to-income ratio is countercyclical as borrowers try to use credit for consumption smoothing.

[20] Note that in an economy where output and inflation move in the same direction, the chosen parametrization for the monetary policy rule (with no reaction term for the output gap) implies a more lenient monetary policy response than in Taylor (1999).

[21] We choose the direction of the shocks so that they both deliver an increase in the stock of debt.

[22] We show the macroeconomic effects of an endogenous financial crisis in Section 4.2.

Figure 1: Impulse Response Functions: Credit Demand and Supply Shocks



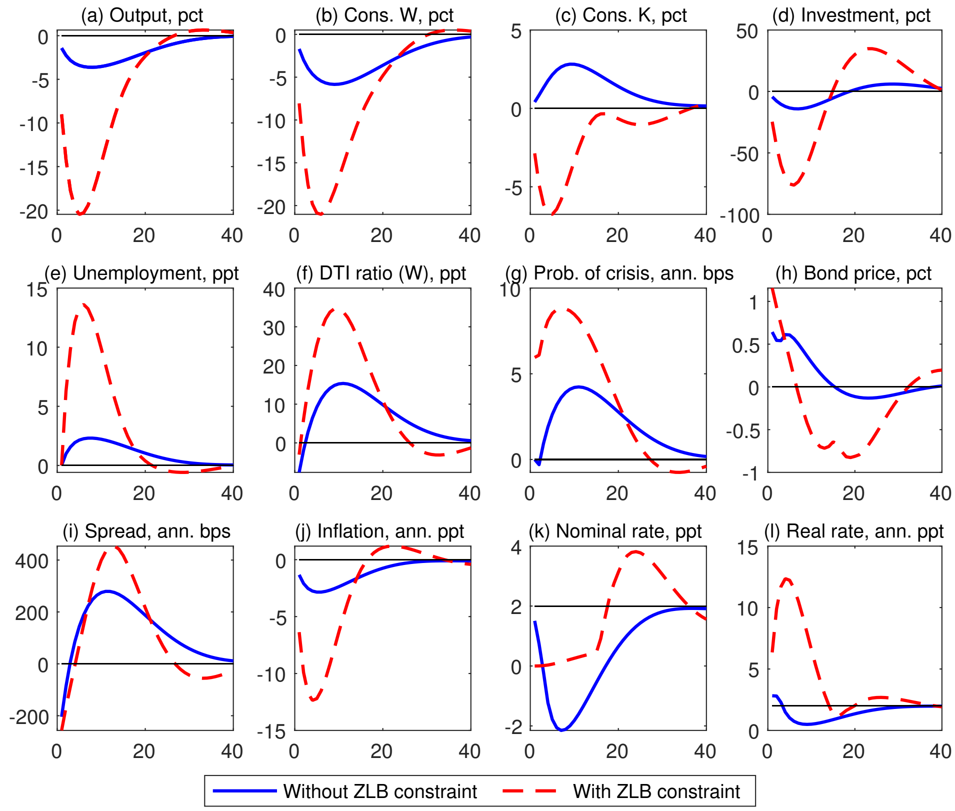
As the monetary authority lowers the nominal interest rate (panel (k)) more than the inflation rate (panel (j)), the real interest rate falls below its long-run value (panel (l)).

A positive shock to the utility weight of the bond-in-the-utility increases the willingness to lend, as the increase in marginal utility from bond holdings makes creditors more likely to accept the given terms of lending. As a result, the bond price increases, reflecting the increase demand for bonds, lowering the borrowing costs, as shown in panels (h) and (i). The cheap credit finances the consumption boom of agent W. The increase in consumption demand boosts aggregate demand, reducing the unemployment rate. The virtuous cycle between consumption demand and increased labor earnings makes borrowers' debt-to-income ratio to drop initially, despite the increase in credit. This is because income expands faster than the stock of debt. However, as the aggregate demand effects abate, the debt-to-income ratio eventually rises and, consequently, the probability of financial crises also rises. In this case, the debt-to-income ratio is weakly countercyclical. The inflation rate, and the nominal and real rates move in the exact opposite way than in the case of the credit demand shock.

4.2 Impulse Responses to a Financial Crisis

A financial crisis occurs in our model economy when the random draw of the utility cost of default is smaller than the gain from default, that is, when $\epsilon_{\delta,t} < U_t^D - U_t^N$. Thus, financial crises are not

Figure 2: Effects of a Financial Crisis: with and without the ZLB constraint



exogenous events in our model because their occurrence depends on the evolution of endogenous states. In other words, for the same level of the utility cost of default, a financial crisis may or may not occur depending on the value of gains from default, which depends on the state of the economy.

Figure 2 illustrates the IRFs of a financial crisis without (blue solid) and with (red dashed) the ZLB constraint imposed. In this exercise, it is assumed that the economy is in the steady state in the first period and that the random draw of the utility cost of default in the second period is low enough to trigger a financial crisis. If the ZLB constraint is not imposed, the contraction in aggregate output that results from a financial crisis peaks at 4 percent and the unemployment rate increases by 2.5 percentage points. The inflation rate falls about 2.5 percentage points, which triggers the monetary policy rate to tumble immediately into negative territory, reaching minus 2 percent at the nadir.

At the beginning of the crisis, credit collapses due to deleveraging, which explains why the debt-to-income ratio falls and the bond price rises initially. However, as the crisis deepens, borrowers' incomes fall much more than the stock of debt, and as a result, the debt-to-income ratio rises strongly over the course of the crisis. Accordingly, the probability of financial crises rises. A notable feature different from KRW is that during the financial crisis, the consumption of creditors increases strongly (panel (c)). This is because the nominal interest rate is lowered substantially to stabilize the economy, which is absent in their RBC economy.

Once the ZLB constraint is imposed, the effects of a financial crisis become much more substan-

Table 3: The Key Moments of the Model Economy

	Credit Demand Shock			Credit Supply Shock		
	(a)	(b)	(c)	(d)	(e)	(f)
	No crises No ZLB	Crises No ZLB	Crises ZLB	No crises No ZLB	Crises No ZLB	Crises ZLB
1. $E[\pi]$, ann., pct.	0.00	-0.49	-1.38	0.00	-0.48	-1.26
2. $E[u]$, pct.	5.88	6.58	8.74	5.87	6.56	8.46
3. $STD[\pi]$, quarterly, pct.	0.20	0.31	1.10	0.14	0.27	1.01
4. $STD[u]$, pt.	1.30	1.88	8.10	1.07	1.68	7.47
5. $SKW[\pi]$	0.00	-1.05	-3.24	0.00	-1.47	-3.34
6. $SKW[u]$	0.00	0.77	3.23	0.00	1.03	3.30
7. $E[DTI]$	1.45	1.48	1.51	1.45	1.48	1.50
8. $E[p^{\delta}]$, ann., pct.	4.36	4.37	4.38	4.36	4.37	4.38
9. $corr[DTI, p^{\delta}]$	0.96	0.99	0.95	0.96	0.98	0.95
10. $FREQ[ZLB]$, pct.	-	-	4.14	-	-	2.96

Notes: We use 50,000 periods to compute the moments with an identical set of random draws for each shock.

tial: aggregate output drops nearly 20 percent at the trough, and the unemployment rate rises 13 percentage points. Notably, with the ZLB constraint, even the consumption of creditors declines strongly as much as 7 percent. This is because the ZLB constraint results in strong deflation, making the real rate jump to 7 percent immediately and reach 12 percent at the nadir of the crisis.

4.3 Key Moments of the Model Economy

This section demonstrates that financial crises and binding ZLB episodes are one direction risks, which create strong asymmetries in the business cycle. Table 3 summarizes key business cycle statistics constructed with 50,000 periods of stochastic simulations, using the baseline monetary policy rule. Columns (a) to (c) show the case where the driving force of the business cycle is the credit demand shock, while columns (d) to (f) correspond to the credit supply shock.

