The Tradeoffs in Leaning Against the Wind

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Abstract

Credit booms sometimes lead to financial crises and subsequent severe and persistent economic slumps. So should monetary policy "lean against the wind" and counteract excess credit growth, or should it focus only on inflation and output stability? We study this issue quantitatively in a small New Keynesian dynamic stochastic general equilibrium model in which the risk of financial crises depends on "excess credit". We compare monetary policy rules responding to the output gap to rules that respond to excess credit. We find that responding to credit can lead to a lower average probability of financial crisis, at the cost of higher cyclical volatility in inflation and output. We discuss the factors that affect the desirability of leaning against the wind.

1 Introduction

Following the Global Financial Crisis of 2008, a consensus emerged that new prudential and regulatory policies are needed to promote financial stability. But the question of whether financial stability concerns also should play a role in the setting of monetary policy remains controversial. In this paper we investigate the wisdom of what has come to be known as “leaning against the wind” (LAW), that is having monetary policy react to perceived financial imbalances such as excess credit growth, which have been found empirically to predict financial crises.1

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1See Schularick and Taylor (2012).
One argument against LAW is that financial stability could be better delivered by an appropriate set of macroprudential policies, that is making prudential and regulatory policies respond to the state of the economy, which would leave monetary policy free to focus on its usual inflation and output stability objectives. While this separation is attractive in principle, we believe it is often difficult to implement practically (as recently explained by Dudley (2015)). Many countries such as the United States have a limited set of macro-prudential tools, and suffer from a dispersion of regulatory authorities. The tools are difficult and slow to adjust, and their effects remain fairly uncertain. Monetary policy has broad effects (it “gets in all the cracks” as Stein (2013) famously noted) while macro-prudential tools may be too narrow (e.g. they lead to a migration of activities from the regulated banking system to the unregulated shadow banking system). These considerations motivate our focus on monetary policy.

The second main argument against LAW is that under inflation targeting, stabilizing inflation is sufficient to stabilize the macroeconomy, as argued by Bernanke and Gertler (1999). Even if there is a trade-off, monetary policy has likely small effects on the likelihood of financial crises, so that having a meaningful effect on this likelihood would require a large interest rate change, at the cost of a large deviation of output and inflation relative to what could be achieved. This argument has been made most clearly by Svensson (2017a).

Our starting point is the evidence, emphasized even before the most recent crisis by Reinhart and Rogoff (2009) and Cerra and Saxena (2008), that recovery from a crisis is typically very slow, making the hangover from a crisis different from a regular recession. In particular, as Figure 1 suggests, in the aftermath of the most recent crisis U.S. per capita real GDP dropped sharply, and shows no sign of returning to the trend. As of 2017Q2, the per capita real GDP was about 13.7 percent below the pre-crisis trend. Subsequent studies since then have documented that financial crises have very persistent effects. Preventing a crisis may, therefore, bring different benefits than

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2 For instance, see Korinek and Simsek (2016) and Farhi and Werning (2016).
3 A distinct argument states that it is preferable to “mop up after the crash”, but this argument seems less compelling now in light of the difficulties in stabilizing the economy in the aftermath of the most recent financial crises - for instance, the zero lower bound and reduced potency of monetary policy when agents want to deleverage.
4 The log linear trend for per capita real GDP is estimated using 1985Q1-2007Q4 sample. The growth rate of per capita real GDP was much higher prior to the 1980s. For this reason, if we estimate the trend starting in 1947Q1, which is the first quarterly data point available, the difference between the last observation and the trend is 18.6 percent. Therefore we chose a shorter sample to be conservative. Blanchard, Cerutti, and Summers (2015) and Martin, Munyan, and Wilson (2015) show that long-lasting effect of financial crisis is a general feature found in most advanced economies.
those associated with smoothing out inefficient business cycle fluctuations (Barro (2009)). This consideration features prominently both in our analysis and in actual conduct of monetary policy. As Greenspan (2004) succinctly put it,

“[Policy practitioners operating a risk-management paradigm may, at times, be led to undertake actions intended to provide insurance against especially adverse outcomes.”

