Monetary policy and endogenous financial crises

F. Boissay* F. Collard† J. Galí‡ C. Manea§¶

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Abstract

Excessive economic booms sometimes lead to financial crises and severe recessions. We study whether central banks should take such booms and the associated financial stability risks into account when they set their policy rate, even though this may come at the cost of inefficient macroeconomic fluctuations when credit markets operate smoothly. We tackle this question within a textbook New Keynesian model augmented with endogenous capital accumulation and micro–founded financial crises. The model is solved globally to allow the economy to depart persistently from its steady state and feature boom–driven crises. We compare several interest rate rules, under which the central bank responds more or less forcefully to inflation and aggregate output. Our main results are threefold. First, monetary policy affects the probability of a crisis both in the short run and in the medium run (*i.e.* over multiple years), through its effects on savings and capital accumulation. Second, the welfare gain from addressing financial stability risks exceeds the cost due to aggregate demand externalities. In particular, welfare is higher when the central bank responds to inflation and —forcefully enough— to output than under strict inflation targeting (SIT). Third, while rule–based policy interventions help to avert crises, discretionary interventions late in a boom instead tend to trigger them.

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*Bank for International Settlements. Email: frederic.boissay@bis.org.

†Toulouse School of Economics. Email: fabrice.collard@gmail.com.

‡CREI, Universitat Pompeu Fabra and Barcelona GSE. Email: jgali@crei.cat.

§Deutsche Bundesbank. Email: cristina.manea@bundesbank.de.

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1 Introduction

The last fifteen years have shown that central banks can stave off financial crises but also inadvertently foster the macroeconomic imbalances that typically bring them about. In response to the Covid–19 shock, for example, central banks swiftly lowered interest rates and acted as lenders–of–last–resort to the financial sector. These moves likely prevented a financial collapse that would otherwise have exacerbated the damage to the economy. At the same time, empirical evidence shows that, by keeping their policy rates too low for too long, central banks may entice the financial sector to search for yield and take excessive risk. And indeed, loose monetary policy is sometimes regarded as one of the causes of the 2007–8 Great Financial Crisis.[1]

The effects of monetary policy on financial stability are complex, and likely depend on the nature of the shocks that hit the economy and the overall macroeconomic context.[2] To study these effects, we develop a New Keynesian (NK) model that helps us understand the role that monetary policy can play in an economy where financial markets are fragile and financial crises have multiple causes —ranging from adverse exogenous shocks to endogenous macroeconomic imbalances.

Our model departs from the textbook —three–equation— NK model in four important ways. First, it features endogenous capital accumulation, so that the economy may deviate persistently from its steady state and generate protracted booms and imbalances. Second, firms are subject to idiosyncratic technology shocks, in addition to aggregate ones. This heterogeneity gives rise to a loan market where low productivity firms lend their capital to high productivity firms. Third, we introduce financial frictions that make this loan market fragile. One friction is that lenders may not be able to seize the capital stock of a defaulting borrower, thus allowing firms to borrow capital and abscond with it. This commitment problem induces lenders to limit the amount of capital that can be borrowed. Another friction is that idiosyncratic technologies are private information. Together, these frictions imply that the loan rate must be above a minimum threshold to entice the least productive firms —whose opportunity cost of absconding is the lowest— to lend their capital rather than borrow and abscond. When the marginal return on capital is too low, not even high–productivity firms can afford paying the minimum loan rate, and the loan market collapses. This is what we call a financial crisis. A crisis is characterized by capital misallocation and brings along a severe recession. In our model, the typical crisis breaks out toward the end of a protracted

[1] Taylor (2011) refers to the period 2003-2005 as the "Great Deviation", which he characterizes as one when monetary policy became less rule–based, less predictable, and loose. Empirical evidence include *e.g.*, Maddaloni and Peydró (2011), Jiménez, Ongena, Peydró, and Saurina (2014). See also Rajan (2011) as well as CGFS (2018) for a recent survey.

[2] The Federal Reserve and European Central Bank (ECB)'s recent strategy reviews both emphasize that the importance of financial stability considerations in the conduct of monetary policy has increased since the Great Financial Crisis (Goldberg, Klee, Prescott, and Wood (2020), ECB (2021)). One reason is that central banks may themselves inadvertently contribute to the buildup of financial stability risks. Another is that macro–prudential policies —which are relatively recent policy tools in advanced economies— still need to be tested and may not yet offer an effective protection against such risks (*e.g.* Schnabel (2021)).

economic boom, when there is excess capital in the economy and the marginal productivity of capital is low. Finally, the fourth departure from the textbook model is that we solve our model globally, which allows us to capture the non–linearities embedded in the endogenous booms and busts of the loan market.

We study the conduct of monetary policy in terms of whether and how hard central banks should curb such booms and busts, and compare the performance of the economy in that case with that of an economy where the central bank follows a strict inflation targeting (SIT) rule —*i.e.* the rule that would be optimal in the absence of financial frictions. Policies that mitigate output fluctuations tend to limit the rise in the expected return of capital during booms, which in turn slows down the accumulation of savings. In addition, mitigating booms and busts is akin to providing the household with an insurance against future aggregate shocks. Such insurance helps them smooth consumption, and therefore reduces their need for accumulating precautionary savings during booms. Ultimately, the lower saving rate stems excess capital accumulation and helps prevent financial crises. As these effects go through agents' expectations, they require that the central bank commit itself to a policy rule, and only materialize themselves over multiple years.

Our main results are threefold. First, monetary policy affects the probability of a crisis not only in the short run (*i.e.* at business cycle frequency), through its usual effects on output and inflation, but also in the medium run, through its effects on savings and capital accumulation. Second, the welfare gain from addressing financial stability risks may exceed the cost due to aggregate demand externalities. In particular, welfare is higher when the central bank responds both to inflation and —forcefully enough— to output than under SIT.[3] One reason is that financial crises typically follow protracted economic booms, which themselves tend to be driven by persistent positive technology shocks, which SIT does not efficiently address. Third, while rule–based policy interventions help to avert crises, discretionary interventions late in a boom instead tend to trigger them.

The paper bridges two main strands of the literature. The first is on monetary policy and financial stability. Like Woodford (2012) and Gourio, Kashyap, and Sim (2018), we introduce endogenous crises in a standard NK framework.[4] The main difference is that they use reduced forms to determine how macro–financial variables (*e.g.* credit gap, credit growth, leverage) affect the likelihood of a crisis, whereas in our case financial crises —including their probability and size— are micro–founded and derived from first principles. This has important consequences in terms of the prescriptions of the model. One is that, in our model, monetary policy also influences the size of the recessions that follow crises, and therefore the welfare cost of the latter —a key element to determine *whether* central banks should lean against fluctuations in output for financial

[3]To be sure, when financial markets are frictionless, SIT is optimal (*i.e.* the "divine coincidence" holds). But when they are frictional, responding to output is desirable.

[4]See Smets (2014) for a review of the literature as well as Filardo and Rungcharoenkitkul (2016), Svensson (2017), Ajello, Laubach, López-Salido, and Nakata (2019), Bernanke and Gertler (2000) and Galí (2014).

stability reasons. Another is that, even though crises can be seen as credit booms "gone wrong", as documented in Schularick and Taylor (2012), not all booms are equally "bad" and conducive to crises in our model (see also Gorton and Ordoñez (2019)) —a key element to determine *when and how hard* to lean against booms. More generally, our findings do not depend on any postulated reduced functional form for the probability of a crisis. In this sense, our model can be seen as a canonical NK model with endogenous financial crises, which provides microfoundations to existing models such as Woodford (2012) and Svensson (2017). The second strand of the literature relates to quantitative macro–financial models with micro–founded endogenous financial crises (Boissay, Collard, and Smets (2016), Gertler, Kiyotaki, and Prestipino (2019)). As in Boissay, Collard, and Smets (2016), crises take the form of a collapse of a wholesale funding market. The main novelty is that we add nominal price rigidities, which allows us to study the link between monetary policy and financial stability.

Though in a more indirect way, our paper is also connected to recent works on how changes in monetary policy rules affect economic outcomes in the medium term (*e.g.* Borio, Disyatat, and Rungcharoenkitkul (2019), Beaudry and Meh (2021)) as well as to works on the link between firms' financing constraints and factor misallocation. In particular, the notion that financial crises impair capital re–allocation chimes well with the narrative of the 2007–8 financial crisis in the US and the literature that shows that a great deal of the recession that followed this crisis can be explained by a lack of creative destruction (Foster, Grim, and Haltiwanger (2016), Argente, Lee, and Moreira (2018)) —notably due to new entrants' inability to borrow (Campello, Graham, and Harvey (2010)).

The paper proceeds as follows. Section 2 describes our theoretical framework, with a focus on the microfoundation of endogenous financial crises, and describes the channels through which monetary policy affects financial stability. Section 3 presents the parametrization of the model as well as the typical economic dynamics around financial crises. Section 4 revisits the "divine coincidence" result and analyses the trade–off between price and financial stability. Section 5 analyses the effect of monetary surprises on financial stability. A last section concludes.

2 Model

The economy is populated with a representative household, a sector of monopolistically competitive retailers, a sector of competitive firms, and a central bank. Our model is a version of the textbook NK model (Galí (2015)) with firms, retailers, nominal price rigidities à la Rotemberg, and capital accumulation. Firms, which are subject to idiosyncratic productivity shocks, are the only non standard agents of the model.

2.1 Agents

2.1.1 Representative household

The representative household lives infinitely. Each period the household supplies N_t work hours, consumes C_t units of final goods, and invests their savings into a one–period riskless nominal bond, B_{t+1}, as well as in intermediate goods firms' equity K_{t+1}, in order to maximize their expected intertemporal lifetime utility:[5]

$$\mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t\left(\frac{C_t^{1-\sigma}}{1-\sigma}-\vartheta\frac{N_t^{1+\nu}}{1+\nu}\right)\right]$$

subject to the sequence of budget constraints

$$P_tC_t+B_{t+1}+P_tK_{t+1}\leq P_t\omega_tN_t+(1+i_{t-1})B_t+P_t(1+r_t^k)K_t+\mathscr{X}_t$$

for $t=0,1,2...$, where $C_t\equiv\left(\int_0^1 C_t(j)^{\frac{\epsilon-1}{\epsilon}}\mathrm{d}j\right)^{\frac{\epsilon}{\epsilon-1}}$ is a standard Dixit–Stiglitz consumption index of differentiated goods with $\epsilon>0$ a measure of their substitutability, $P_t\equiv\left(\int_0^1 P_t(j)^{1-\epsilon}\mathrm{d}j\right)^{\frac{1}{1-\epsilon}}$ is the unit price of the consumption basket, ω_t is the real wage, i_{t-1} is the nominal interest rate on the bonds purchased at $t-1$ (determined in $t-1$), r_t^k is the real return on firm equity, and $\mathscr{X}_t$ are other sources of income that are of a lump–sum nature.[6] The optimality conditions describing the household's behaviour are given by (together with the transversality condition):

$$\beta\mathbb{E}_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}(1+r_{t+1})\right]=Z_t \tag{1}$$

$$\beta\mathbb{E}_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(1+r_{t+1}^k\right)\right]=1 \tag{2}$$

$$\vartheta N_t^{\nu}C_t^{\sigma}=\omega_t \tag{3}$$

where $1+r_{t+1}\equiv(1+i_t)/(1+\pi_{t+1})$ is the real gross rate of return on bonds, with $\pi_t\equiv\frac{P_t}{P_{t-1}}-1$ the inflation rate, and Z_t is a demand shock à la Smets and Wouters (2007) that follows an exogenous AR(1) process $\ln(Z_t)=\rho_z\ln(Z_{t-1})+\varepsilon_t^z$, with $\rho_z\in[0,1)$. The innovation ε_t^z is realized at the beginning of period t.[7]

2.1.2 Central bank

The central bank sets its policy rate according to the following rule:

$$1+i_t=\frac{1}{\beta}(1+\pi_t)^{\phi_\pi}\left(\frac{Y_t}{Y}\right)^{\phi_y} \tag{4}$$

[5]In what follows, $\mathbb{E}_t(\cdot)$ denotes the expectation operator over the aggregate shocks conditional on the information set available at the end of period t.