We start analyzing columns (a) and (d), which assume that financial crises never occur and that there is no ZLB constraint. In this cases, all endogenous variables follow Gaussian distributions, as the shocks hitting the economy do so and the model is linearized. Thus, the economy faces no asymmetry in business cycles, as can be seen in the zero skewness of inflation and unemployment rates (rows 5 and 6). Consequently, the means of all endogenous variables correspond to their steady state values (rows 1 and 2).

Columns (b) and (e) present the moments when occasional financial crises occur and the ZLB constraint is not imposed. In this case, the distribution of inflation is left-skewed, while the distribution of the unemployment rate is right-skewed. Rows 1 and 2 show how the asymmetric distributions of inflation and unemployment rates affect their means. In particular, the occurrence of financial crises reduces the mean inflation rate by 50 basis points, and increases the mean unemployment rate by almost a percentage point. The occurrence of financial crises also increases the volatility of endogenous variables (rows 3 and 4).

Columns (c) and (f) present the moments when both financial crises and the ZLB constraint occasionally hit the economy. In this case, the skewness of the inflation rate and the unemployment rate nearly triples, when compared with columns (b) and (e). The combination of financial crises and the ZLB constraint lowers the mean inflation rate by 130 to 140 basis points, and increases the mean unemployment rate by almost 3 percentage points in both cases. Additionally, the volatility of endogenous variables increases substantially. In particular, the standard deviations of inflation and the unemployment rate increase about seven times when compared with columns (a) and (d).

As shown in Table 3, financial crises and the ZLB constraint create a nontrivial amount of deflationary pressure. Importantly, the deflationary pressure increases borrowers' real debt burden through the Fisher's debt deflation channel. Rows 7 and 8 confirm this: as the economy suffers from deflationary pressure due to financial crises and the ZLB constraint, the mean of the debt-to-income ratio goes up, and, consequently, the probability of financial crises also rises.

Our model economy features a high positive correlation between the debt-to-income ratio and the probability of financial crises (see row 9). Such a tight link is often used in the literature as a rationale for monetary policy tightening to limit the tail risks of the economy (see, for instance, Juselius et al. (2017)). We analyze next whether such a proposal can be justified in our environment. For now it suffices to mention that, in our model economy, the deflation bias due to the asymmetric distributions undermines both price stability and financial stability. Therefore, any monetary policy strategy to enhance price stability and financial stability cannot be successful without correcting the asymmetric distributions of equilibrium quantities and prices. We study next what types of strategies can be more successful for this task.

5 Price Stability and Financial Stability

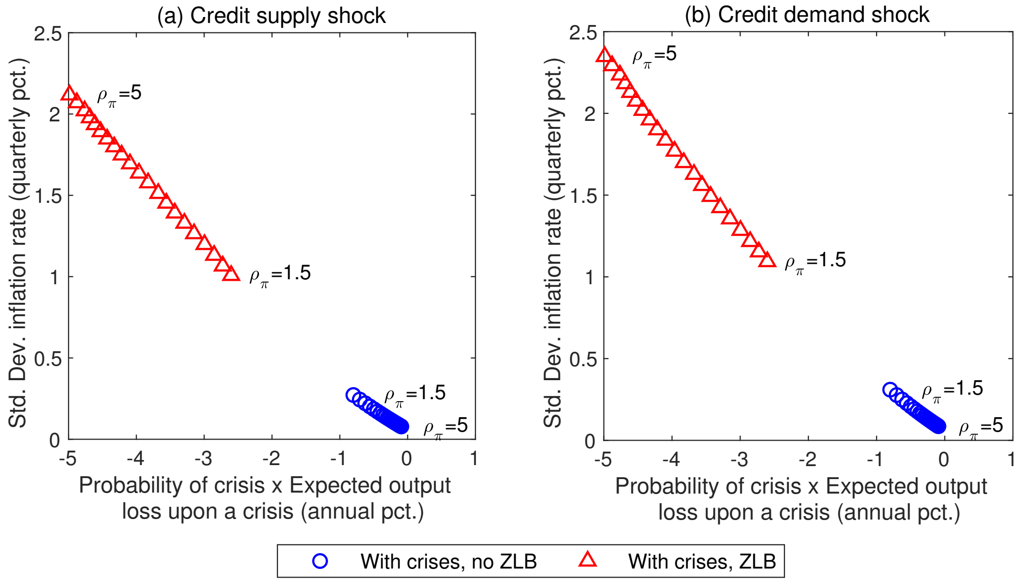
This section studies the relationship between price stability and financial stability under different monetary policy regimes. We first approach the issue from the view point of traditional inflation and price-level targeting rules. We then revisit the same issue allowing the monetary authority to change its policy rate in direct response to financial imbalances. We allow for two alternatives: a "leaning against the wind" policy focused on the quantity of credit, and a "leaning with the credit spreads" policy focused on the price of credit.

5.1 Inflation Targeting and Financial Stability

The results so far have assumed that monetary policy is implemented by a strict IT with the inflation coefficient fixed at $\rho_\pi = 1.5$. While we calibrate this from Taylor (1999), in reality, this falls on the realm of the preferences of each central bank. In this section, we analyze how such preferences could alter the properties of the model economy from those in the baseline particularly focusing on the matters of price stability and financial stability.

We start this analysis by posing a question: What if the central bank of the model economy is run by a much more conservative central banker who is more adverse to inflation than our baseline monetary policy rule? The consensus in the New Keynesian literature is that having

Figure 3: Hawkishness of Inflation Targeting, Price Stability and Financial Stability



such a conservative central banker conduct monetary policy can only lead to better stabilization outcomes, especially in the absence of price/wage markup shocks that move the inflation gap and the output gap in opposite directions. In our model economy only buffeted by credit demand and supply shocks, this property is satisfied: output and inflation are highly correlated. Clarida et al. (1999) showed that the optimal feedback coefficient to inflation under optimal discretionary policy should approach infinity if the central bank can focus on the stabilization of inflation either because of its preferences or because of the so-called divine coincidence.

However, what if such a conservative monetary policy undermines financial stability? Should the central bank sacrifice price stability for financial stability or vice versa? For instance, in facing downward pressures on inflation, the consensus on central banking recommends to cut interest rates aggressively. However, Kocherlakota (2014) argues that if "raising the real interest rate may reduce the risk of a financial crisis," "the Committee has to weigh the certainty of a costly deviation from its dual mandate objectives against the benefit of reducing the probability of an even larger deviation from those objectives." Woodford (2012) provides a formal justification of this position by showing how the optimal target criterion of Clarida et al. (1999) should be modified in order to address the concern for financial stability.

Figure 3 shows the effects of increasing the reaction coefficient to inflation, ρ_π, on price stability (vertical axis) and financial stability (horizontal axis) in our model economy. We measure price stability by the standard deviation of inflation, and financial stability by the product of the probability of financial crises and the cumulative output loss upon a crisis. Panel (a) corresponds to the case when the business cycle is driven by credit supply shocks and panel (b) is the case when the business cycle is driven by credit demand shocks. In Figure 3, we show the combination of price stability and financial stability when we gradually increase the inflation reaction coefficient ρ_π from 1.5 to 5. Each of the bullets shows the moments obtained from stochastic simulations of

50,000 periods with the same sequence of shocks used in Table 3. The blue circles (red triangles) represent the cases without (with) the ZLB constraint imposed.