Our main contribution is to analyze the efficacy of LAW in a stylized dynamic stochastic general equilibrium (DSGE) model. We depart from the usual model in two ways. First, we follow Gourio (2013) and introduce a standard capital structure choice in which debt receives a tax subsidy, but creates the risk of costly bankruptcy (that is avoided for an all equity financed firm). Capital is accumulated by firms that face costs of issuing equity. We introduce a “financial shock” in this economy by assuming that the tax benefit varies over time. As we explain below, this is a shorthand for various forms of inefficient credit use. We view the tradeoff theory as providing a compact way to introduce variation in the use of debt financing (that could in fact arise for many reasons). The combination of the tax subsidy and the equity issuance costs leads the firms to over-rely on debt financing. In what follows we refer to the difference between the actual amount of credit and what would occur if there were no financial shocks (and prices were flexible) as “excess credit” or “inefficient credit”.

Our second modification is to introduce the possibility of a large financial crisis that can hit the economy. This is similar to the rare disasters that have received attention recently in the asset pricing literature. We assume that a financial crisis leads to a significant, permanent reduction in total factor productivity and a one-off shock to the capital stock. We view this modeling choice as a convenient device to capture the idea that financial crises lead to large and highly persistent declines in output and consumption, without taking a stand on the particular mechanism driving the persistence. Put differently, associating a permanent reduction in productive capacity with disaster-type crises is a simple shortcut to replicate the crisis dynamics of real GDP.

We study two types of crises. The first kind occurs exogenously, as in Gourio (2012) and Gourio (2013). The second supposes that the probability of the crisis depends on the amount of inefficient credit. By comparing the two alternatives, we can understand how the policy consequences may

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differ when leaning against the wind can change the likelihood of a crisis.

The model also allows for productivity and demand shocks that are present in most DSGE models. The centerpiece of the analysis is a comparison of different monetary policy rules that vary with respect to the signals on which the central bank’s policy rate is set. In our baseline, we compare policies that rely on perfectly measured variables and then in some extensions analyze what happens when the central bank must rely on imperfectly measured proxies. In this respect we follow in the long line of papers starting with Bernanke and Gertler (1999) and Gilchrist and Leahy (2002) that ask whether monetary policy should take account of asset price movements. A common conclusion in that literature is that after accounting for movements in inflation, and possibly output, there is no need to respond to asset prices. We explore whether the same conclusion holds in our environment.

Our main finding is that gains from responding to excess credit depend importantly on the relative importance of the various shocks hitting the economy and the nature of the financial crisis risk. In some versions of the model, for instance, when only productivity and demand shocks are present, the possibility of a crisis (endogenous or not) makes little difference for policy. In this environment, stabilizing inflation is optimal – a result that Blanchard and Gali (2007) dubbed
"divine coincidence". Loosely speaking, once the central bank eliminates demand shocks and accommodates productivity shocks, it can stabilize inflation and simultaneously control crisis risk to the extent possible. In this setup, even if financial crises are endogenous it will make little difference for the policy choices because the central bank’s control of demand will also control credit and limit crisis risk. This result is consistent with the previous literature, in particular Bernanke and Gertler (1999).

If financial shocks are present, when crises still occur exogenously, policies that ignore credit continue to perform better than ones that focus on credit. This finding reinforces the conclusion that the model does not automatically imply that inefficient credit movements must always be offset.

However, in our baseline model we assume that there are financial shocks and that they affect the probability of a crisis. The key result of the paper is that in that case, reacting systematically to excess credit lowers the average probability of financial crisis. Because crises are very costly, the optimal policy is willing to trade off leaning against the wind to reduce crisis risk against the costs of larger fluctuations in output and inflation. We emphasize that this result arises even though monetary policy is not a particularly powerful tool for managing the risk of financial crises. Moreover, the agents in our model are only moderately risk averse. Nonetheless, lowering the probability of financial crises brings large welfare gains because they are so costly.

We explore several variants of the baseline model to understand the features of the model that govern when LAW is preferred. In general, the more important are the financial shocks, the more risk averse are households, and the larger are the sizes of the crises, the stronger is the case for LAW. We describe these mechanisms in more detail below and provide a preliminary quantitative assessment.