[6]These lump–sum transfers consist of retailers' rebated profits and menu costs.

[7]This demand shock creates a wedge between the interest rate controlled by the central bank and the return on assets held by the household, and has the opposite effects of Smets and Wouters (2007)'s risk premium shock. A negative demand shock increases the required return on assets and reduces current consumption. At the same time, it also increases firms' cost of capital and reduces the value of capital and investment. In contrast to a discount factor shock, this type of demand shock helps to generate a positive correlation between consumption and investment.

where Y_t is aggregate output in period t and Y is the average aggregate output in the stochastic steady state.[8]

2.1.3 Retailers

A continuum of retailers purchase intermediate goods from firms (described in next section) at price p_t, differentiate them, and resell them in a monopolistically competitive environment subject to nominal price rigidities. Retailers live infinitely and are indexed by $j \in [0,1]$. Each retailer j sells $Y_t(j)$ units of a differentiated final good j and sets their price $P_t(j)$ subject to Rotemberg–style adjustment costs $\frac{\varrho}{2} P_t Y_t \left(\frac{P_t(j)}{P_{t-1}(j)} - 1\right)^2 \geq 0$, where $Y_t \equiv \left(\int_0^1 Y_t(j)^{\frac{\epsilon-1}{\epsilon}} \mathrm{d}j\right)^{\frac{\epsilon}{\epsilon-1}}$ is aggregate output —in which the adjustment costs are expressed. Retailers' objective is to choose their price $P_t(j)$ and quantity $Y_t(j)$ so as to maximize their expected stream of future profits:

$$\mathbb{E}_0 \left[\sum_{t=0}^{\infty} \Lambda_{0,t} \left(\frac{P_t(j)}{P_t} Y_t(j) - \frac{(1-\tau)p_t}{P_t} Y_t(j) - \frac{\varrho}{2} Y_t \left(\frac{P_t(j)}{P_{t-1}(j)} - 1 \right)^2 \right) \right]$$

subject to the sequence of demand schedules

$$Y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\epsilon} Y_t \tag{5}$$

where $\Lambda_{t,t+k} \equiv \beta^k \left(C_{t+k}/C_t\right)^{-\sigma}$ is the stochastic discount factor and $\tau = \frac{1}{\varepsilon}$ is the subsidy rate on the purchase of intermediate goods which corrects for monopolistic market–power distortions in the flexible–price version of the model. In the symmetric equilibrium, the first–order optimality condition yields:

$$(1+\pi_t)\pi_t = \mathbb{E}_t \left(\Lambda_{t,t+1} \frac{Y_{t+1}}{Y_t} (1+\pi_{t+1})\pi_{t+1} \right) - \frac{\epsilon - 1}{\varrho} \left(1 - \frac{\epsilon}{\epsilon - 1} \frac{1}{\mathscr{M}_t} \right) \tag{6}$$

where

$$\mathscr{M}_t \equiv \frac{P_t}{(1-\tau)p_t} \tag{7}$$

is retailers' average markup.

2.1.4 Intermediate good producers

Intermediate good producers ("firms") are at the core of our model. They produce the intermediate goods that retailers differentiate, are perfectly competitive, and live one period only. The firms that operate in period t are born at the end of any period $t-1$, and experience idiosyncratic productivity shocks at the beginning of period t. More particularly, a firm that experiences shock q has access to a technology represented by the production function

$$y_t(q) = A_t(qK_t(q))^{\alpha} N_t(q)^{1-\alpha} \tag{8}$$

[8] The average inflation rate in the steady state is implicitly set to $\pi = 0$. Throughout the paper, we will experiment with different values of ϕ_π and ϕ_y.

where $K_t(q)$ and $N_t(q)$ denote the firm's capital stock and labor input, A_t is an aggregate technology shock that evolves exogenously over time according to an AR(1) process $\ln(A_t) = \rho_a \ln(A_{t-1}) + \varepsilon_t^a$, and $q \in \{0, 1\}$. A mass μ of firms draw $q = 0$ —*i.e.* are unproductive— and a mass $1 - \mu$ draw $q = 1$ —*i.e.* are productive.[9] Like the idiosyncratic shock, the aggregate productivity shock ε_t^a is realized at the beginning of period t. When they are born, firms are identical, purchase the same amount of capital goods K_t at price P_{t-1}, and finance these purchases by issuing equity $P_{t-1}K_t$.[10] Capital goods take the form of a Dixit–Stiglitz bundle of final goods identical to that defining the composite consumption good, and depreciate at rate δ.

Upon observing the productivity shocks, firms may re–scale their capital stock by purchasing or selling capital goods — depending on their respective qs. To fund any gap between their desired capital, $K_t(q)$, and their initial capital stock, K_t, they can use a loan market. Thus, $K_t(q) - K_t$ represents the net borrowing (resp. lending) by firm q if $K_t(q) > K_t$ (resp. $K_t(q) < K_t$). The real interest rate on the resulting loan market is denoted r_t^ℓ, and expressed in terms of the final good bundle. Loans are paid back at the end of period t.[11] Once its capital stock re–scaled, a firm with productivity q may lend its capital stock at rate r_t^ℓ or alternatively hire labor $N_t(q)$ and start the production of intermediate goods. In the later case, it will sell its production $y_t(q)$ to retailers at price p_t (which is taken as given by both sides) at the end of the period, sell its un–depreciated capital $(1 - \delta)K_t(q)$ at price P_t, pay the workers at real wage rate ω_t, and reimburse its loans. In both cases, firm q will and distribute its profit

$$\frac{1}{(1-\tau)\mathscr{M}_t} y_t(q) - \omega_t N_t(q) + (1-\delta)K_t(q) - (1 + r_t^\ell)(K_t(q) - K_t),$$

as dividends to its shareholders. Dividing the above expression by K_t, subtracting one to obtain a rate of return, and re–arranging the terms yields (by definition) the firm's net real rate of return on equity

$$r_t^k(q) = \frac{1}{(1-\tau)\mathscr{M}_t} \frac{y_t(q)}{K_t} - \omega_t \frac{N_t(q)}{K_t} - (r_t^\ell + \delta) \frac{K_t(q) - K_t}{K_t} - \delta \tag{9}$$

The firm chooses $K_t(q)$ and $N_t(q)$ to maximize its return on equity $r_t^k(q)$. We study the choices of unproductive ($q = 0$) and productive firms ($q = 1$) in turn.

Choices of unproductive firms. Since an unproductive firm makes losses when it hires labour, one obtains $N_t(0) = 0$ and, therefore (using (9)),

$$r_t^k(0) = -(r_t^\ell + \delta)\frac{K_t(0) - K_t}{K_t} - \delta$$

[9] To be sure, our analysis and results hold for more general distribution of the idiosyncratic shocks.

[10] Part of that capital stock is purchased from exiting firms (an amount $(1 - \delta)K_{t-1}$), with the rest consisting of purchases of final goods produced in period $t - 1$ (*i.e.* new investment $K_t - (1 - \delta)K_{t-1}$).

[11] In effect, a loan is akin to an outright sale of capital goods on credit, and the loan rate is net of capital depreciation. Without loss of generality, we assume that loans are dis–intermediated. To be sure, firms have access to two external financial markets: an inter–period equity market at the end of period $t - 1$, and an intra–period loan market at the beginning of period t.

which in turn implies that the firm lends its entire capital stock (*i.e.* $K_t(0) = 0$) whenever $r_t^\ell + \delta > 0$ and is indifferent between lending capital and keeping it idle (*i.e.* $K_t(0) \in [0, K_t]$) when $r_t^\ell = -\delta$.[12] In any case, the unproductive firm's return on equity $r_t^k(0)$ is always equal to r_t^ℓ in equilibrium.

Choices of productive firms. In contrast, it is optimal for a productive firm to hire labour and produce. Consider first the choice of $N_t(1)$ given $K_t(1)$. The optimal labor hiring satisfies the first order condition

$$\omega_t = \frac{1-\alpha}{(1-\tau)\mathscr{M}_t} \frac{y_t(1)}{N_t(1)}$$

$$\Leftrightarrow \frac{y_t(1)}{K_t(1)} = \Phi_t \equiv A_t^{\frac{1}{\alpha}} \left(\frac{1-\alpha}{(1-\tau)\mathscr{M}_t \omega_t} \right)^{\frac{1-\alpha}{\alpha}} \tag{10}$$

where the expression in (10) emphasizes that the firm's capital productivity, denoted Φ_t, is a function of the real wage ω_t and retailers' markup $\mathscr{M}_t$, and therefore is taken as given by the firm. Given its optimal hiring plan, the firm's return on capital can be re–written as (using (9))

$$r_t^k(1) = \alpha \frac{\Phi_t}{(1-\tau)\mathscr{M}_t} \frac{K_t(1)}{K_t} - (r_t^\ell + \delta) \frac{K_t(1)}{K_t} + r_t^\ell \tag{11}$$

which implies that the firm borrows to scale up its capital stock ($K_t(1) > K_t$) only if $\alpha \frac{\Phi_t}{(1-\tau)\mathscr{M}_t} - \delta \geq r_t^\ell$.

Overall return on equity. Given the firms' respective returns on equity, and using the identity $y_t \equiv (1-\mu) y_t(1)$ and the result $\Phi_t = \frac{y_t(1)}{K_t(1)}$ (from (10)), we can derive the household's overall return on equity as[13]

$$r_t^k \equiv \mu r_t^k(0) + (1-\mu) r_t^k(1) = \frac{\alpha y_t}{(1-\tau)\mathscr{M}_t K_t} - \delta + (r_t^\ell + \delta) \left(1 - \frac{(1-\mu) K_t(1)}{K_t} \right) \tag{12}$$

We now turn to the analysis of the loan market.

2.2 Frictionless loan market

A useful benchmark is given by the case of a frictionless loan market, where the idiosyncratic productivity shocks can be observed by all potential lenders, and where loan contracts are fully enforceable, with no constraints on the amounts that a firm can borrow. In that case productive firms will borrow capital until they break even. Thus, for a competitive equilibrium to exist the borrowing rate r_t^ℓ ought to rise until (from (11))

$$\frac{\partial r_t^k(1)}{\partial K_t(1)} = 0 \Leftrightarrow \alpha \frac{\Phi_t}{(1-\tau)\mathscr{M}_t} - \delta = r_t^\ell$$

[12] It should be clear that r_t^ℓ cannot be strictly below $-\delta$ in equilibrium as otherwise no firm would lend. We therefore ignore this case throughout our analysis. Unproductive firms are thus natural lenders of capital goods in the economy.

[13] See Appendix 7.1 for the intermediate steps of the derivation. In the next two sections, we show that the last term is always equal to zero in equilibrium, so that this expression ultimately simplifies to $r_t^k = \frac{\alpha y_t}{(1-\tau)\mathscr{M}_t K_t} - \delta$.

which implies

$$r_t^k(0) = r_t^k(1) = r_t^\ell = \alpha \frac{\Phi_t}{(1-\tau)\mathscr{M}_t} - \delta$$

Absent frictions, the loan market thus perfectly hedges firms against the idiosyncratic shocks, with unproductive firms lending their entire capital stock to the productive ones: $K_t = (1-\mu)K_t(1)$. Since only productive firms hire and produce, one obtains $N_t = (1-\mu)N_t(1)$ and therefore —using $y_t \equiv (1-\mu)y_t(1)$—

$$y_t = A_t K_t^\alpha N_t^{1-\alpha} \tag{8'}$$

which, together with the equilibrium conditions for aggregate variables, results in a system that corresponds to the standard NK model with a representative intermediate goods firm and endogenous capital accumulation.