Without the ZLB constraint: We find that, without the ZLB constraint, increasing the strength of IT enhances both price stability and financial stability, regardless of the type of shock. In fact, our results indicate that by indefinitely increasing the IT reaction coefficient ρ_π, the economy can achieve nearly complete stabilization of inflation as well as removing the downside effects of financial crises. It is not surprising that a stronger implementation of IT brings down inflation volatility. Importantly, the reason why a more hawkish IT regime (that is, a monetary policy regime where the interest rate responds strongly to inflation) helps safeguard financial stability is because such a policy is also very effective in limiting the damage caused by a financial crisis: The central bank may not be able to remove the probability of financial crises, but it can offset the effects of financial crises by providing sufficient stimulus. Therefore, we conclude that there is no trade-off between price stability and financial stability in the absence of the ZLB constraint.

The nonexistence of a trade-off between price stability and financial stability in the absence of the ZLB constraint stands in stark contrast with the findings in Woodford (2012), who shows

> "...the target criterion does not depend solely on the paths of the general price level and of the aggregate output gap; it also depends on the projected evolution of ... the *marginal crisis risk*" (Woodford (2012), p. 19).

The author shows that such a criterion implies that in facing an increase in the marginal crisis risk, the central bank should be willing to lower the path of nominal GDP in his framework.

The difference between our results and Woodford (2012) crucially depends on the cyclicality of leverage. In particular, he models in a reduced form way both the relationship between aggregate activity and leverage on the one hand, and the relationship between leverage and the probability of financial crises on the other hand. If, as he assumes, leverage and economic activity are positively correlated, and the probability of financial crises is positively correlated with leverage, such a trade-off is intuitive. The two positive relationships, taken together, imply a positive relationship between aggregate activity and the probability of financial crises, opening a room for the argument that a central bank that wants to safeguard financial stability may have to sacrifice economic activity. In contrast, if leverage and economic activity are negatively correlated, the best policy to secure financial stability can be found in monetary policies minimizing the downside risks to economic activity. Importantly, the negative correlation appears to be consistent with the data: using the growth rates of household sector credit-to-GDP ratio and real GDP, we find that the correlation is -0.38 over the 1952Q1–2018Q3 period. In our model economy, the leverage is negatively correlated with output. When the driving force of the business cycle are credit demand shocks, the correlation is -0.77, while it is -0.20 when credit supply shocks are the driving force.

Importantly, note that both in the model and in the data, the negative correlation between the debt-to-income ratio and aggregate output is not because aggregate credit is negatively correlated with aggregate output.[23] Instead, the negative correlation is due to the fact that income moves faster than aggregate credit, such that in downturns income falls faster, and the leverage ratio goes up (in upturns instead, income rises faster and the leverage ratio falls). This is one of the main reasons why financial crises are more likely to happen during bad times, i.e., when leverage ratios are relatively high. With the credit supply shock driving the business cycle, the correlation between aggregate output with the probability of financial crises is -0.43. With the credit demand shock driving the business cycle, the negative correlation almost doubles to -0.85. This is why a stronger monetary policy response to downward pressure on inflation (and rise in unemployment rate) is more likely to enhance financial stability in our model economy.

There is an important caveat to this conclusion. In an economy where the leverage cycle is driven by firms that invest in risky projects and, as a result, the leverage ratio of corporate sector is highly procyclical and the corporate debt share of total private debt is more substantial, one may find much more support for "leaning against the wind" (LAW, henceforth). See, for instance, Gourio et al. (2018), who finds that LAW improves considerably upon Taylor type monetary policy rules in an economy where the debt is primarily used to finance entrepreneurs' risky investments. Therefore, it matters whether the credit cycle is driven by household sector debt or by corporate sector debt in deciding whether to lean against the wind. During the 2004-2008 period, the cycle was definitely driven by household sector debt.

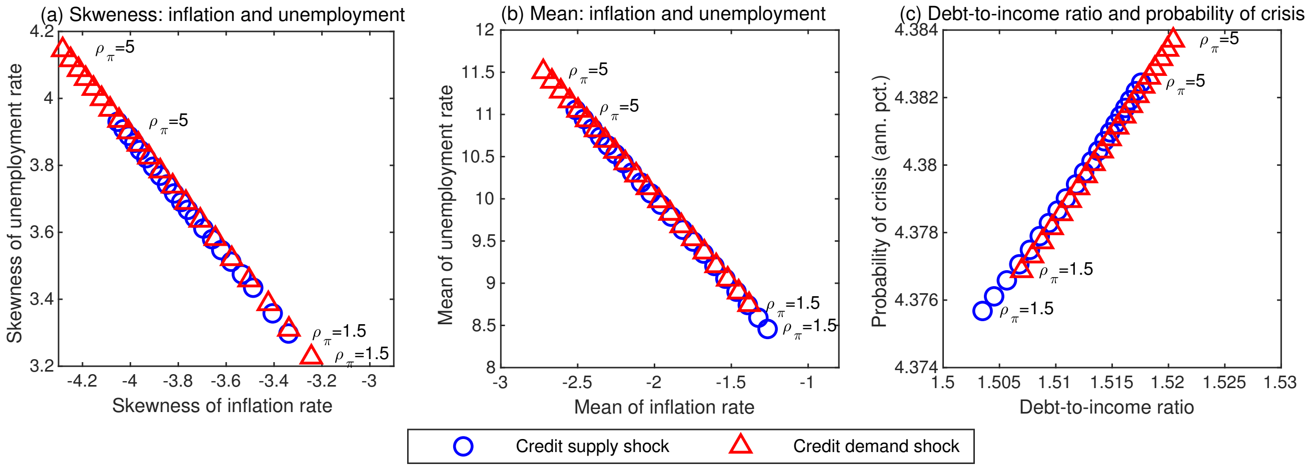
With the ZLB constraint: So far our discussion has assumed that there is no ZLB constraint. Importantly, the existence of the ZLB constraint dramatically changes the conclusions about the benefit of a "conservative central banker". The red triangles in Figure 3 show that adopting a more aggressive response to inflation under an IT regime when the ZLB constraint is imposed may severely undermine both price stability and financial stability. This conclusion is again not affected by whether the business cycle is driven by credit demand shocks or by credit supply shocks. With the ZLB constraint imposed, inflation volatility jumps to around 1 percent in both panels when $\rho_\pi = 1.5$. This aspect was already shown in Table 3. What is new in Figure 3 is that imposing the ZLB constraint severely weakens the stabilization function of monetary policy during financial crises and the cost of financial crises significantly increases.

By increasing the inflation reaction coefficient, the central bank faces larger inflation volatility. For example, when the coefficient reaches $\rho_\pi = 5$, the central bank essentially doubles inflation volatility from the baseline case, $\rho_\pi = 1.5$. This is because the increase in downside inflation volatility, due to the binding ZLB constraint and more frequent financial crises, is far greater than the reduction in upside inflation volatility, elevating overall inflation volatility. In addition, the hawkish monetary policy increases the cost of financial crises to up to 5 percent. Two reasons explain this result. On the one hand, due to the binding ZLB constraint, the benefit of aggressively easing monetary policy during financial crises cannot be obtained by a hawkish IT regime. On the other hand, a more hawkish IT regime faces higher probability of financial crises.

Why does a hawkish IT regime increase the likelihood of financial crises? In the presence of

[23] Aggregate credit is indeed positively correlated with aggregate output both in the data and in our model economy.

Figure 4: Consequences of Conservative Inflation Targeting



the ZLB constraint, there is a clear limit to how aggressive an IT central bank can be in response to downside risks to inflation. However, there is no opposite limit in response to upside risks to inflation. This means that the mix of the ZLB constraint and a hawkish IT rule makes the distribution of inflation more left-skewed. Panel (a) of Figure 4 shows this: by increasing ρ_π from 1.5 to 5, left-skewness of inflation and right-skewness of unemployment rate increase dramatically. This creates deflation bias, that is, makes the mean of inflation deviate from the target to the downside as shown in panel (b) of Figure 4. Panel (c) of the figure shows that the deflation bias, through Fisher's debt deflation channel, elevates borrowers' real debt burden and, consequently, elevates the probability of financial crises. Overall, our results suggest that appointing "conservatives " to head the central bank (Rogoff, 1985) may not be desirable for an economy that suffers from deflation bias due to the ZLB constraint and financial crises.