The remainder of the paper proceeds as follows. In the next section, we provide a brief literature review. In section 3, we introduce the model. Most elements are very standard and are common to many New Keynesian models. In presenting the model, therefore, we concentrate on the two novel aspects mentioned above. Section 4 discusses the parameters used and examines basic properties of the model economy. Finally, in section 5, we compare the performance of a number of policy rules for different versions of the model, and illustrate how a number of alternative versions of the model perform. Section 6 concludes.
2 Literature Review

Smets (2014) provides an excellent survey of most of the research on leaning against the wind through 2014, so we summarize his main conclusions and then focus on a few notable papers written since his survey. Smets notes that the case for using monetary policy to promote financial stability depends in part on the availability and effectiveness of other tools. The paper then reviews a number of analyses, most notably Lim, Costa, Columba, Kongsamut, Otani, Saiyid, Wezel, and Wu (2011), that study the experience using macroprudential tools and reaches two important conclusions: that “the empirical literature tentatively supports the effectiveness of macroprudential tools in dampening procyclicality” and “to what extent such measures are effective enough to significantly reduce systemic risk is, however, as yet unclear.”

Given the ambiguity over whether financial stability can be delivered without appealing to monetary policy, the paper then turns to the question of what the evidence says regarding the effectiveness of monetary policy in limiting the build up of financial vulnerabilities. Here again the evidence is mixed. On the one hand, there are a variety of studies that link higher risk-taking by banks with looser monetary policy. Smets stresses that the risk-taking can occur on both the asset-side of the banks’ balance sheet as they reach for yield and through funding choices that entail extra reliance on short-term financing. He argues that although there is ample evidence of risk-taking, the question of whether actively using monetary policy to head it off creates too much collateral damage remains open. He cites several articles that suggest, for instance, that using monetary policy to forestall property price booms would have created a recession. Overall we read his paper as suggesting that there may be scope for leaning against the wind, but doing so would entail non-trivial risks.\footnote{Smets also stresses that if the central bank is given responsibility for financial stability and fails to achieve it, then the bank’s monetary independence could be compromised. Though as Peek, Rosengren, and Tootell (2015) mention, central banks that are simply acting as a lender of last resort can also face this kind of pressure.}

Perhaps the most prominent paper written after the Smets survey is Svensson (2017a). This paper provides a simple and transparent framework for evaluating LAW policies. It starts with empirical estimates of the effects of higher interest rates on the likelihood of a crisis (obtained by combining estimates of the effect of interest rates on credit, and of credit growth on the likelihood of crisis (Schularick and Taylor (2012))) and on inflation and output in the short run as well as the
cost of a financial crisis (a sharp, temporary recession). Svensson emphasizes that on the one hand, tighter policy reduces the risk of financial crises in the short-run but increases it later on since the effect of tighter policy works through the growth rate of credit (and the long-term level of real credit is assumed to be independent of monetary policy because of long-run neutrality). On the other hand, tighter policy reliably reduces growth and inflation in the short-run. Overall, the costs of slowing down the economy are much higher than the gains from only marginally reducing the risk of a crisis. Indeed, if one accounts for the fact that crises are to a certain extent inevitable and unavoidable, then a policy that steers the economy to be above potential during non-crisis periods is optimal. Hence, Svensson argues that a careful treatment of this problem calls for leaning with the wind.\footnote{Juselius, Borio, Disyatat, and Drehmann (2017) argue that one cost of low interest rates is an exacerbation of the financial cycle.}

The IMF 2015 staff study (IMF (2015)) reaches similar conclusions to Svensson. On their reading of the empirical literature, a 100 basis point increase in the central bank policy rate for one year is needed to reduce the probability of a crisis by only 0.02 percentage point per quarter. There is obviously much uncertainty around this estimate, but they argue that even using the largest reported estimates of a 0.3 percentage point reduction per quarter in crisis risk, the costs of a slowdown are likely to exceed the gains from preventing a crisis. Ajello, Laubach, Lopez-Salido, and Nakata (2016) similarly argue that the optimal response is small for the median estimate of the effect of monetary policy on risk of crisis, but may be significant if the policymaker takes into account the uncertainty surrounding the estimate, and focuses on the worst-case scenario.\footnote{See also Gerdrup, Hansen, Krogh, and Maih (2016) and Bauer and Granziera (2016) for recent studies of the effectiveness of monetary policy in LAW.}