2.3 Frictional loan market

Next we consider the case of financial frictions arising from limited commitment and asymmetric information. We assume that a firm that keeps its capital idle has the option to sell its un–depreciated capital stock at the end of the period and abscond, and therefore cannot commit itself to repay its loan. We also assume that lenders cannot observe a firm's productivity q, and hence cannot assess its incentives to stay idle and abscond.[14] As we show next, these frictions imply an upper bound on the leverage of any individual firm.

Suppose that an unproductive firm were to borrow like a productive firm, keep its entire capital idle, resell it at the end of the period, and default on its loan. The implied return for that firm would be $P_t(1-\delta)K_t(1)$. That firm will not abscond as long as this return is smaller than the return $P_t(1+r_t^\ell)K_t$ from lending out all its capital in the loan market (which is unproductive firms' best alternative). It follows that a productive firm's leverage ratio, $\frac{K_t(1)-K_t}{K_t}$, must satisfy the incentive compatibility constraint

$$\frac{K_t(1)-K_t}{K_t} \leq \psi_t \equiv \frac{r_t^\ell + \delta}{1-\delta} \tag{13}$$

where ψ_t is the firm's borrowing limit. As long as condition (13) is satisfied, unproductive firms will refrain from borrowing and absconding. This condition also implies that the borrowing limit ψ_t

[14]To be sure, the assumption here is that the proceeds from the sales of capital goods at the end of period t can only be concealed if the capital goods have not been used for production. One can think of the firms that produce and sell intermediate goods as firms that operate transparently, and whose revenues can easily be seized by creditors. In contrast, the firms that keep their capital idle have the possibility to "go underground" and default. Since a firm that absconds forgoes the proceeds from lending (which is the same for all firms) or from producing (which is higher for productive firms), the opportunity cost of absconding is always higher for productive than for unproductive firms. Because firm productivity is private information, though, productive firms cannot commit themselves to borrowing bigger amounts and paying back their loans. Both frictions are needed for the economy to depart from the frictionless aggregate outcome. Without asymmetric information, unproductive firms would lend their entire capital stock to productive firms. Without limited commitment, productive firms could borrow until they break even, as in the frictionless case. This set of assumptions and frictions are standard in the macro–finance literature (see *e.g.* Gertler and Rogoff (1990), Azariadis and Smith (1998), Boissay, Collard, and Smets (2016)).

increases with r_t^ℓ: the higher the interest rate in the loan market, the higher the opportunity cost of absconding, and hence the higher the leverage ratio consistent with the incentive to repay.

Aggregate loan supply and demands. When $-\delta < r_t^\ell \leq \alpha \frac{\Phi_t}{(1-\tau)\mathscr{M}_t} - \delta$, the aggregate supply of loans emanates from the μ unproductive firms and is given by $L_t^S(r_t^\ell) = \mu K_t$. When $r_t^\ell = -\delta$, unproductive firms are indifferent between lending out their capital or keeping it idle, implying $L_t^S(r_t^\ell) \in [0, \mu K_t]$. When $r_t^\ell > \alpha \frac{\Phi_t}{(1-\tau)\mathscr{M}_t} - \delta$, then even productive firms want to lend, and $L_t^S(r_t^\ell) = K_t$. The blue line in Panel (I) of Figure 1 represents that loan supply schedule. On the demand side, the $1-\mu$ productive firms borrow only if the net return from expanding their capital stock is positive. When $\alpha \frac{\Phi_t}{(1-\tau)\mathscr{M}_t} - \delta > r_t^\ell$, this return is strictly positive and productive firms leverage up as much as possible until they reach the borrowing limit ψ_t. As each firm borrows $\psi_t K_t$, the aggregate loan demand is (using (13)) $L_t^D(r_t^\ell) = \frac{1-\mu}{1-\delta}(r_t^\ell + \delta)K_t$ in that case. When $\alpha \frac{\Phi_t}{(1-\tau)\mathscr{M}_t} - \delta = r_t^\ell$, productive firms break even on their loans and are indifferent as to how much they borrow, implying $L_t^D(r_t^\ell) \in [0, \frac{1-\mu}{1-\delta} \alpha \frac{\Phi_t}{(1-\tau)\mathscr{M}_t} K_t]$. Finally, when $\alpha \frac{\Phi_t}{(1-\tau)\mathscr{M}_t} - \delta < r_t^\ell$, productive firms make losses on every loan and so do not borrow: $L_t^D(r_t^\ell) = 0$. The red line in Panel (I) of Figure 1 represents that loan demand schedule —which is non–monotonic— under the assumption that there is a range of interest rates for which that demand exceeds the loan supply. Formally, this corresponds to the case when

$$\lim_{r_t^\ell \nearrow \alpha \frac{\Phi_t}{(1-\tau)\mathscr{M}_t} - \delta} L_t^D\left(r_t^\ell\right) \geq \lim_{r_t^\ell \nearrow \alpha \frac{\Phi_t}{(1-\tau)\mathscr{M}_t} - \delta} L_t^S\left(r_t^\ell\right)$$

$$\Leftrightarrow \alpha \frac{\Phi_t}{(1-\tau)\mathscr{M}_t} - \delta \geq \hat{r}^\ell \equiv \frac{(1-\delta)\mu}{1-\mu} - \delta \tag{14}$$

In the above expression, $\hat{r}^\ell$ is the minimum incentive–compatible loan rate required for all unproductive firms to be able to lend their entire capital stock —and therefore for an equilibrium with trade to exist.

Equilibrium outcomes. The loan market equilibrium depends on whether condition (14) holds. When it does, productive firms can afford paying the required loan rate, and there exist three possible loan market equilibria, denoted by E, U, and A in the figure. Equilibria E and U feature trade, whereas equilibrium A does not. In what follows, we focus on equilibria A and E which, unlike U, are stable under tatônnement.[15]

Consider equilibrium A (for "autarky"), where $r_t^\ell = -\delta$. At that rate, unproductive firms are indifferent as to lending out capital, and any loan in the interval $[0, \mu K_t]$ is consistent with optimal

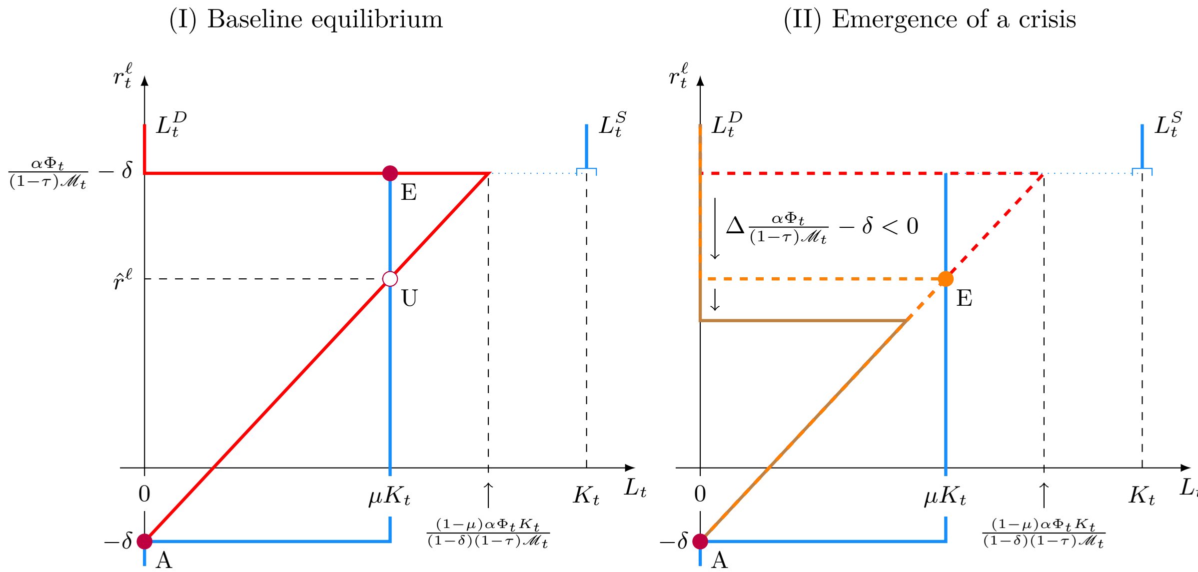
[15] We rule out equilibrium U because it is not tatônnement–stable. An equilibrium loan rate r_t^ℓ is tatônnement–stable if, following any small perturbation to r_t^ℓ, a standard adjustment process —whereby the loan rate goes up (down) whenever there is excess loan demand (supply)— pulls r_t^ℓ back to its equilibrium value (see Mas-Colell, Whinston, and Green (1995), Chapter 17). Since firms take r_t^ℓ as given, tatônnement stability is the relevant concept of equilibrium stability. Note that U and E yield the same aggregate outcome and same overall return on equity r_t^k, and only differ in terms of productive and unproductive firms' respective returns $r_t^k(0)$ and $r_t^k(1)$.

firm behavior. At the same time, however, the incentive compatibility constraint prevents productive firms from borrowing any positive amount ($\psi_t = 0$). As a result, $L_t^D(-\delta) = L_t^S(-\delta) = 0$ and there is no trade. Productive firms keep their initial capital stock unchanged (*i.e.* $K_t(1) = K_t$), resulting in capital misallocation, lower aggregate productivity, and lower aggregate output than in the absence of financial frictions (compare relations (8') and (8")):

$$y_t = A_t\left((1-\mu)K_t\right)^{\alpha} N_t^{1-\alpha} \tag{8"}$$

In what follows, we refer to the autarkic equilibrium A and the associated recession as a "financial crisis".

Figure 1: Loan market equilibrium



Note: This figure illustrates the aggregate loan supply (blue) and incentive–compatible aggregate demand (red, orange, brown) curves. In Panel (a), equilibria A and E are stable, whereas U is unstable —and ruled out. In Panel (b), the orange line is associated with a value of $\alpha\frac{\Phi_t}{(1-\tau)\mathscr{M}_t} - \delta$ equal to $\hat{r}^\ell$, and to multiple equilibria A and E. The brown line is associated with a value of $\alpha\frac{\Phi_t}{(1-\tau)\mathscr{M}_t} - \delta$ strictly below $\hat{r}^\ell$ and A as unique equilibrium. The threshold loan rate $\hat{r}^\ell$ corresponds to the equilibrium loan rate when the supply and demand curves are tangent. This threshold is constant, and can be interpreted as the minimum incentive–compatible loan rate that is required to ensure that all unproductive firms lend their entire capital stock.

Equilibrium E, in contrast, features a loan rate $r_t^\ell = \alpha\frac{\Phi_t}{(1-\tau)\mathscr{M}_t} - \delta \geq \hat{r}^\ell > -\delta$, at which all unproductive firms lend and productive firms borrow. We refer to this equilibrium as "normal times". In normal times, the entire capital stock is used productively ($K_t = (1-\mu)K_t(1)$) and, given the stock of capital K_t and labour supply N_t, the aggregate quantity of intermediate goods is the same as in the frictionless economy (see (8')).[16]

Finally, consider what happens when productive firms' return on capital, $\alpha\frac{\Phi_t}{(1-\tau)\mathscr{M}_t} - \delta$, falls below the loan rate threshold $\hat{r}^\ell$, so that condition (14) is not satisfied anymore. The brown loan

[16]Importantly, the possibility and expectation of a crisis in the future imply that K_t and N_t will not be the same as in the frictionless economy, though. More generally, given the state variables of the economy in normal times, any gap between the frictional economy and the frictionless economy is driven by agents' expectations of a crisis.

demand schedule in Panel (II) of Figure 1 illustrates that possibility. In this case, the range of loan rates for which $L_t^D(r_t^\ell) > L_t^S(r_t^\ell)$ vanishes altogether, and there is only one possible equilibrium, the autarkic one, A.