5.2 Price-Level Targeting and Financial Stability

We have shown that monetary policy conservatism may be harmful for both price stability and financial stability when the central bank adopts an IT regime in the presence of the ZLB constraint. We now study whether the same conclusion holds when the central bank implements such conservatism in the context of a price-level targeting (PLT) regime:

$$i_t = \max\left\{0, i^* + \rho_\Pi \Pi_t\right\}, \quad \Pi_t \equiv \sum_{s=0}^{T} \frac{(\pi^Y_{t-s} - \pi^*)}{4}. \tag{24}$$

Equation (24) is fundamentally different from IT in that the policy rate responds to past misses in hitting the inflation target. If $T = 0$, this is the special case of IT known as the "*bygones be bygones*" principle. If $T = \infty$, this is the special case of PLT and it allows for a recursive formulation:

$$\Pi_t = \Pi_{t-1} + \frac{\pi^Y_t - \pi^*}{4}.$$

Figure 5: Hawkishness of Price-Level Targeting, Price Stability and Financial Stability

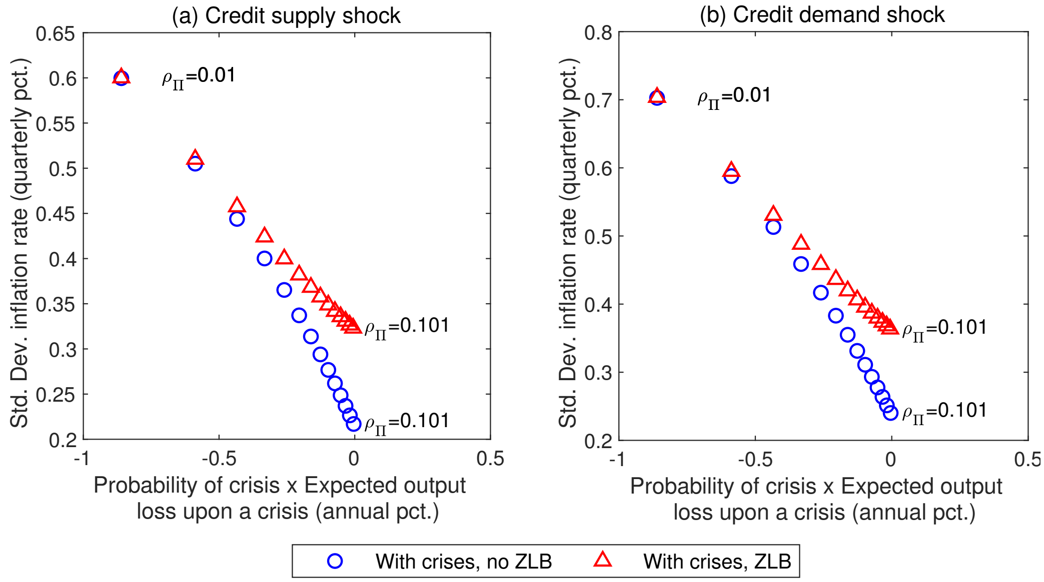


Figure 5 shows the PLT's counterpart of Figure 3, where panel (a) is the case with credit supply shock and panel (b) the case with credit demand shock. Blue circles and red triangles show the cases without and with the ZLB constraint, respectively, when we vary the reaction coefficient ρ_Π in the range of $[0.01, 0.101]$.[24]

Figure 5 is in stark contrast to Figure 3 in that conservatism in PLT always improves both price stability and financial stability, regardless of the presence of the ZLB constraint. Also, this conclusion does not depend on the source of credit market disruptions. The only difference created by the ZLB constraint is that, for a given level of reaction coefficient ρ_Π, the central bank may not be able to achieve the same degree of price stability that would have been achieved in the absence of the ZLB constraint.

The reason why PLT can overcome the obstacles imposed by the ZLB constraint and enhance financial stability is clear: this policy promises to overshoot the inflation target to make up for the inflation misses during the ZLB episode. Such a promise lowers future real interest rates, which then immediately stabilizes consumption, thereby lessening the current deflation pressure. By limiting the deflation pressure, PLT prevents the debt-to-income ratio from rising to a dangerous level, reducing the probability of financial crises.

Note that the benefits of a PLT regime in achieving both price and financial stability crucially depend on the assumptions of rational expectations and the credibility of commitment by economic agents. A PLT regime would not be as successful if agents' expectations were backward-looking or were formed with sticky information, or agents did not perceive as credible the policy strategy

[24] While the reaction coefficients considered here seem seemingly small, note that ρ_Π is multiplied to infinite terms of current and lagged inflation gaps. Note also that values of ρ_Π above 0.101 deliver positive responses in cumulative output during a financial crisis, as the overshooting of output during the recovery phase surpasses the initial drop during a crisis. Such an outcome is counterintuitive and we assume that the monetary policy stops providing stimulus once the cumulative output drop reaches zero. This explains our calibration for the upper bound of ρ_Π.

followed by the monetary authority.

5.3 Leaning Against the Wind

Our discussion so far has shown that the traditional approach to price stability may be consistent with safeguarding financial stability provided that monetary policy overcomes the challenges created by the binding ZLB constraint. That is, the low and predictable inflation delivered by IT may not promote financial stability, but the price stability under PLT may do so.

Nonetheless, many commentators have proposed alternative monetary policy frameworks to respond to financial imbalances more directly. A proposal that has been particularly influential in both academia and policy circles is LAW. Given the practical importance of this approach, we evaluate the performance of such a policy framework using our model economy as a laboratory.[25]

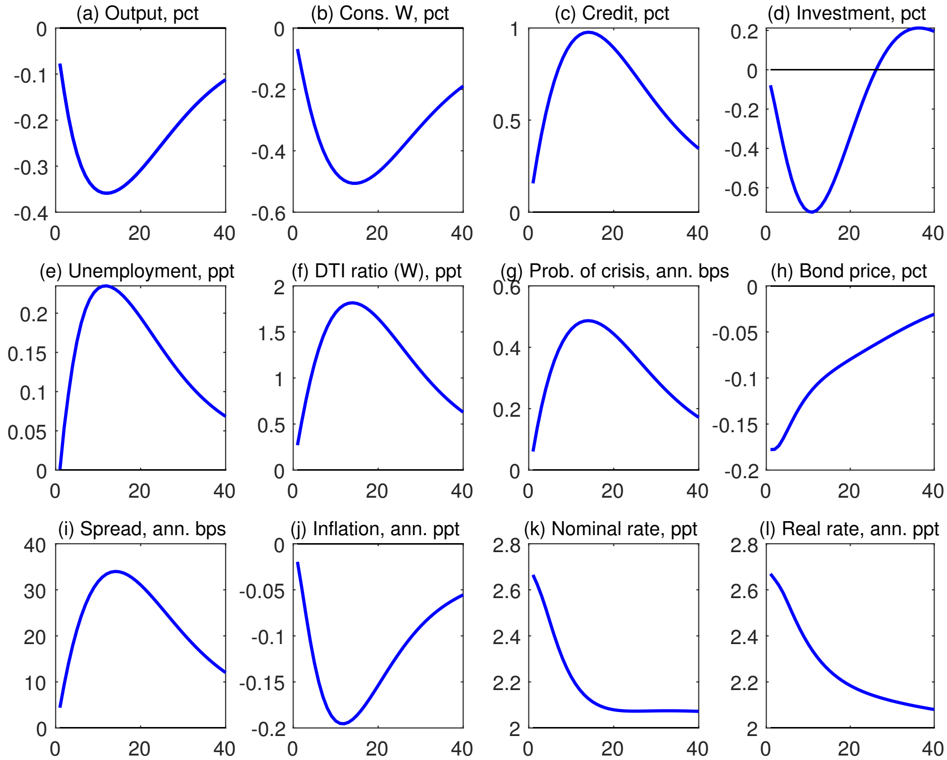
The proponents of LAW suggest that a central bank needs to tighten monetary policy in response to a build up of financial imbalances (such as rising leverage ratio of the household sector), even when tightening is not warranted by other macroeconomic fundamentals (such as inflation and employment levels). The advocates argue that the costs of financial crises are so large that the potential costs of implementing the LAW in terms of foregone output and downward pressure on inflation may be justifiable. Our model economy features endogenous financial crises in an environment where monetary policy can be conducted in a way consistent with the LAW. Therefore, the model economy provides a useful testing ground for the LAW.