Filardo and Rungcharoenkitkul (2016), in contrast, reach the opposite conclusion studying optimal monetary policy in an environment of recurring, endogenous financial booms and busts. In their environment leaning systematically over the whole cycle is justified because leaning not only influences the probability of a crisis, but also smooths the financial cycle, resulting in less virulent boom and bust episodes. The optimal monetary policy in this setting calls for progressively stronger leaning as financial imbalances grow but reducing the degree of leaning against the wind as a crisis becomes imminent. The persistence of the financial cycle and the degree to which monetary policy influences the amplitude and duration of booms and busts are key distinguishing features of the
modelling approach.\footnote{Filardo and Rungcharoenkitkul (2016) solve for the optimal nonlinear policy rule using collocation method. This allows the intensity of leaning to change with the level of financial imbalances. Linear rules do not permit this possibility.}

Our approach cannot be mapped directly into the Svensson style calculation. There are several critical differences. First, in terms of methodology we optimize a policy rule in a DSGE model while Svensson conducts a one-time cost/benefit analysis. Second, our objective function is utility while he bases his analysis on a quadratic loss function.\footnote{While representative agent based welfare calculations can be criticized, there is no reason to believe that it biases our results in a particular direction.} Third, we model crises as permanent effects on output while he considers them a temporary “gap” in unemployment or output. For instance, in our benchmark calculation the level of output drops by 10 percentage points in a crisis. Svensson assumes a five percentage points increase in unemployment for two years followed by a return to normal. The total loss in output in his baseline is, therefore, much smaller than in ours. Below we show that with much smaller crises a LAW policy is not welfare improving.

Finally, there is a difference between the way the models approach long-run monetary neutrality. In our model, monetary policy shocks have only transient effects on credit and other variables, similar to Svensson. But Svensson’s specification implies that lower credit growth reduces the probability of crisis in the short-run before increasing it in the medium run. In our model, LAW can deliver a lower probability throughout.

Svensson (2017b) attempts to reconcile the calculations of Svensson (2017a) with ours. In particular, he describes how (and when) in his framework it is possible for LAW to be desirable by pointing out two types of cost associated with LAW: the weaker economy prior to financial crises and the weaker economy during financial crises due to LAW. Svensson (2017b) emphasizes that in our model, the cost of a crisis is independent of monetary policy. It is true that the decline of output during a crisis is independent of monetary policy in our model. However, if a crisis strikes during a recession that is induced by LAW, then the level of output is lower than if LAW had not been pursued. So our model embodies both types of costs contemplated by Svensson (2017b). Hence, the differences between his findings and ours are instead due to the various other factors described above. Of course, our conclusions are not fully general and depend on a number of model properties that we will highlight. For instance, the finding that model features such as risk-aversion could be important in assessing the efficacy of LAW may not be surprising, but within the Svensson
IMF (2015), like Smets, questions whether monetary policy is the right tool to address these problems and proposes a three part test that should be considered before monetary policy should be used to lean against the wind. First, are financial risks in the economy excessive? If they are not, then adjusting monetary policy is unnecessary. Second, can other tools, particularly macroprudential ones, be used instead of monetary policy? Finally, will monetary policy, if set in a conventional fashion based on inflation and output developments, take care of financial stability concerns?

Our model allows us to partially address two of the three considerations. We suppose that monitoring financial risks is challenging. Inefficient credit movements may not be observable, so we can study policies that can only be based on noisy indicators of financial risk. Our model has multiple shocks, so we can also study which ones give rise to scenarios where there is a genuine tradeoff between managing the near term inflation and output fluctuations and preventing crises; as will be clear, there are some shocks where a standard inflation targeting central bank will contain financial risks just as a by-product of following its mandate.

We do not discuss macroprudential tools. Partly, this is a tractability issue. There is no consensus model that integrates macroprudential policy levers in a standard monetary model. As Smets (2014) emphasizes even the empirical evidence how this might work is mixed. Developing that kind of framework is beyond the scope of our paper.