Equilibrium selection. In the rest of the paper, we assume that when both equilibria A and E are present, market participants coordinate on the most efficient one, namely, equilibrium E.[17] As a result, a crisis breaks out if and only if A is the only possible equilibrium, *i.e.* (using (10), (14), and the result that $\Phi_t = \frac{y_t(1)}{K_t(1)} = \frac{y_t}{K_t}$ in equilibrium E) if and only if

$$\frac{\alpha y_t}{(1-\tau)\mathscr{M}_t K_t} - \delta < \hat{r}^\ell \tag{15}$$

In the following sections we analyze the factors that may trigger a financial crisis, as well as its macroeconomic consequences.

2.4 Monetary policy's transmission channels

Household's and retailers' expectations of a financial crisis can be summarized by the one–period–ahead crisis probability (using relation (15) and the result that $y_t = Y_t$ in the general equilibrium),

$$\mathbb{E}_{t-1}\left(\mathbb{1}\left\{\frac{\alpha Y_t}{(1-\tau)\mathscr{M}_t K_t} - \delta < \hat{r}^\ell\right\}\right) \tag{16}$$

where $\mathbb{1}\{\cdot\}$ is a dummy variable equal to one when the inequality inside the curly braces holds (*i.e.* there is a crisis) and to zero otherwise.

Expression (16) is key to understanding the effects of monetary policy on financial stability in our model. It emphasizes that crises may emerge through a fall in aggregate output (the "Y–channel"), a rise in retailers' markup (the "M–channel"), or excess capital accumulation (the "CA–channel"). Given a (predetermined) capital stock K_t, a crisis is more likely to break out following a shock that lowers output and/or increases the markup. Such a shock needs not to be large to trigger a crisis, if the economy has accumulated a large capital stock.[18] When K_t is high, all other things equal, firms' real return on equity —and therefore their opportunity cost of absconding— is low, the loan market is fragile, and even a small variation in Y_t or $\mathscr{M}_t$ may trigger a crisis.

One important reason why crises break out despite their implied inefficiencies is that rational agents do not fully internalize the effects of their individual choices on Y_t, $\mathscr{M}_t$ and K_t and, through these variables, on financial fragility. To see this, assume that —for whichever reason— the representative household believes that a crisis is looming. To hedge against the future recession

[17]There are of course several —but less parsimonious— ways to select the equilibrium. For example, one could include a stochastic sunspot, *e.g.* assume that firms coordinate on equilibrium E (*i.e.* are "optimistic") with some constant and exogenous probability whenever this equilibrium exists. It should be clear, however, that the central element of our analysis is condition (14) for the existence of E, not the selection of E conditional on its existence. In other terms, our analysis does not hinge on the equilibrium selection mechanism that we assume.

[18]This would for example be the case after an unusually long economic boom, as we show later.

and smooth consumption, they tend to save relatively more (or dis–save less), which contributes to increasing (or slowing down the fall in) K_t, and makes the crisis even more likely through the CA–channel. Boissay, Collard, and Smets (2016) refer to this externality as "the savings glut externality". Retailers' price setting behaviour in anticipation of the crisis may also precipitate the latter, if retailers attempt to smooth the costly price increase they will have to implement when aggregate productivity falls by front–loading part of it and increasing their markups ahead of the crisis (the M–channel).[19]

As the above discussion suggests, the central bank affects the probability of a crisis both in the short run and in the medium run (*i.e.* over multiple years). In the short run, it does so through the effect of contemporaneous changes in its policy rate on output and inflation (i.e. via the Y– and M–channels). For example, assume that the central bank unexpectedly hikes its policy rate. On impact, all other things equal, the hike works to reduce aggregate demand and prices, and to increase retailers' markups. As a result, firms' return on capital diminishes, which brings the economy closer to a crisis (as shown in expression (16)). In the medium term, in contrast, monetary policy affects financial stability through its impact on households' saving behaviour and capital accumulation (i.e. via the CA–channel). For example, a central bank that commits itself to systematically and forcefully responding to variations in output (*i.e.* to a high ϕ_y) will slow down the accumulation of capital during booms and make the financial sector more resilient to adverse shocks. The channel is twofold. First, there is the usual effect of the expected rate of return of capital on capital accumulation. As the central bank commits itself to curbing growth, it also lowers investors's expected returns during booms and thus makes capital investment less attractive. Second, by smoothing the business cycle, such a policy in effect provides the household with an insurance against future aggregate shocks, and helps them smooth their consumption. This, in turn, reduces the need for precautionary savings and contributes to slowing down the accumulation of capital during expansions. The upshot is that a rule with a higher ϕ_y can contribute to lowering the probability of a crisis. Because capital accumulation takes time, though, these effects only materialize themselves over multiple years.

3 Anatomy of a Financial Crisis

The aim of this section is to describe the dynamics of a typical financial crisis in the model under a realistic parametrization.[20]

[19]As they do so, retailers will also concomitantly and inefficiently reduce the level of activity and contribute to brewing the crisis through the Y-channel. Note that the M– and Y–channels are also related to what Blanchard and Kiyotaki (1987) referred to as aggregate demand externalities.

[20]The model is solved globally by finding the fixed point solution for agents' decision rules. For a detailed description of the solution method, see Appendix [x].

3.1 Parametrization of the model

We parameterize our model based on quarterly data and under a standard Taylor rule (STR); see Table 1). Compared to the textbook NK model with endogenous capital accumulation, there is only one additional parameter: the proportion of unproductive firms μ. This parameter implicitly governs the degree of asymmetric information and, therefore, the prevalence of financial frictions. All other things equal, the higher μ, the higher the aggregate supply of loans, the lower the equilibrium loan rate, and the higher the probability of a crisis. We set $\mu = 2.39\%$ so that the economy spends 8% of the time in a crisis in the stochastic steady state, which is in line with existing data on financial crises.[21]

Table 1: Parametrization

Parameter	Target	Value
Preferences		
β	4% annual real interest rate	0.989
σ	Logarithmic utility on consumption	1.000
ν	Inverse Frish elasticity equals 2	0.500
ϑ	Steady state hours equal 1	0.814
Technology and price setting		
α	64% labor share	0.360
δ	6% annual capital depreciation rate	0.015
ϱ	Same slope of the Phillips curve as with Calvo price setting	105.000
ϵ	11% markup rate	10.000
Aggregate shocks		
ρ_a	Persistence of TFP	0.950
σ_a	Standard deviation of TFP innovation (in %)	0.700
ρ_z	Persistence in Smets and Wouters (2007)	0.220
σ_z	Standard deviation of risk–premium innovation in Smets and Wouters (2007) (in %)	0.230
Interest rate rule		
ϕ_π	Standard quarterly Taylor rule (Taylor (1993))	1.500
ϕ_y	Standard quarterly Taylor rule (Taylor (1993))	0.125
Proportion of unproductive firms		
μ	The economy spends 8% of the time in a crisis	0.0239

The values of the other parameters are standard. More particularly, the utility function is logarithmic with respect to consumption ($\sigma = 1$). The parameters of labor dis–utility are set to $\vartheta = 0.814$ and $\nu = 0.5$ so as to normalize hours to one in the deterministic steady state and to obtain an inverse Frish labor elasticity of 2 —this is in the ballpark of the estimates for industrialized countries. We set the discount factor β so that the annualized average return on equity is 4%. The elasticity of substitution between intermediate goods ϵ is set to 10 in order to generate a markup of 11% in the steady state. Given this, we set the capital elasticity parameter α to 0.36 in order to obtain a labor income share of 64% in the steady state. We assume that capital depreciates by 6% per year ($\delta = 0.015$). We set the price adjustment cost parameter to $\varrho = 105$, so that the

[21]The textbook NK model corresponds to our model when $\mu = 0$. In Reinhart and Rogoff (2014)'s and Laeven and Valencia (2018)'s databases, for example, countries spend on average 11.9% and 6.6% of the time in a financial crisis —this figure takes into account that crises last several quarters. The gap is due to differences in the definition and dating of financial crisis (see Baron, Verner, and Xiong (2020)), as well as in the country coverage of the databases.

model generates the same slope of the Phillips curve as in a Calvo pricing model with an average duration of prices of 4 quarters. The parametrization of the technology shock is also standard, with $\rho_a = 0.95$ and $\sigma_a = 0.007$. That of the demand shock is borrowed from Smets and Wouters (2007), with $\rho_z = 0.22$ and $\sigma_z = 0.0023$.

3.2 Typical path to crises

To derive the dynamics of the typical crisis, we proceed in two steps. First, we solve our non–linear model numerically and globally.[22] Second, starting from the stochastic steady state, we feed the model with the risk–premium and productivity shocks, simulate it over 1,000,000 periods, and identify the crises' starting dates as well as the sequences of shocks around them. We then compute the average dynamics 20 quarters around these dates. The outcome is reported in Figure 2.

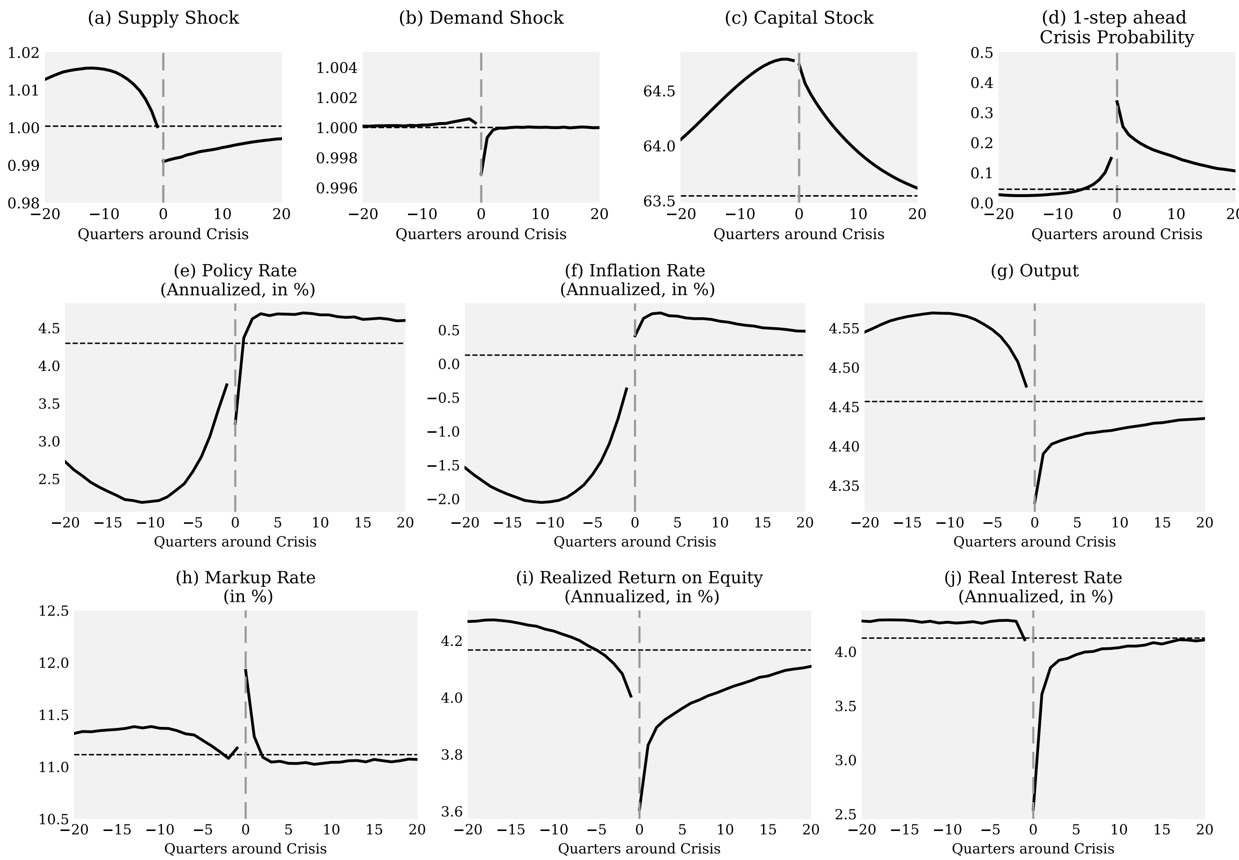
The first result that emerges from the analysis is that the typical crisis is not caused by an unusually large adverse exogenous shock.[23] Rather, it occurs on the heels of a protracted economic boom (Figure 2, Panel (g)) driven by a long sequence of relatively small positive technology and demand shocks (Panels (a) and (b)). Throughout the boom, the economy accumulates capital (Panel (c)), which over time gradually exerts downward pressures on firms' realized return on equity (Panel (i)).[24] At first, these pressures are more than compensated by the series of favorable exogenous shocks that hit the economy. In the first phase of the boom, firms' realized return on equity and, hence, their opportunity cost to keeping their capital idle is relatively high (*i.e.* above its steady state). The loan market reallocates capital effectively to the most productive firms, and the probability of a crisis is relatively small (Panel (d)). The boom in output ends around seven quarters before the crisis (Panel (g)), once the sequence of favorable supply and demand shocks has run its course. Just before the crisis, productivity and demand shocks recede and output falls back toward its steady state, leaving firms with excess capital. As a result, firms' return on equity goes down and the probability of a crisis goes up (Panel (d)). The crisis eventually breaks out in the face of relatively mild adverse shocks, which on impact reduce the TFP and aggregate demand exogenous components (A_t and Z_t) by around 1% and 0.2%, respectively (Panels (a) and (b)). The typical crisis is characterized by a freeze of the loan market, capital misallocation, and a recession (see also Table 2).