An implicit assumption shared by both advocates and opponents of LAW policies is that monetary policy tightening can reduce the probability of financial crises, by raising borrowing costs and reducing borrowers' leverage. Thus, the debate resides on whether the benefits from reducing the probability of financial crises are large enough to justify the costs in terms of foregone output and employment. However, both sides of the debate seem to bypass the following question: can monetary policy tightening reduce the leverage of household and the probability of financial crises?

Figure 6 shows the IRFs of a monetary policy tightening in our model economy using the baseline IT rule. Since our baseline monetary policy rule has no inertia component, we assume that the monetary authority raises the nominal interest rate with a persistent sequence of shocks. In particular, we assume that the nominal interest rate is initially raised by $\epsilon_{m,t} = 66$ basis points in annualized terms, and the shock fades out gradually, i.e, $\epsilon_{m,t+j} = 0.95^j \epsilon_{m,t}$ for $j \geq 1$. Given the contractionary monetary policy shock, aggregate output declines persistently in panel (a). Panel (b) shows that borrowers' consumption declines persistently as well. However, in response to the tightening shock, the borrowers in the model borrow more to smooth out their consumption (a more detailed explanation to follow), which meets increased demand for bonds of lenders who reduce their

[25] There are at least, to our best knowledge, two central banks that implemented LAW policies: Sveriges Riksbank and Norges Bank. The former implemented the approach in the context of rising household debt and housing prices during the recovery from the GFC, but stopped employing the approach amid concerns of unanchored inflation expectations. The latter's stance on the LAW can be seen in this statement: "If there are signs that financial imbalances are building up, consideration of stable production and employment in some situations may lead to the interest rate being held slightly higher than it otherwise would have been" (see https://www.norges-bank.no/en/topics/Monetary-policy/Mandate-monetary-policy/).

Figure 6: Monetary Policy Tightening and the Probability of Financial Crises



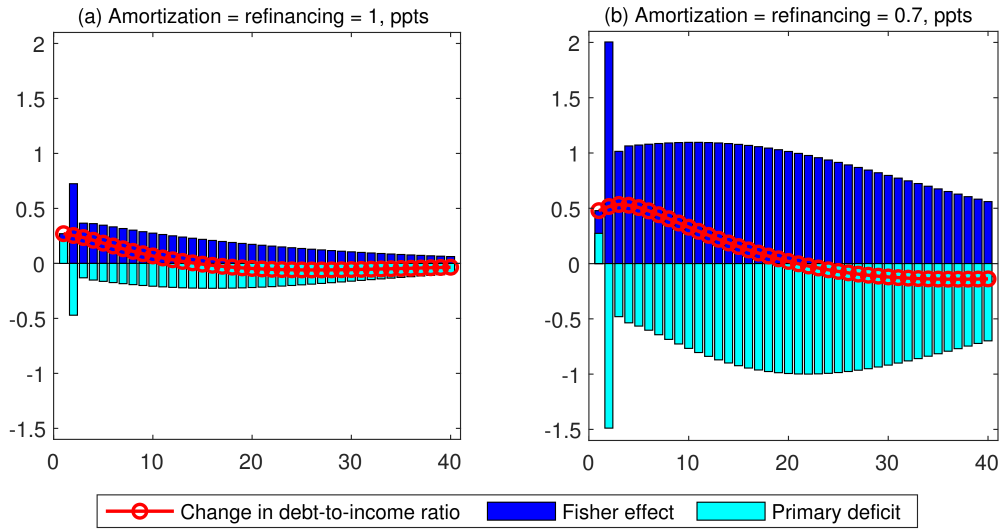
consumption to lend more (not shown). In other words, the monetary policy tightening leads to a credit expansion, not a credit contraction (panel (c)).

The decline of aggregate demand results in a higher unemployment rate (panel (e)), which reduces borrowers' labor earnings. The combination of credit expansion and declining income implies rising leverage, as shown with the rise of the debt-to-income ratio in panel (f). Consequently, monetary policy tightening brings an unintended consequence of elevating the probability of financial crises. The decline of inflation (panel (j)) also contributes to the rise of real debt burden and jeopardizes financial stability. Note that the result does not require actual credit expansion. In other words, even when monetary policy tightening is successful in reducing the credit aggregate, which is possible if the debt financing is obtained for risky investment rather than consumption smoothing, the tightening policy may still end up raising the probability of financial crises. This is because income declines faster than the stock of credit after a monetary policy tightening. In this case, the debt-to-income ratio will still go up, elevating financial instability.

Note that the increases in credit and debt-to-income ratio shown in panels (c) and (f) create an impression that borrowers have difficulties to deleverage their balance sheet during the monetary contraction. However, such an interpretation is not valid. The change in the debt-to-income ratio can be decomposed into

$$\Delta\left(\frac{b_t}{y_t^W}\right) \approx \frac{d_t}{y_t^W} + [i_{t-1}^B - g_t - (\pi_t - 1)]\frac{b_{t-1}}{y_{t-1}^W},$$

Figure 7: Fisher Effects, Maturity of Debt and Debt-to-Income Dynamics



where y_t^W is the real income of the borrowers, d_t is the primary deficit of the borrowers, $i_{t-1}^B \equiv 1/q_{t-1}^B - 1$ is the nominal interest rate on private bonds, $g_t \equiv y_t^W / y_{t-1}^W - 1$ is the real growth rate of borrowers' income, and $\pi_t - 1$ is the realized net inflation rate. The expression decomposes the change in the debt-to-income ratio into two terms: primary deficit and what Mason and Jayadev (2014) called the "Fisher effect,"which is the bracketed term on the right hand side. The second term is a generalized version of Fisher (1933)'s "debt deflation" in that it incorporates the effects of the nominal interest rate and the real income growth rate. One can view the primary deficit channel as the active component of the debt-to-income ratio, and the Fisher channel as the passive component as it is beyond borrowers' control.

Panel (a) of Figure 7 decomposes the total change in the debt-to-income ratio (red circled line) due to the monetary policy tightening into two terms: the Fisher effect (dark blue bars) and the primary deficit effect (light blue bars). Except for the first period, the primary deficit effect is negative, implying that borrowers are trying to consolidate their balance sheet by reducing debt. However, as panels (c) and (f) of Figure 6 show, the actual credit and debt-to-income ratio increase following the monetary policy tightening. This is because the Fisher effect (i.e., nominal interest minus nominal income growth) is dominating the primary deficit effect. Hence, the rise of the debt-to-income ratio arises despite borrowers' deleveraging efforts. This decomposition shows that if the monetary authority desires to reduce the debt ratio for financial stability concerns, what it needs is monetary easing, not tightening. In other words, the monetary authority can stabilize the debt ratio by expanding the income side rather than shrinking the size of debt.