More importantly, in many countries the scope for deploying macroprudential tools is limited. The case study developed by Adrian, de Fontnouvelle, Yang, and Zlate (2015) highlights some of the challenges in the U.S. context. In their hypothetical scenario, that they dub a “tabletop exercise”, the Federal Reserve is facing a situation where commercial real estate prices are rising sharply, while its inflation and employment objectives are close to being met. Most of the funding fueling the boom are coming from small banks and through capital markets (via securitization). When confronted with this scenario, the four Federal Reserve Bank Presidents who were attempting to implement policies to manage the situation concluded that “from among the various tools considered, tabletop

11 For instance, in the Svensson (2017b) calculations a small change in the probability of a crisis is viewed as inconsequential. The utility based calculations suggest that this is not necessarily the case.

12 This funding constellation matters because in the U.S. the central bank can use some tools, such as stress tests, to steer decisions for very large banks. Restricting the behavior of small banks and stopping securitization is more difficult.
participants found many of the prudential tools less attractive due to implementation lags and limited scope of application. Among the prudential tools, participants favored those deemed to pose fewer implementation challenges, in particular stress testing, margins on repo funding, and supervisory guidance. Nonetheless, monetary policy came more quickly to the fore as a financial stability tool than might have been thought before the exercise.”

3 Model

The model economy consists of a representative household, a continuum of monopolistic competitors, a representative investment good producer, and a continuum of financial intermediaries that hold capital financed by debt and equity. All firms, including the intermediaries are owned by the household and therefore discount future cash flow using the stochastic discount factor of the representative household.

3.1 Households

The preferences of the representative household are

$$\mathbb{E}_t \sum_{s=t}^{\infty} \beta^{s-t} U(C_s, N_s)$$

where

$$U(C_t, N_t) = \frac{C_t^{1-\tau}}{1-\tau} - \frac{N_t^{1+\upsilon}}{1+\upsilon}. \quad (1)$$

The household consumption bundle is made up of differentiated products,

$$C_t = \left( \int_0^1 C_t(i)^{1-\eta} di \right)^{1-\eta}.$$

The dual problem of cost minimization gives rise to a good-specific demand,

$$C_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\eta} C_t$$

where

$$P_t \equiv \left[ \int_0^1 P_t(i)^{1-\eta} di \right]^{1/(1-\eta)}.$$
The representative household earns wage income \((w_t N_t)\), and receives the profits of intermediate-goods firms \((\Pi_t^F)\) and the profits of financial intermediaries \((\Pi_t^I)\). The investment good producer makes zero profits due to perfect competition and constant returns to scale. The household saves by holding securities issued by financial intermediaries and government bonds \((B_t^G)\), which are in zero net-supply. The bonds issued by the intermediaries are unsecured and risky. We denote the price of a bond by \(q_t\). If the bond issuer avoids default, the bond yields one unit of consumption tomorrow. In default, the household receives a partial payment. Since there are a continuum of issuers, the law of large number applies and the household can form rational expectations about how many bonds fail and how many deliver the promised payment. We denote the probability of default by \(H_t\) and the average recovery rate conditional upon default by \(R^D_t\). We can then express the budget constraint of the household as

\[
C_t = w_t N_t + \Pi_t^F + \Pi_t^I - q_t B_t + [(1 - H_t) + H_t R^D_t] B_{t-1} + \frac{R_{t-1}}{\Pi_t} B_{t-1}^G - B_t^G. \tag{2}
\]

We denote the Lagrange multiplier associated with the budget constraint by \(\Lambda_t\). The household’s efficiency conditions are summarized as:

\[
C_t : \Lambda_t = U_C(C_t, N_t), \tag{3}
\]

\[
N_t : \Lambda_t w_t = -U_N(C_t, N_t), \tag{4}
\]

\[
B_t^G : 1 = \beta E_t \left[ \frac{\Lambda_{t+1}}{\Lambda_t} \frac{R_{t+1}}{\Pi_{t+1}} \right] \tag{5}
\]

and \(\Pi_{t+1} = P_{t+1}/P_t\), gross inflation rate.