[22] Our model cannot be solved linearly because of discontinuities in the decision rules. And it cannot be solved locally because crises may break out when the economy is far away from its steady state (*e.g.* when K_t is high). Details on the numerical solution method are provided in the appendix.

[23] This results is also present in Boissay, Collard, and Smets (2016).

[24] Note that there is nothing systematic about the prevalence of boom–driven crises, as the typical crisis could *a priori* have been caused by large adverse shocks. This result can be explained by the asymmetric effects the household's consumption smoothing behaviour on financial stability. Following adverse shocks, the household tends to dis–save, which slows down capital accumulation and, all else equal, augments the resilience of the loan market to adverse shocks (see expression (16)). In good times, in contrast, the economy accumulates more capital, which —all else equal— hampers the resilience of the loan market to adverse shocks.

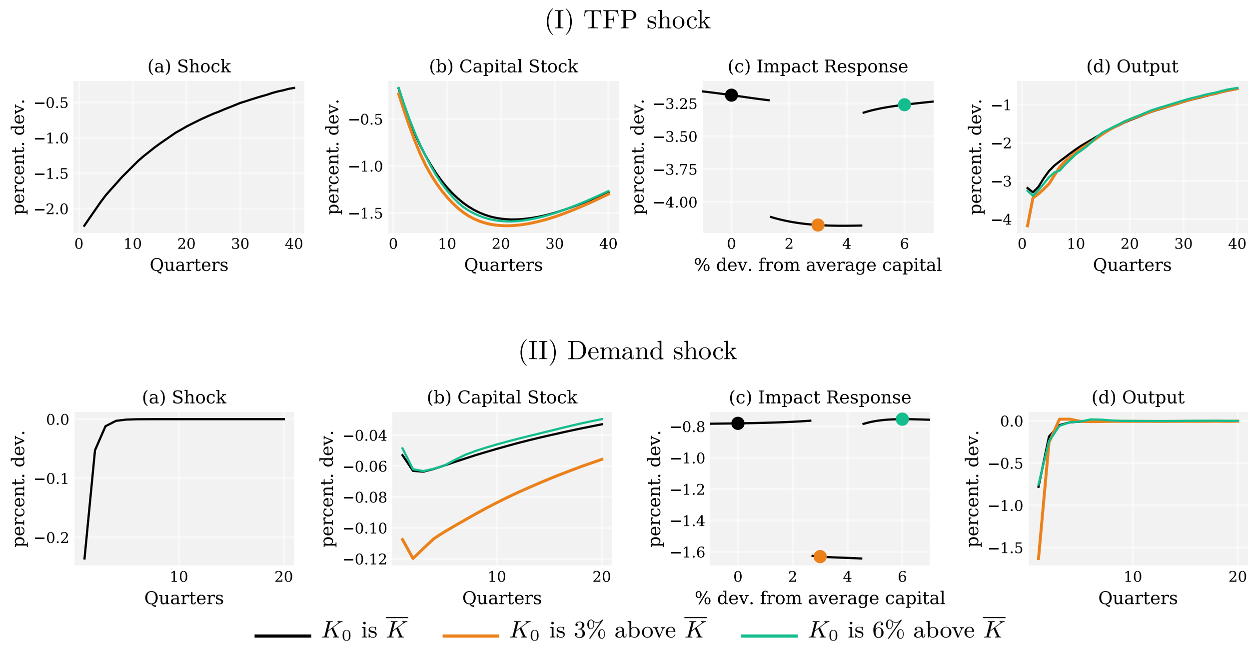
Figure 2: Typical path to crisis



Note: Simulations for the STR economy. Panel (a): dynamics of the technology shock following a negative one standard deviation from its average level. Panels (b) and (d): generalized impulse response function (IRF) of capital and output obtained from 10,000 draws. Panel (c): effect of the shock on output on impact (y–axis) depending on the initial level of capital (x–axis). K_0 and $\overline{K}$ denote, respectively, the level of the capital stock at the time of the shock and the average level of the capital stock in the stochastic steady state. Generalized IRFs compare the dynamics of the shocked economy with those of the baseline economy, starting from the three different levels of K_0. They take into account not only the effects of the shock itself but also the transition dynamics toward the stochastic steady state.

Importantly, these adverse shocks are not the root cause of the crisis but only its trigger, in the sense that an identical sequence of shocks would not have led to a crisis, had the economy (notably the capital stock) been closer to its steady state. The presence of a large capital overhang is indeed a pre–condition for a financial crisis to break out in the absence of large adverse exogenous shocks. Figure 3 illustrates this point. Panel (d) shows the impulse response functions of aggregate output to a negative one–standard deviation technology or demand shock, for moderate (black line), fairly high (orange line) and very high (green line) initial capital stocks. Panels (c) show how the effect of the shock depends on the initial level of capital. When capital is relatively low, a negative shock has a limited effect on output on impact. The economy is initially in normal times and remains there following the shock (black dot). When the capital stock is initially so high that the economy is already in a crisis, the effect is again limited. The economy is initially in a crisis and remains there following the shock (green dot). The interesting case is for intermediate values of the initial capital stock, when the economy is on the brink of a crisis. In this case, a one–standard deviation shock suffices to trigger the crisis, which in turn induces a larger drop in output (orange dot). This experiment highlights the central role of capital accumulation in the dynamics of financial crises, and therefore the endogenous nature of the latter. Excess capital accumulation in normal times weighs on firms' realized real return on equity and opportunity cost of keeping their capital idle, impairs the economy's resilience to adverse shocks, and lays the ground for a crisis.

Figure 3: Initial conditions matter



Note: Generalized Impulse Response Functions (IRF) following a one–standard deviation negative technology or demand shock under STR. Generalized IRFs compare the dynamics of the shocked economy with those of the baseline economy, starting from the three different levels of K_0. They take into account not only the effects of the shock itself but also the transition dynamics toward the stochastic steady state. Panel (a): dynamics of the technology shock following a negative one standard deviation from its average level. Panels (b) and (d): generalized impulse response function (IRF) of capital and output obtained from 10,000 draws. Panel (c): effect of the shock on output on impact (y–axis) depending on the initial level of capital (x–axis). K_0 and $\overline{K}$ denote, respectively, the level of the capital stock at the time of the shock and the average level of the capital stock in the stochastic steady state.

Even though under STR the central bank commits itself to responding to future variations in output, which helps to slow down capital accumulation, the economy still experiences protracted "bad" economic booms that lead to crises —the CA–channel. How monetary policy stabilizes output and inflation (and markups) in response to current adverse shocks is also an important factor of financial (in)stability. Under STR, the central bank lets output decline in the face of negative technology and demand shocks. This partly explains why crises coincide with recessions —the Y–channel. At the same time, markups typically increase following negative demand shocks and decrease following negative technology shocks. These shocks therefore financial stability in the short run in opposite directions through the M–channel (see Figure 2). Ultimately, whether a crisis breaks out depends on the relative strengths of the Y– M– and CA– channels as well as size of the shocks.

Finally, to get a sense of which type of shock is most conducive to a crisis, we solve and simulate our model separately for two "counterfactual" economies that experience either technology or demand shocks —not both, and compute statistics on crises (see Table 2). The main result is that crises are essentially due to technology shocks —either alone or in combination with demand shocks. Being relatively more persistent (see Table 1), such shocks are indeed more likely to give rise to protracted booms and capital overhang, which are pre-conditions for a crisis.[25] Technology–driven crises also last twice as long as the few demand–driven ones and, accordingly, are associated with larger losses in output.

Table 2: Crisis statistics and origins

	Crisis time (%)	Length	Output loss (%)
Economy with both shocks	8.00	1.78	-3.20
Economy with TFP shocks only	3.42	3.98	-4.76
Economy with demand shocks only	0.00	1.01	-2.90

Note: The first row reports statistics of the stochastic steady state ergodic distribution in the economy with both technology and demand shocks. The second and third rows report the same statistics, in counterfactual economies that experience either technology or demand shocks. In all cases, we assume that the central bank follows a STR. "Crisis time (%)" is the percentage of the time that the economy spends in a crisis. By construction, it is equal to 8% in the economy with both technology and demand shocks (square brackets). "Length" is the average duration of a crisis (in quarters). "Output loss (%)" is the percentage fall in output from one quarter before the crisis until the trough of the crisis.

4 The "divine coincidence" revisited

We now study whether central banks should account for financial stability risks when setting their policy rate. To do so, we compare welfare under different monetary policy rules (varying parameters ϕ_π and ϕ_y in relation (4)) with that under strict inflation targeting (SIT), the limit case where $\phi_\pi = +\infty$ and $\phi_y = 0$ and the central bank fully stabilizes inflation. As is well known, absent financial frictions, SIT also stabilizes inefficient fluctuations in output —the so–called "divine coincidence"— and delivers the first best allocation (Blanchard and Galí (2007)). We are interested in whether the central bank should depart from this benchmark when the financial sector is fragile.

4.1 Welfare cost of financial crises

We start by analyzing the incidence and cost of crises under SIT, when the central bank eliminates the inefficiencies due to nominal rigidities and aggregate demand externalities. Since the only

[25] Figure 7.1 in the appendix illustrates this latter point.

remaining inefficiencies stem from financial frictions in this case, comparing welfare in this economy with that in the frictionless economy (where $\mu = 0$ and prices are flexible) allows us to pinpoint the specific welfare cost of crises under SIT. We find that this cost amounts to 0.057% in terms of permanent consumption equivalent. This cost has two components. There is the usual *ex post* cost, which corresponds to the inefficient fall in employment and consumption during crises. In the context of our model, this cost is due to the misallocation of capital following the collapse of the loan market. The other —more subtle— cost is incurred *ex ante*, *i.e.* before a crisis occurs, and is due to agents adjusting their behaviour in anticipation of the crisis. As noted in Section 2.4, this leads the household to accumulate more precautionary savings than socially optimal. Thus, even though financial markets operate frictionlessly in normal times, the mere possibility of a crisis suffices for the economy to deviate from the first best allocation, thus further raising the cost of crises.[26]

Table 3: Economic performance under alternative monetary policy rules

	Rule paramaters		Frictionless economy	Frictional economy							
	ϕ_π	ϕ_y	PCE	PCE	Crisis	Length	Output	Y–, M–, and CA–channels			
			(%)	(%)	time (%)	(quarters)	loss (%)	$\sigma(Y_t)$	$\sigma(\mathscr{M}_t)$	$\sigma(K_t)$	$\rho(Y_t, \mathscr{M}_t)$
SIT	$+\infty$	0.000	–	–	5.03	4.59	-5.60	3.92	0.00	3.70	0.00
STR	1.500	0.125	-0.0062	-0.0408	[8.00]	1.78	-3.20	3.62	1.09	3.16	0.14
IR–[0.212]	1.500	0.212	-0.0059	-0.0116	[5.03]	1.78	-2.83	3.26	1.06	2.77	0.50
IR–[0.309]	1.500	0.309	-0.0075	0.0117	[2.50]	1.68	-2.54	2.93	1.16	2.42	0.72
IR–[0.415]	1.500	0.415	-0.0101	0.0239	[1.00]	1.54	-2.26	2.67	1.32	2.11	0.84
IR–[0.491]	1.500	0.491	-0.0124	0.0267	[0.50]	1.47	-2.12	2.50	1.43	1.92	0.88

Note: Statistics of the stochastic steady state ergodic distribution. "Crisis time", "Length", and "output loss" are the same statistics as in Table 2. Welfare is measured in terms of the permanent consumption equivalent increase (PCE, in %) that the household should be given to live in the SIT economy rather than in the STR, IR–[0.212], IR–[0.309], IR–[0.415], or IR–[0.491] economy. A negative PCE means that welfare is higher in the SIT economy. The frictionless economy corresponds to a case where $\mu = 0$ —all else equal. The IR–[ϕ_y] is an interest rate rule as in relation (4), whose parameter ϕ_y is set to 0.212, 0.309, 0.415, 0.491 so that the economy respectively spends 5.03%, 2.5%, 1.0%, and 0.5% of the time in a crisis under this rule. In the case of the IR–[0.212] rule, notably, the economy spends by construction as much time in a crisis as under SIT (*i.e.* 5.03%).