Note that our theoretical model assumes one period debt. If instead long-term debt is issued, the Fisher effect can be much larger than in our baseline model. To show this, we modified the model's FOCs (5) and (8) such that they are consistent with long-term debt:

$$q_t^B = \beta^W \mathbb{E}_t \left[\frac{\Lambda_{t+1}^W}{\Lambda_t^W} [1 - (1-\rho^B)(1-\alpha^B) q_{t+1}^B] \left(\frac{1 - hp_{t+1}^\delta}{\pi_{t+1}} \right) \right], \tag{25}$$

$$q_t^B = \beta^K \mathbb{E}_t \left[\frac{\Lambda_{t+1}^K}{\Lambda_t^K} [1 - (1-\rho^B)(1-\alpha^B) q_{t+1}^B] \left(\frac{1 - hp_{t+1}^\delta}{\pi_{t+1}} \right) \right] + \frac{\psi^B}{\Lambda_t^K} \left[1 + b_t \left(\frac{1-\chi}{\chi} \right) \right]^{-1/\sigma_b}, \tag{26}$$

where $\rho^B \in (0,1]$ and $\alpha^B \in (0,1]$ are the refinancing ratio and amortization ratio, respectively. Our baseline model assumes $\rho^B = \alpha^B = 1$, in which case the debt has one period maturity.[26]

Panel (b) of Figure 7 shows the case when $\rho^B = \alpha^B = 0.7$ (70 percent of principal is amortized and refinancing ratio is 70 percent). The moderate increase in maturity almost doubles the effect of a monetary policy tightening on the debt-to-income ratio, as shown by the red circled line. This is because the increase in maturity (both through lower amortization rate and refinancing rate), and the increased portion of nominal debt strengthen the Fisher effect. This result is in line with Gelain et al. (2017) despite the difference that, in their case, financing is tightly linked to housing demand through binding collateral constraint. Note, however, that $\rho^B = \alpha^B = 0.7$ is a relatively short maturity. In the data, the average duration of mortgage debt is about 8 years, which is consistent with $\rho^B = 0.031$ and $\alpha^B = 0.019$. This means that the effects on the debt-to-income ratio can be much larger following a tightening of monetary policy.[27]

What if the LAW policy is implemented as part of a systematic monetary policy response instead of as an unanticipated monetary policy shock, such that economic agents can predict its implementation? To explore this case, we modify our baseline IT rule to

$$i_t = \max \left\{ 0, i^* + \rho_\pi \left(\frac{\pi_t^Y - \pi^*}{4} \right) + \rho_{DTI} \log \left(\frac{b_t / y_t^W}{\bar{b} / \bar{y}^W} \right) \right\}, \quad \rho_{DTI} > 0 \tag{27}$$

such that the policy rate is endogenously, and therefore predictably, raised in response to the rise of borrowers' leverage. We illustrate the effects of this policy using a credit demand shock in Figure 8.[28] Blue solid lines correspond to the baseline IT rule, where $\rho_\pi = 1.5$ and $\rho_{DTI} = 0$. Red dashed lines are the case with $\rho_\pi = 1.5$ and $\rho_{DTI} = 0.1$. We find that LAW aggravates not only the business cycle, but also the credit cycle. In this example, borrowers' income falls faster than credit, elevating

[26] To derive the FOCs with long-term debt does not require the change of the budget constraints of the two agents. It only requires to add an additional equation and a variable to the system:

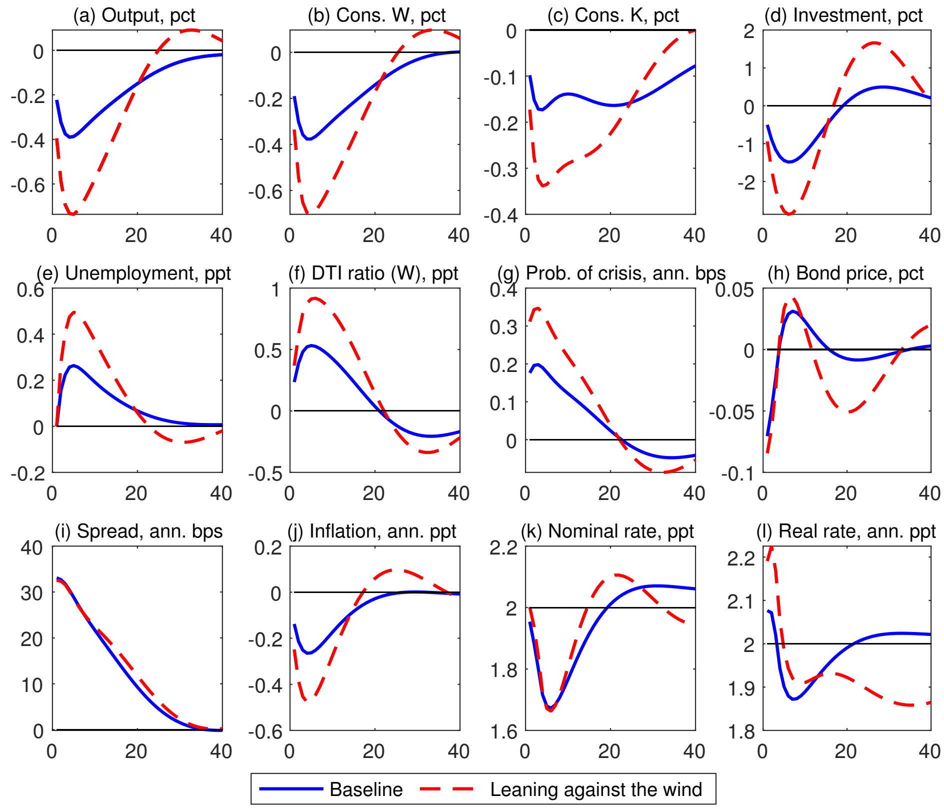
$$b_t = b_{n,t} + (1-\rho^B)(1-\alpha^B)(1-h\delta_t^B)\frac{b_{t-1}}{\pi_t},$$

where now b_t is interpreted as the total outstanding debt at the end of period t. $b_{n,t}$ is newly issued debt and the second term on the right-hand side is the remainder of old debt after default, refinancing, and amortization. Equations (25) and (26) can then be thought of as the FOCs for $b_{n,t}$.

[27] We do not implement this case as it would require a totally different calibration from our baseline calibration, which might make comparisons difficult.

[28] The conclusion is similar when we consider a credit supply shock.

Figure 8: Leaning Against or With the Wind?



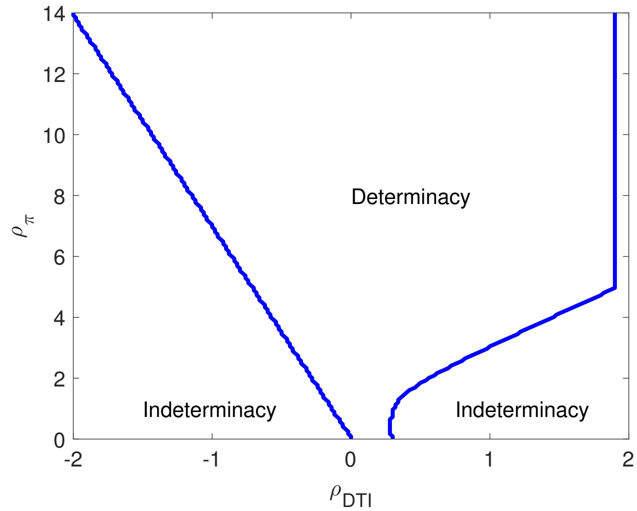
borrowers' leverage and the probability of financial crises. LAW deepens this process. Monetary policy is being tightened in response to the rise of leverage, which then makes the income of the economy fall even faster, making the swing of the leverage ratio even greater.