\[
B_t : q_t = \beta E_t \left[ \frac{\Lambda_{t+1}}{\Lambda_t} ((1 - H_{t+1}) + H_{t+1} R^D_t) \right] \tag{6}
\]

A few remarks are in order. First, the two static FOCs together also imply the following efficiency condition.

\[
w_t = \frac{-U_N(C_t, N_t)}{U_C(C_t, N_t)}. \tag{7}
\]
Second, we assume that the economy is subject to the risk premium shock as in Smets and Wouters (2007). Following Fisher (2015), we interpret this as the shock to the demand for safe assets. We denote the shock by $\Xi_t$ and modify the first-order-condition (FOC) to be

$$1 = \beta E_t \left[ \frac{\Lambda_{t+1}}{\Lambda_t} \Xi_t \frac{R_{t+1}}{\Pi_{t+1}} \right].$$

(8)

These shocks do not affect the flexible economy and hence are an inefficient source of business cycle fluctuations.

Third, the FOC for intermediary bond holding plays the role of the pricing equation for intermediary problem. We will provide more details on this, including the determinants of the recovery rate $R_D^t$, when we discuss the intermediary’s problem. For later purposes, we define the stochastic discount factor of the household as

$$M_{t,t+1} \equiv \beta \frac{\Lambda_{t+1}}{\Lambda_t}.$$  

(9)

### 3.2 Investment Goods Producers

We assume that there exists a continuum of competitive firms indexed by $k \in [0, 1]$. These firms produce an identical composite good $I_t$ using a linear technology subject to an adjustment cost related to the change in the level of investment. We parameterize the costs to be $\frac{\kappa}{2} \left( I_t/I_{t-1} - 1 \right)^2 I_{t-1}$. The composite good $I_t$ is sold at a price $Q_t$ and is used in the production of capital. Production of the composite good requires the use of all varieties of intermediate goods. Since the industry is competitive, the size of an individual firm is indeterminate. Hence we assume a representative firm that is a price taker. The profit maximization problem of the investment goods producers can be cast as choosing the input level given the cost of adjusting the level of investment, i.e.,

$$\max_{I_s} \mathbb{E}_t \sum_{s=t}^{\infty} M_{t,s} \left\{ Q_s I_s \left[ I_s + \frac{\kappa}{2} \left( \frac{I_s}{I_{s-1}} - 1 \right)^2 I_{s-1} \right] \right\}.$$ 

The FOC of the problem is given by

$$Q_t = 1 + \kappa \left( \frac{I_t}{I_{t-1}} - 1 \right) - \mathbb{E}_t \left\{ M_{t,t+1} \frac{\kappa}{2} \left[ \left( \frac{I_{t+1}}{I_t} \right)^2 - 1 \right] \right\}. \quad (10)$$

\[13\] In this interpretation, the shock $\Xi_t$ can be viewed as a disturbance to demand for money and hence can also be thought of as shifting nominal aggregate demand.
3.3 Retailers

There exists a continuum of monopolistic competitors indexed by $i \in [0, 1]$. These retailing firms combine labor and capital using a Cobb-Douglas production technology

$$Y_t(i) = Z_t K_t(i)^\alpha N_t(i)^{1-\alpha}$$

where $Z_t$ is the aggregate technology. Following Rotemberg (1982), we assume that the retailers face quadratic costs of adjusting prices

$$\frac{\varphi}{2} \left( \frac{P_t(i)}{P_{t-1}(i)} - 1 \right)^2 Y_t = \frac{\varphi}{2} \left( \Pi_t \frac{p_t(i)}{p_{t-1}(i)} - 1 \right)^2 Y_t,$$

where $p_t(i) \equiv P_t(i)/P_t$ and $\Pi_t \equiv P_t/P_{t-1}$ is aggregate inflation. Hence, the firm’s static profit is given by

$$\Pi_t(i) = p_t(i)Y_t(i) - w_t N_t(i) - r_t^K K_t(i) - \frac{\varphi}{2} \left( \frac{p_t(i)}{p_{t-1}(i)} \Pi_t - 1 \right)^2 Y_t,$$