The above analysis prompts the question whether the central bank could address financial inefficiencies more effectively by following a rule other than SIT. If so, this would necessarily come at the cost of deviating from price stability. We study the potential trade–off between price and financial stability in next section.

[26]Recall that the property that financial markets operate frictionlessly in normal times follows from the specific —Bernouilli— distribution of idiosyncratic productivity shocks (*i.e.* $q \in \{0, 1\}$). In normal times, the entire capital stock of the economy is used by the productive firms, as it would in a frictionless economy. This property would cease to hold if we assumed a continuous distribution of idiosyncratic productivity shocks.

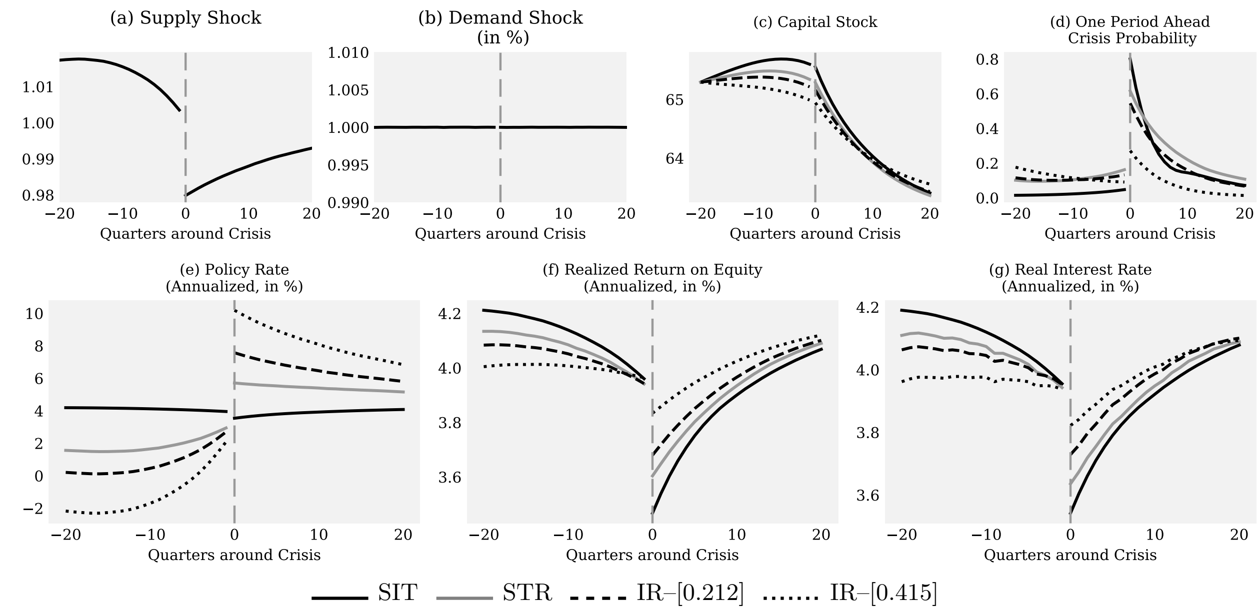
4.2 The price versus financial stability trade–off

To study the price versus financial stability trade–off and its implications for monetary policy, we first compare crises statistics and welfare under SIT and four alternative parametrizations of the policy rule (4). To discipline the analysis, we consider alternative rules that put the same weight on inflation as under STR ($\phi_\pi = 1.5$) and only differ in terms of how the central bank responds to fluctuations in output. Accordingly, we denote these interest rate rules by IR–[ϕ_y], with parameter ϕ_y ranging from 0.212 to 0.491. Our focus is on whether the central bank can improve welfare upon SIT by committing itself to leaning against economic booms and busts (*i.e.* when ϕ_y is higher).

The findings are reported in the four last rows of Table 3. Our main results are twofold. First, the central bank does face a trade–off between price and financial stability: when it responds more forcefully to output —$\phi_y \geq 0.309$— it reduces the incidence and severity of crises relatively to SIT, but the volatility of retailers' markup ($\sigma(\mathscr{M}_t)$ is higher) and prices increases. Second, the net welfare gain from leaning may be positive. With $\phi_y = 0.491$, for example, the welfare gain from financial stability exceeds the welfare losses due to nominal rigidities and permanent consumption is 0.0267% higher than under SIT. The upshot is that the central bank should account for financial stability risks, even though this comes at the cost of inefficient variations in prices.

To gain intuition for the above result, we next analyze the effects of the alternative monetary policy rules on the probability of a crisis. The effects play out in the long as well as in the short run. In the long run, monetary policy may help reduce the probability of a crisis by reining in the buildup of macro–financial imbalances via the CA–channel. To illustrate this point, we report in Figure 4 the typical path to a crisis under SIT along with the dynamics of the economies under STR, IR–[0.212] and IR–[0.415], when these economies are fed with the very same sequences of shocks as those leading to a crisis under SIT (Panels (a) and (b)). These counterfactual dynamics show how the economy would have evolved had the central bank followed —all else equal— these alternative rules rather than SIT. We find that capital would have been accumulated more slowly where the central bank curbs the economic boom more aggressively (Panel (c)). In these economies, the central bank reduces firms' realized and expected equity returns during booms (Panels (f) and (g)), which discourages capital accumulation. Moreover, by smoothing the business cycle, the central bank provides the household with an insurance against the fall in consumption should the crisis materialize itself, which reduces the need for precautionary savings and further slows down capital accumulation. Panel (c) however shows that curbing the boom takes time, meaning that the effects of monetary policy on financial stability via the CA–channel only materializes themselves over multiple years.

Figure 4: Counterfactuals



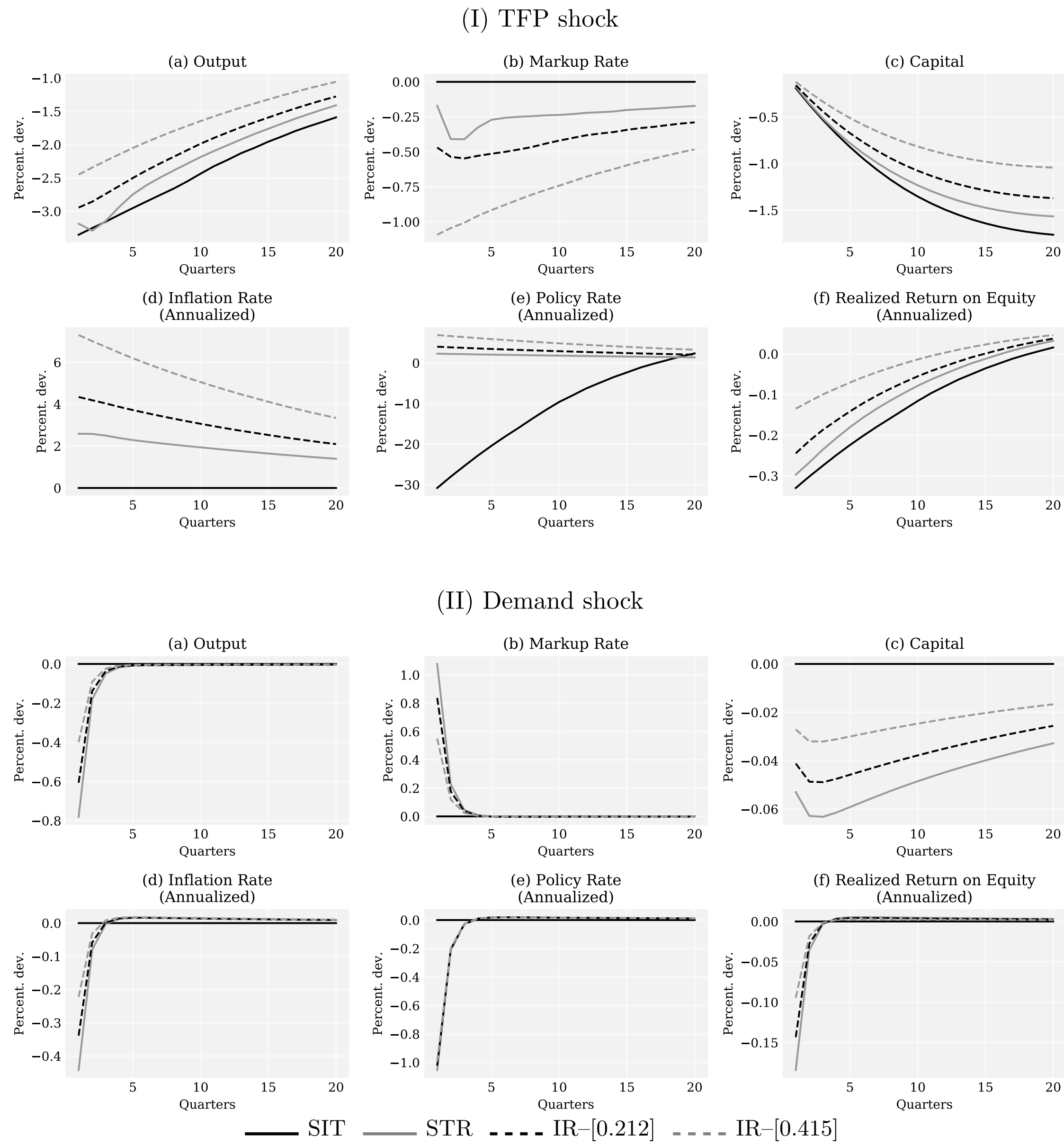
Notes: For SIT: typical path to crisis. For STR, IR–[0.212], and IR–[0.415]: counterfactual average dynamics, when the economy starts with the same capital stock in quarter $t = -20$ and is fed with the same technology and demand shocks as under the SIT economy (Panels (a) and (b)).