The vicious cycle between endogenous tightening of monetary policy and larger swings in leverage can make the economy suffer from indeterminacy if the LAW coefficient is sufficiently large. A greater reaction coefficient to the leverage makes monetary tightening stronger, which then leads to greater leverage due to falling income and calls for an even stronger tightening, which then leads to a greater leverage cycle, and so on and so forth. Figure 9 shows how the indeterminacy region changes as the values of ρ_π and ρ_{DTI} change. On the horizontal axis $\rho_{DTI} > 0$ is the LAW region, whereas $\rho_{DTI} < 0$ is the "leaning with the wind" region. The figure shows that for a given level of ρ_π, there exists a unique value of the LAW coefficient beyond which the economy falls into indeterminacy. The figure also shows that a greater nominal anchor in terms of ρ_π tolerates a greater degree of the LAW, while keeping determinacy. However, we find that for a value of $\rho_{DTI} > 1.8$, there is no ρ_π value that ensures determinacy. This is in contrast to the leaning with the wind policy, for which, a greater value for ρ_π always expands the determinacy region for ρ_{DTI}.

5.4 Leaning With the Credit Spreads

In the context of an IT regime, we have shown in Section 5.1 that increasing the monetary policy reaction against inflation may undermine both price stability and financial stability in the presence

Figure 9: Leaning Against or With the Wind and Indeterminacy



of the ZLB constraint. In this section, we assume that the monetary authority is reluctant to increase the inflation coefficient from the baseline of $\rho_\pi = 1.5$ for this reason. Instead, the monetary authority attempts to complement the traditional IT rule by reacting to financial market variables. The monetary policy rule considered in the previous section, equation (27), is in fact one example of such attempts. However, we have shown some undesired properties of that rule. Here, we consider an alternative strategy, where monetary policy responds to the price of credit rather than to credit aggregate or leverage. In particular, we consider the following monetary policy rule:

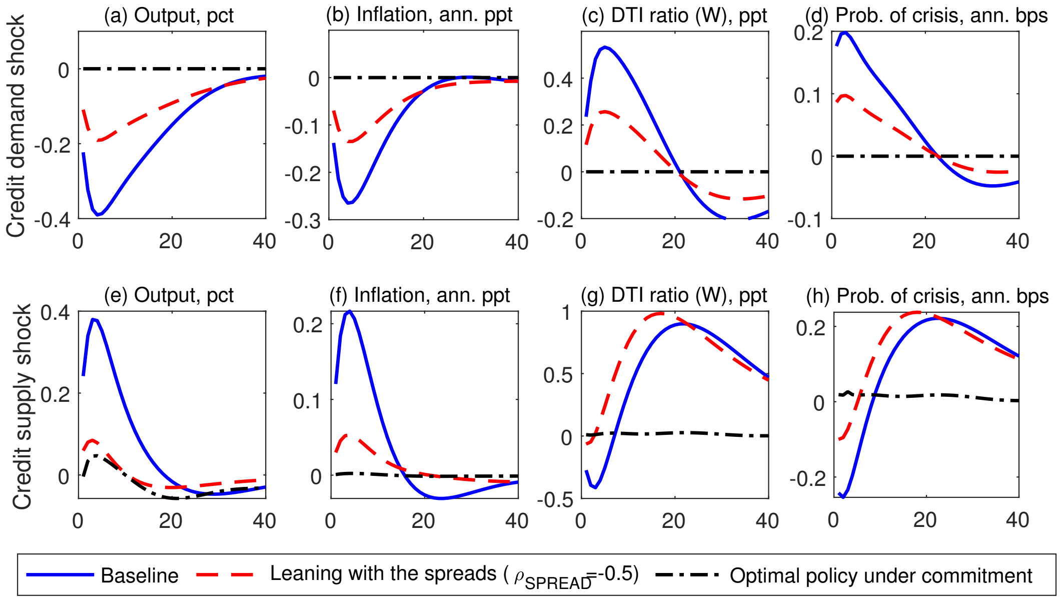
$$i_t = \max\left\{0, i^* + \rho_\pi \left(\frac{\pi_t^Y - \pi^*}{4}\right) + \rho_{SPREAD}[(i_t^B - i_t) - (\bar{i}^B - \bar{i})]\right\}, \quad \rho_{SPREAD} < 0, \tag{28}$$

where $i_t^B - i_t$ is the "credit spread" and $\bar{i}^B - \bar{i}$ its steady state value. A negative value for ρ_{SPREAD} captures the idea of leaning with the credit spreads (LWS, henceforth).

Figure 10 illustrates the effects of a LWS regime. Panels (a) to (d) show the effects on output, inflation, debt-to-income ratio, and the probability of financial crises in response to a credit demand shock. In turn, panels (e) to (h) show the effects of the same variables in response to a credit supply shock. Blue solid lines correspond to the baseline IT rule, where $\rho_\pi = 1.5$ and $\rho_{SPREAD} = 0$. Red dashed lines correspond to the case of the IT-LWS case, where $\rho_\pi = 1.5$ and $\rho_{SPREAD} = -0.5$. In addition, black dash-dotted lines correspond to the case of optimal control under commitment, where the objective function of the planner is defined as the population weighted Benthamite welfare, $\chi U_t^K + (1-\chi)U_t^W$, with the discounting factor set equal to the steady state risk-free rate.

The red dashed lines in Figure 10 show that the IT-LWS policy is very effective in stabilizing output and inflation in response to both types of credit market disturbances, moving the response of the economy towards the outcomes under the optimal commitment policy. Since the credit demand shock is implemented with Smets and Wouters (2007)'s risk premium shock, which is a pure demand disturbance, a complete stabilization of the shock is optimal (as prescribed by the optimal policy under commitment). The situation is slightly different with the credit supply shock, because the

Figure 10: Inflation Targeting, Leaning With the Spreads and Optimal Policy



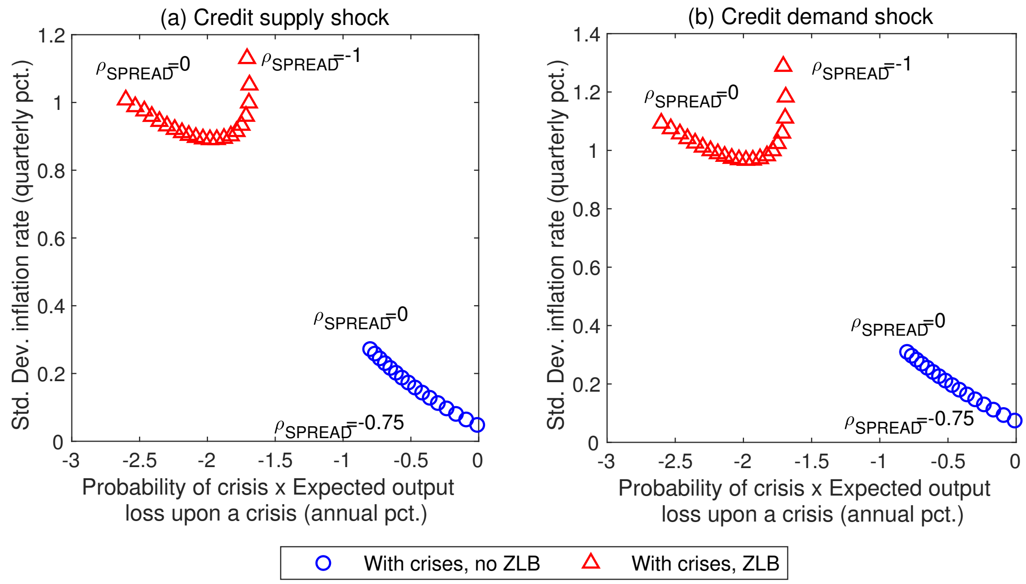
shock is a disturbance to preferences. This is the reason why the optimal policy under commitment does not completely stabilize the effects on output of the credit supply shock. However, even in this case, optimal policy almost fully stabilizes the debt-to-income ratio and the default probability.