where $w_t \equiv W_t/P_t$ is the real wage. The retailers are owned by the representative household, and hence discount future cash flow using the stochastic discount factor of the household. Prices are set to maximize the present value of expected profits:

$$\mathcal{L} = E_t \sum_{s=t}^{\infty} M_{t,s} \{ \Pi_s(i) + \mu_s(i) [Z_s K_s(i)^\alpha N_s(i)^{1-\alpha} - Y_s(i)] + \nu_s(i) [p_s(i)^{-\eta} Y_s - Y_s(i)] \}$$

where $\nu_s(i)$ and $\mu_s(i)$ are the shadow values of the demand constraint and technological constraints.

The efficiency conditions in a symmetric equilibrium (where all firms choose identical relative prices) are:

$$w_t = (1 - \alpha) \mu_t \frac{Y_t}{N_t}, \quad (11)$$

$$r_t^K = \alpha \mu_t \frac{Y_t}{K_t}, \quad (12)$$

$$\nu_t = 1 - \mu_t \quad (13)$$
and

\[ 0 = 1 - \varphi \Pi_t (\Pi_t - 1) - \eta \nu_t + \varphi \mathbb{E}_t \left[ M_{t,t+1} \Pi_{t+1} (\Pi_{t+1} - 1) \frac{Y_{t+1}}{Y_t} \right]. \] (14)

### 3.4 Financial Intermediaries

This part of the model follows the setup in Gourio (2013). We assume that there exists a continuum of financial intermediaries indexed by \( s \in [0, 1] \). The financial intermediaries combine debt and equity to invest in physical capital. From now on we omit the intermediary index.

If intermediary invests \( Q_t K_{t+1} \) at time \( t \), then at time \( t + 1 \) its return on the asset will be

\[ \varepsilon_{t+1} R_{t+1}^{K} = \varepsilon_{t+1} \frac{R_{t+1}^{K} + (1 - \delta) Q_{t+1}}{Q_t}, \]

where \( \varepsilon_{t+1} \) is an idiosyncratic risk associated with the intermediary. The shocks are i.i.d. across time and producers, have a cdf \( H(\cdot) \), and a pdf \( h(\cdot) \). (Below we assume that \( \varepsilon_{t+1} \) follows a lognormal distribution, \( \log \varepsilon_{t+1} \sim N(-0.5\sigma^2, \sigma^2) \)).

The intermediary here can be thought of integrating a set of financially unconstrained borrowers with a banking system. In a more complete set up where even borrowers are subject to financial constraints, we could have richer financial accelerator mechanism that comes both from the borrowers and the lenders. Here we collapse the actors together so that when the banks expand, they directly create more physical capital (as in Gertler and Karadi (2011)).

The choice of debt vs. equity is driven by the standard trade-off model from corporate finance. For now, we assume that debt is set in real terms\(^{14}\) and has a tax advantage \( \chi_t > 1 \). This means that for each unit of debt issued at time \( t \), the corporation receives a subsidy equal to \( \chi_t - 1 > 0 \). This subsidy is a stand-in for many considerations that make debt issuance attractive. For instance, it is commonly argued that the presence of debt is beneficial as it gives stronger incentives on managers to maximize profits, and to avoid engaging in empire building. So one can view \( \chi_t \) as a shortcut that captures the “agency benefits” of debt. On the other hand, if there are no benefits to debt but simply issuance costs, \( \chi_t \) could be less than unity. Critical for our purpose is the assumption that \( \chi \) varies over time. One could also think of \( \chi \) varying because of unmodeled changes in the ease of placing debt issues. The intermediary’s problem is to choose capital and debt (and hence

\(^{14}\)This is innocuous since our financial crises will not have deflation, so changing this assumption would not materially affect the results.
equity) to maximize its expected present discounted value.