Monetary policy also affects the probability of a crisis through its short run macro–stabilisation properties. To illustrate this point, we compare the impulse response functions of the economy to adverse technology and demand shocks under SIT and under the alternative policy rules (Figure 5).[27] Consider the response to the technology shock first (Panel (I)). Panel (I–a) shows that, following such a shock, output falls by less when the central bank follows a IR–[ϕ_y] rule (*i.e.* fights the recession) than when it follows the SIT rule (in which case it does not stabilize output at all). Moreover, as under the alternative rules the central bank commits itself to only partially stabilizing inflation, it lets retailers' markup decline during the recession (Panel (I–b)), which further props up firms' return on equity (Panel (I–f)). In contrast, markups stay constant under SIT. It follows that, under the alternative rules, the central bank limits the fall in capital returns through both the Y– and the M–channels, thus making the financial sector more resilient to adverse technology shocks (see relation (16)). Consider next the response of the economy to an adverse demand shock (Panel (II)). Following SIT perfectly neutralises the effects of the shock, and prevents crises. Under the alternative rules, in contrast, the economy features a fall in firms' equity returns on impact of the shock (Panel (II–f)) and, therefore, financial crises. However, the more aggressive the central bank's response to output fluctuations, the milder the fall in firms' equity return, and the fewer the crises. All in all, taking both technology and demand shocks into account, provided that ϕ_y is high enough, a IR–[ϕ_y] rule will thus be better equipped than SIT to shield the economy from financial stability

[27] Recall that the typical crisis is triggered by adverse technology and demand shocks (see Figure 2).

risks in the short–run.

Figure 5: Impulse response functions around steady state



<u>Note:</u> Generalized Impulse Response Functions following a a one–standard deviation negative technology or demand shock under SIT, STR, IR–[0.212] and IR–[0.415], around the average of the ergodic distribution in the stochastic steady state.

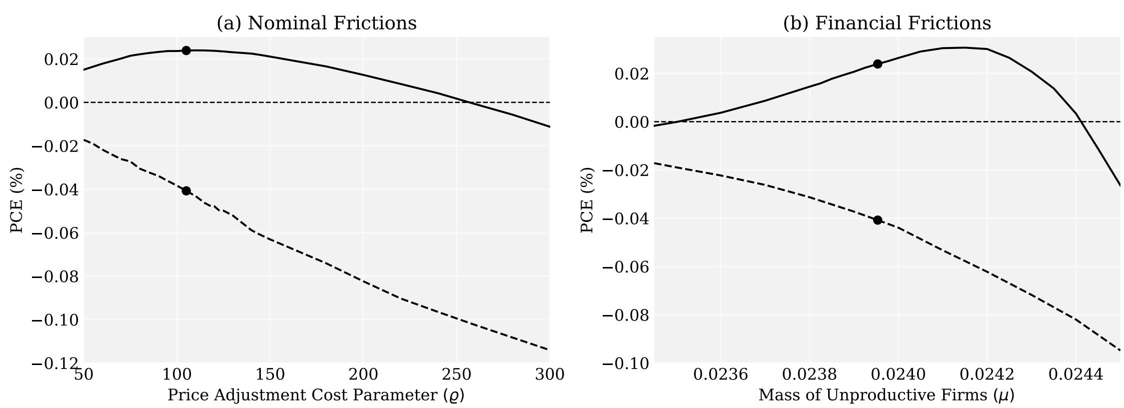
4.3 Leaning systematically does not require higher rates

Curbing economic booms is often associated with setting a policy rate *above* that of the STR (e.g. Svensson (2017)). The comparison of rules STR and IR–[0.415] in the counterfactual experiment of Figure 4, which shows that the policy rate is lower under IR–[0.415] than under STR during the booms that precede crises (Panel (e)), questions this conventional wisdom. The reason is that protracted booms tend to be driven by long sequences of positive technology shocks. During such booms, how the central bank sets its policy rate is the outcome of two opposite forces. On the one hand, the positive technology shocks boost aggregate productivity, supply, and output. The rise in output warrants a higher rate hike under IR–[0.415] than under STR. On the other hand, the central bank's stronger commitment to raising the policy rate (and hence contracting demand) if output increases tends to anchor the economy around an equilibrium where persistent productivity gains only entail a moderate rise in permanent income and, therefore, in aggregate demand. For a given productivity gains and shift in aggregate supply, equilibrium output thus increases by less under IR–[1.00%] than under STR, which magnifies the initial deflationary pressures due to the productivity gains (see Figure 5, Panel (d)). Ultimately, the rate cut due to lower inflation more than offsets the rate hike due to the stronger coefficient on output, leaving the policy rate lower under IR–[0.415] than under STR during the boom.[28]

4.4 Pre–conditions for leaning

How does the welfare gain from leaning vary with the degree of price rigidities and the severity of financial frictions? To answer this question, we report in Figure 6 the welfare gains over SIT of following the IR–[0.415] or STR rule, for different values of parameters ϱ (nominal frictions) and μ (financial frictions).

Figure 6: When should a central bank lean?



Notes: Welfare gain (PCE, in %) of the IR–[0.415] or STR rule over SIT (y–axis) as nominal (Panel (a)) or financial (Panel (b)) frictions become more severe —keeping all else equal. A negative PCE means that welfare is higher under SIT than under IR–[0.415] or STR. The dots correspond to our calibrated model, with $\varrho = 105$ and $\mu = 2.39\%$.

Panel (a) shows the net welfare gains over SIT, as a function of nominal rigidities. The main result that emerges from this exercise is that IR–[0.415] outperforms SIT as long as prices are not "too sticky" (*i.e.* ϱ is lower than 250). In the latter case, the inefficiencies due to nominal

[28]Note that this result is not specific to our model, and is *a priori* also present in the standard New Keynesian model with capital accumulation (which our model nests in the absence of credit frictions). Our model only unveils that this property of the NK model holds during the booms that precede financial crises.

rigidities are indeed so prominent that the welfare gain from addressing variations in prices with SIT outweighs that of fighting financial crises with IR–[0.415]. Note that the net welfare gain of following IR–[0.415] rather than SIT does not decrease monotonically with ϱ, though, and even increases when ϱ is below 100. This points two opposite effects of a rise in nominal rigidities on welfare. On the one hand, larger distortions due to nominal rigidities lowers the gain of leaning. When prices are stickier, on the other hand, the IR-[0.415] rule is more effective in fighting crises, which increases the gain of leaning. All in all, the net welfare gain of following IR-[0.415] thus increases with price stickiness, as long as prices are not "too sticky".

Panel (b) shows the net welfare gains over SIT, as a function of the severity of financial frictions. The relationship is non–monotonic, and the net welfare gain of leaning with IR–[0.415] is only positive for intermediate values of μ. When financial frictions are mild (low values of μ), there is relatively little gain from fighting (rare) financial crises, while there is a cost in terms of inefficient variations in prices. SIT is therefore preferable to IR–[0.415] in that case. When financial frictions are severe, in contrast, the potential welfare gain from fighting crises are large. But, given its IR–[0.415] rule, the central bank is also less effective in fighting these crises. In particular, Figure 7.2 shows that, for the highest values of μ, leaning with the IR–[0.415] rule does not stabilize the financial sector more than SIT. In other terms, the net welfare gain from leaning under IR-[0.415] turns negative when financial frictions become too severe. In this case, the central bank may either follow SIT or lean even more forcefully by committing to a stronger response to fluctuations in output (*i.e.* with $\phi_y > 0.415$).

Finally, Figure 6 shows that welfare is always lower under the STR rule than under SIT. This result, due to the relatively weak macroeconomic stabilization properties of STR in response to demand shocks (Figure 5, Panel (II-f)), further emphasizes that leaning is only effective if the central bank commits itself to responding forcefully enough to fluctuations in output.

5 Monetary surprises and financial stability

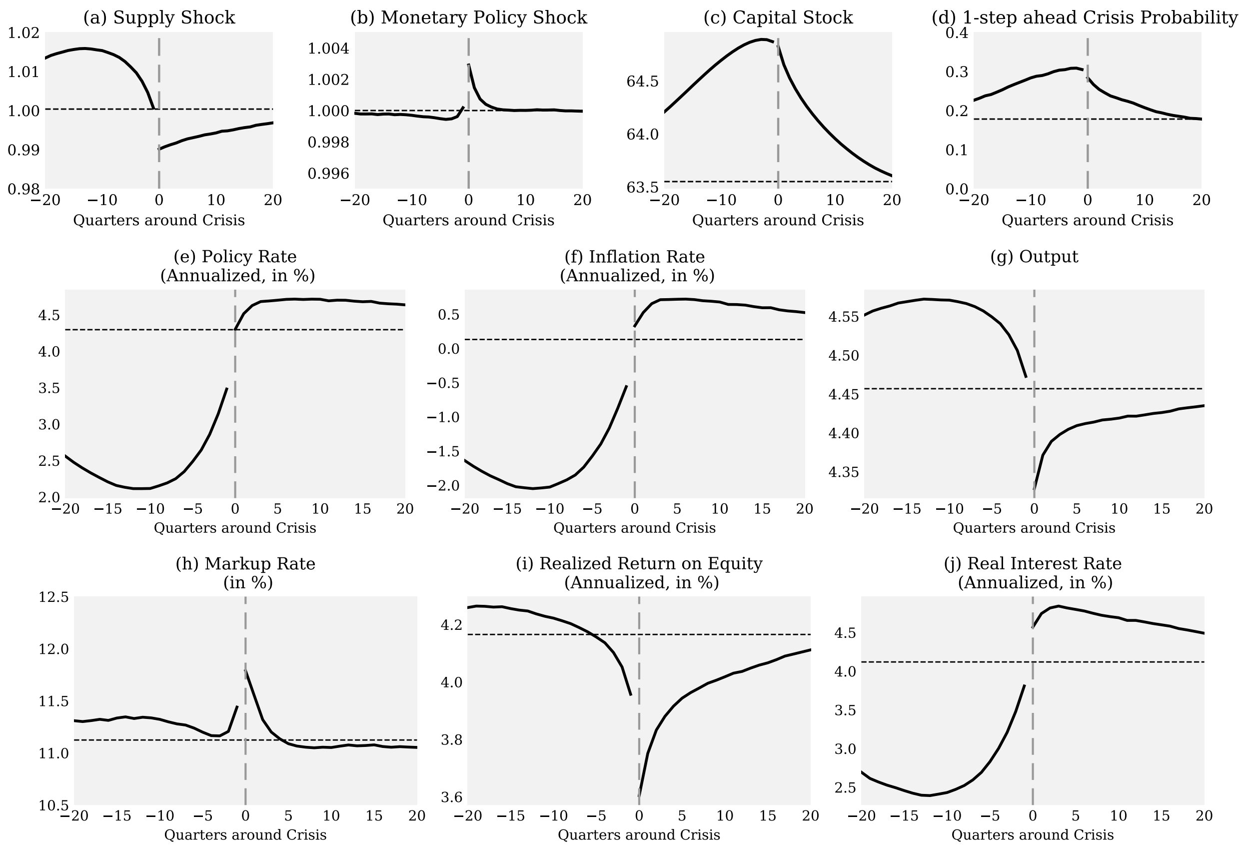
The aim of this section is to assess the effects of monetary surprises —as opposed to rules— on financial stability. To do so, we consider a STR economy that experiences random deviations from the STR —"monetary surprises"— alongside technology ones.[29]

Figure 7 shows the typical path to crises in this new environment. We find that crises occur after a long period of unexpected monetary easing, where the policy rate remains below the one prescribed by STR for almost five years (Panel (b)). Persistently lower rates fuel the boom that precedes the typical crisis. The crisis is triggered by three consecutive, unwarranted (according to

[29]The process of these shocks is standard (see Galí (2015)). More specifically, we consider the monetary policy rule $1 + i_t = \frac{1}{\beta}(1 + \pi_t)^{1.5} \left(\frac{Y_t}{Y}\right)^{0.125} \varsigma_t$ where ς_t follows an exogenous AR(1) process $\ln(\varsigma_t) = \rho_\varsigma \ln(\varsigma_{t-1}) + \epsilon_t^\varsigma$, with $\rho_\varsigma = 0.5$ and $\sigma_\varsigma = 0.0025$. In the context of our model, monetary policy shocks are isomorphic to demand shocks.

the rule), and abrupt interest rate hikes toward the end of the boom, at a time when the crisis probability is very high (Panel (d)). This finding is consistent with the recent empirical evidence in Schularick, Ter Steege, and Ward (2021) that unanticipated "last minute" interest rate hikes at the end of a boom are more likely to trigger a crisis than to avert it (see also Taylor (2012)). Schularick, Ter Steege, and Ward (2021) refer to such policy as "discretionary" leaning against the wind.