Figure 10 suggests that while the IT-LWS rule is successful in limiting fluctuations in output and inflation, it is less effective in limiting fluctuations in the probability of financial crises, especially when compared with the optimal commitment policy. However, this does not necessarily imply that the IT-LWS rule is ineffective in improving financial stability. The reason is that the IT-LWS rule may substantially contribute to financial stability if it is very successful in limiting the output loss upon a crisis. Figure 11 shows this aspect. The blue circles plot the combinations of inflation volatility (vertical axis) and the product of probability of financial crises and cumulative output loss upon a crisis (horizontal axis) under the assumption of no ZLB constraint, when we increase the absolute value of ρ_{SPREAD}. Panel (a) shows the case when the business cycle is driven by a credit supply shock and panel (b) the case when the business cycle is driven by a credit demand shock. In the figure, ρ_{SPREAD} is changed from 0 to -0.75, with ρ_{π} fixed at 1.5.[29] The blue circles in the figure clearly show that the IT-LWS can improve upon the traditional IT for both price stability and financial stability in the absence of the ZLB constraint. While the LWS is not very effective in limiting the fluctuations in the probability of financial crises as mentioned above, it nonetheless provides a decisive accommodation during a financial crisis, contributing to financial stability by reducing the severity of crises.

Figure 11 also suggests that such stabilization benefits by the IT-LWS may not be feasible in the presence of the ZLB constraint. The red triangles show the cases under the ZLB constraint.

[29]We do not consider values of ρ_{SPREAD} below -0.75 because they deliver positive cumulative *gains* in output upon a financial crisis. The reason is again that the overshooting of output during the recovery phase is larger than the loss of output during the crisis.

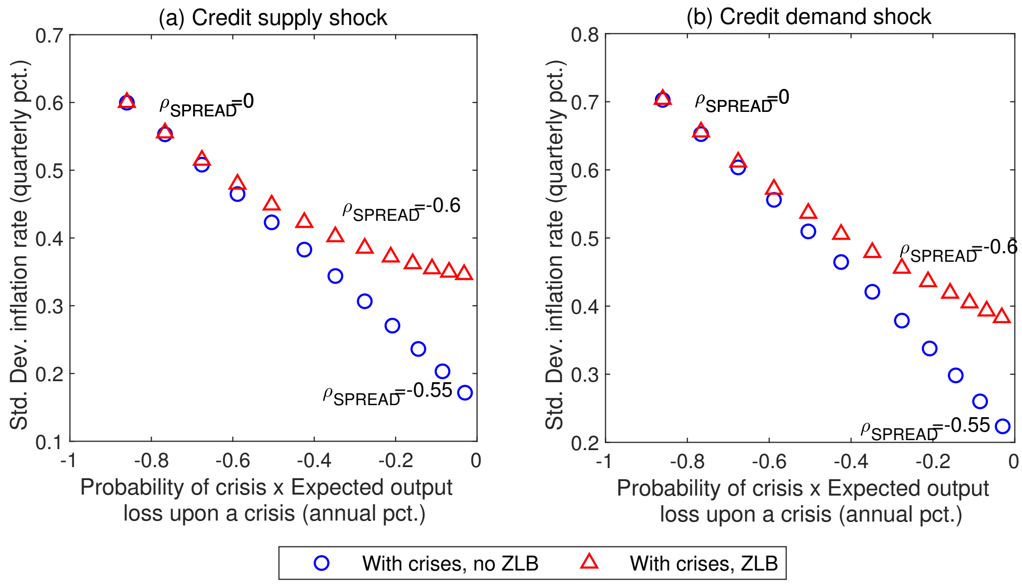
Figure 11: Leaning With the Spreads, Inflation Targeting and Financial Stability



First, notice that inflation volatility and the expected output loss from a crisis with $\rho_{SPREAD} = 0$ show large jumps from the case with no ZLB constraint. This is consistent with Figure 3. As we change ρ_{SPREAD} from zero towards negative values, we observe that both price stability and financial stability are improved initially. This is in contrast with the case where we increase the inflation coefficient in the presence of the ZLB constraint in Figure 3. However, eventually, further increases in the absolute value of ρ_{SPREAD} makes the central bank face a trade-off: Further reduction in financial instability requires the central bank to sacrifice inflation volatility. This is because the value of ρ_{SPREAD} that further limits the fallout during a crisis delivers too much inflation volatility in normal times. To avoid such a trade-off, the central bank would need to vary the policy rule judiciously depending on whether or not the economy is experiencing a slowdown in activity triggered by a financial crisis. The results indicate that the efficiency gain of the IT-LWS policy is limited by the ZLB constraint, but nonetheless the IT-LWS policy rules dominate the conservative IT policy rules considered in Figure 3.

A LWS monetary policy regime could also be implemented in the context of the PLT as well. We have shown in Figure 5 that, in contrast to the IT regime, a stronger inflation response in a PLT regime always improves both price stability and financial stability regardless of the presence of the ZLB constraint. Can a similar statement be made for a PLT-LWS monetary policy regime? In other words, does a stronger reaction to credit spreads always enhance both price stability and financial stability regardless of the ZLB constraint if the LWS is implemented in a PLT framework? Figure 12 shows that this is indeed the case. Blue circles show the case when the ZLB constraint is absent, while red triangles show its counterpart when the ZLB constraint is imposed. In both cases, ρ_{SPREAD} is changed from 0 to -1, with ρ_{Π} fixed at 0.01. Without the ZLB constraint, the PLT-LWS can approach the complete price stability and financial stability. However, in the presence of the ZLB constraint, the ZLB prevents the central bank implementing the PLT-LWS from reducing the

Figure 12: Leaning With the Spreads, Price-Level Targeting and Financial Stability



volatility of inflation rate beyond a certain point. Nonetheless, the PLT-LWS regime can at least avoid the trade-off that characterizes the IT-LWS regime.

In summary, the PLT regime appears to be able to avoid the trade-off between price stability and financial stability, regardless of the presence of the ZLB constraint. In contrast, an IT regime may lead to an inferior outcome for both price stability and financial stability if it is implemented by a conservative central banker. An IT-LWS regime may face a trade-off between price stability and financial stability in the presence of the ZLB constraint, and the nature of the trade-off can be made worse if the policy strategy is implemented by a conservative central banker.

6 Conclusion

The IT regime has faced criticism that its narrow focus on price stability made the monetary authority blind to the buildup of financial imbalances that ended up in the global financial crisis in 2008. In this paper we show that, in the presence of the ZLB constraint, an IT regime indeed may achieve neither price stability nor financial stability in an environment where financial crises happen endogenously. This failure, however, can be made even worse if the IT regime is implemented by a conservative central banker that reacts strongly to deviations of inflation from its target. We also show that the IT's failure to achieve financial stability is due to the fact that the combination of its "bygones be bygones" principle with the ZLB constraint makes the real debt burden of the economy unstable, raising the probability of financial crises. In contrast, a PLT regime can improve both price stability and financial stability regardless of the ZLB constraint. That is, the commitment to overshoot the inflation target to make up for the inflation misses during a binding ZLB episode turns out to be beneficial to both price stability and financial stability. Finally, the paper shows that a LAW policy may undermine both price stability and financial stability, and may suffer from indeterminacy. If responding to a financial variable is deemed necessary, it is much more efficient to react to credit spreads rather than to credit aggregates. We also find that the benefits of doing so (in terms of price stability and financial stability) can be maximized in a PLT framework.

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