Figure 7: Typical path to crisis with technology and monetary policy shocks



Note: Simulations for the STR with MP shocks economy in lieu of demand shocks. Average dynamics of the economy around the beginning of a new crisis (in quarter 0). To filter out the potential noise due to the aftershocks of past crises, we only report averages for new crises, *i.e.* crises that follow at least 20 quarters of normal times. Panels (a) and (b) show the average dynamics of the technology and monetary policy shocks. The dashed line corresponds to the unconditional average across simulation.

Overall, our analysis highlights an important difference between discretionary and rule–based leaning against the wind, *i.e.* that leaning discretionarily and late in the boom is conducive to financial crises. To understand this, consider a booming economy and the central bank's policy options. If the central bank unexpectedly and abruptly increases its policy rate, it may trigger a sudden fall in aggregate demand and firms' return on equity, and ultimately a crisis. If instead it unexpectedly reduces its policy rate, it may boost aggregate demand further and avert the crisis in the short term. But this will only kick the can down the road. Following the rise in aggregate demand and equity returns, the household will keep on accumulating capital, making the financial sector even more fragile in the medium term. None of these discretionary policies helps to avert the crisis. Rather, our analysis prescribes that the central bank address financial externalities by committing itself to curbing the boom should it persist and propping up the economy should a recession breaks out. In effect, systematically leaning against the booms amounts, *inter alia*, to providing the household with an insurance against future aggregate shocks. By helping smooth consumption, such insurance inhibits the household's saving behaviour, slows down —and prevents excess— capital accumulation over the medium term, and shields the economy against crises.

6 Conclusion

We have developed a version of the NK model with capital accumulation and heterogeneous firms and inter–firm lending. In the absence of financial frictions the equilibrium outcome collapses to that of the standard model with a representative firm. With financial frictions, however, there is an upper bound on the leverage ratio of any individual firm resulting from an incentive–compatibility constraint, which prevents capital from being fully reallocated to the most efficient firms. When the average return on capital is low, possibly due to a capital overhang at the end of a long boom, the loan market collapses, triggering a financial crisis and a fall in activity due to capital misallocation.

Our analysis of varied monetary policies points to the advantages of systematic leaning policies, whereby the central bank commits itself to raising the interest rate in response to an investment boom.

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7 Appendix

7.1 Derivation of expression (12)

By definition, $r_t^k \equiv \mu r_t^k(0) + (1-\mu) r_t^k(1)$, which can be rewritten using $r_t^k(0) = r_t^\ell$, (9) and (10) as

$$\begin{aligned} r_t^k &= \mu r_t^\ell + (1-\mu)\left(\frac{\alpha}{(1-\tau)\mathscr{M}_t}\frac{y_t(1)}{K_t} - (r_t^\ell + \delta)\frac{K_t(1) - K_t}{K_t} - \delta\right) \\ &= r_t^\ell + \frac{\alpha}{(1-\tau)\mathscr{M}_t}\frac{(1-\mu)y_t(1)}{K_t} - (r_t^\ell + \delta)\frac{(1-\mu)K_t(1)}{K_t} \end{aligned}$$

Since only the productive firms produce, we use $y_t = (1-\mu)y_t(1)$ to obtain

$$r_t^k = \frac{\alpha}{(1-\tau)\mathscr{M}_t}\frac{y_t}{K_t} - \delta + (r_t^\ell + \delta)\left(\frac{K_t - (1-\mu)K_t(1)}{K_t}\right)$$

which corresponds to (12). In equilibrium, the last term is equal to zero in both E —where $K_t = (1-\mu)K_t(1)$— and A —where $r_t^\ell = -\delta$. Moreover, since $y_t = Y_t$ in the general equilibrium, (12) can be simplified to

$$r_t^k = \frac{\alpha}{(1-\tau)\mathscr{M}_t}\frac{Y_t}{K_t} - \delta$$

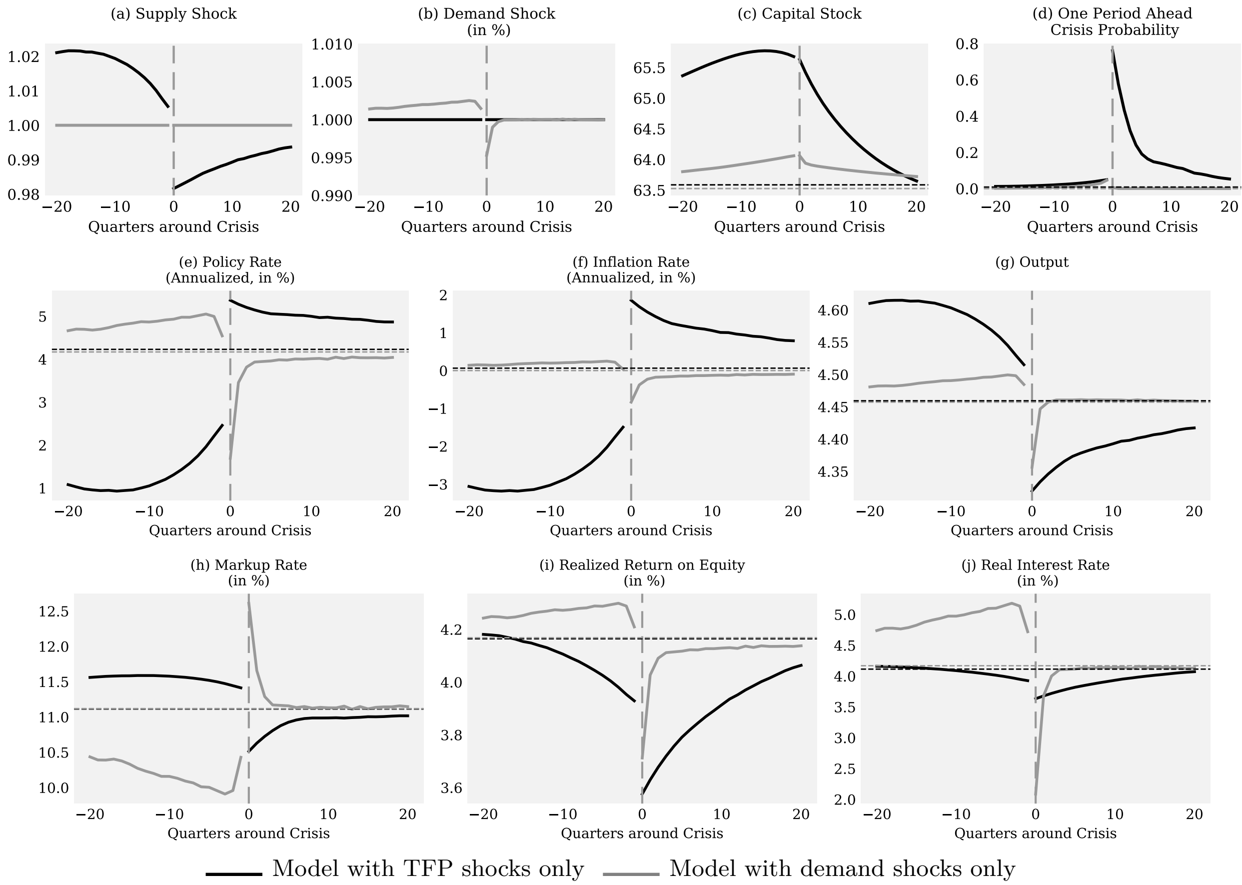
7.2 Equations of the model

The model can be summarized by the following equations:

1. $Z_t = \mathbb{E}_t\left\{\Lambda_{t,t+1}(1 + r_{t+1})\right\}$
2. $1 = \mathbb{E}_t\left\{\Lambda_{t,t+1}(1 + r_{t+1}^k)\right\}$
3. $\omega_t = \vartheta N_t^\nu C_t^\sigma$
4. $Y_t = A_t\left(\overline{q}_t K_t\right)^\alpha N_t^{1-\alpha}$
5. $\omega_t = \frac{(1-\alpha)Y_t}{(1-\tau)\mathscr{M}_t N_t}$
6. $r_t^k + \delta = \frac{\alpha Y_t}{(1-\tau)\mathscr{M}_t K_t}$
7. $(1+\pi_t)\pi_t = \mathbb{E}_t\left(\Lambda_{t,t+1}\frac{Y_{t+1}}{Y_t}(1+\pi_{t+1})\pi_{t+1}\right) - \frac{\epsilon - 1}{\varrho}\left(1 - \frac{\epsilon}{\epsilon - 1}\cdot\frac{1}{\mathscr{M}_t}\right)$
8. $1 + i_t = \frac{1}{\beta}(1+\pi_t)^{\phi_\pi}\left(\frac{Y_t}{Y}\right)^{\phi_y}$
9. $Y_t = C_t + K_{t+1} - (1-\delta)K_t$
10. $\overline{q}_t = 1$ if $r_t^k + \delta \geq \frac{(1-\delta)\mu}{1-\mu}$ and $1-\mu$ otherwise
11. $\Lambda_{t,t+1} \equiv \beta\frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}}$
12. $1 + r_t = \frac{1 + i_{t-1}}{1 + \pi_t}$

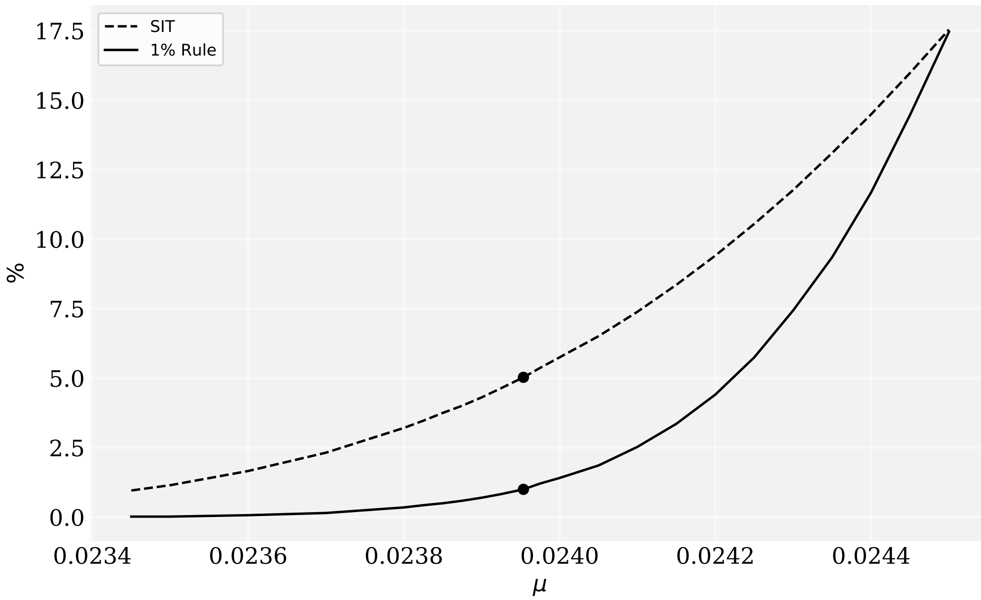
7.3 Additional figures

Figure 7.1: Typical path to crisis — Technology versus demand shocks



<u>Note:</u> Simulations for the STR economy. Average dynamics of the economy around the beginning of a new crisis (in quarter 0). To filter out the potential noise due to the aftershocks of past crises, we only report averages for new crises, *i.e.* crises that follow at least 20 quarters of normal times. The model is solved and simulated with either the technology or the demand shocks. The processes for these shocks are the same as in the baseline calibration. Panels (a) and (b) show the average dynamics of the technology and demand shocks. The horizontal lines correspond to the averages of the ergodic distributions.

Figure 7.2: Times spent in a crisis under SIT and IR-[0.415]



Notes: Percentage of time spent in a crisis under SIT and IR–[0.415] (y–axis) as financial frictions become more severe —keeping all else equal. The dots correspond to our calibrated model, with $\mu = 2.39\%$.