We also assume that the issuance of equity is costly and that the cost per-unit of equity issuance is an increasing function of the equity share relative to the size of the project:

$$\gamma_t = \gamma \left( \frac{S_t}{Q_t K_{t+1}} \right), \quad \gamma(0) = 0, \quad \gamma'(\cdot) \geq 0 \text{ and } \gamma''(\cdot) \geq 0$$

where $S_t$ is equity issuance today. The maximization problem of the intermediary can then be expressed as

$$\max_{B_{t+1}, S_t, Q_t, K_{t+1}} \mathbb{E}_t \left[ M_{t, t+1} \max \{ V_{t+1} - B_{t+1}, 0 \} \right] - \left[ 1 + \gamma \left( \frac{S_t}{Q_t K_{t+1}} \right) \right] S_t,$$

(15)

where $V_{t+1} = \varepsilon_{t+1} R^K_{t+1} Q_t K_{t+1}$ is the value at time $t+1$. The maximization is subject to the funding constraint:

$$Q_t K_{t+1} = \chi_t q_t B_{t+1} + S_t,$$

(16)

where $q_t$ is the price of the bonds and the debt pricing equation is given by

$$q_t B_{t+1} = \mathbb{E}_t \left[ M_{t, t+1} \left( 1 + \Omega(\varepsilon_{t+1}^* \frac{V_{t+1}}{B_{t+1}} + 1_{V_{t+1} \geq B_{t+1}}) \right) \right].$$

(17)

$1_{V_{t+1} < B_{t+1}}$ is a dummy indicating default, and $\zeta$ is the recovery rate. The intermediary chooses its debt and capital, recognizing that higher leverage will lead to lower bond prices.

To derive the efficiency conditions of the problem, first, we rewrite the bond pricing function as

$$q_t B_{t+1} = \mathbb{E}_t \left[ M_{t, t+1} \Omega(\varepsilon_{t+1}^* \frac{R^K_{t+1} Q_t K_{t+1}}{B_{t+1}} + 1 - H(\varepsilon_{t+1}^*)) B_{t+1} \right],$$

(18)

where $\Omega(x) \equiv \int_0^x \varepsilon dH(\varepsilon) = x h(\varepsilon)$, and $\varepsilon_{t+1}^* \equiv \frac{B_{t+1}}{R^K_{t+1} Q_t K_{t+1}}$, i.e., the default threshold.\footnote{This equation assumes that the producer only maximizes its one-period ahead value. It is easy to see that this corresponds to maximizing its long-term value because the present value of rents is zero due to free entry.} Substitut-\footnote{Note that the recovery rate that appears in the household problem can be expressed as $R^K_{t+1} = \frac{\Omega(\varepsilon_{t+1}^*) \zeta R^K_{t+1} Q_t K_{t+1}}{H(\varepsilon_{t+1}^*) B_{t+1}}$.}
ing (16) and (18) into (15), we re-express the objective function as

$$\max_{B_{t+1}, K_{t+1}} \mathbb{E}_t M_{t+1}[(1 - (1 - \chi_t)\Omega(\epsilon^*_{t+1})) - (1 - \chi_t)(1 - H(\epsilon^*_{t+1}))\epsilon^*_{t+1}] R^K_{t+1} Q_{t+1} K_{t+1}$$

(19)

$$- Q_{t+1} K_{t+1} \left[1 + \gamma \left(\frac{S_t}{Q_{t+1} K_{t+1}}\right) \frac{S_t}{Q_{t+1} K_{t+1}}\right]$$

Dividing (18) by the size of the balance sheet $Q_{t+1} K_{t+1}$, we define

$$L \left(\frac{B_{t+1}}{Q_{t+1} K_{t+1}}\right) \equiv \frac{q_t B_{t+1}}{Q_{t+1} K_{t+1}} = \mathbb{E}_t M_{t+1} \left[\Omega(\epsilon^*_{t+1})\zeta R^K_{t+1} + (1 - H(\epsilon^*_{t+1}))\epsilon^*_{t+1} R^K_{t+1}\right].$$

(20)

Using (16) and (20), we transform the second line of (19) into an expression that does not depend on the amount of equity:

$$Q_{t+1} K_{t+1} \left[1 + \gamma \left(\frac{S_t}{Q_{t+1} K_{t+1}}\right) \frac{S_t}{Q_{t+1} K_{t+1}}\right] = Q_{t+1} K_{t+1} \left[1 + \gamma \left[1 - \chi_t L \left(\frac{B_{t+1}}{Q_{t+1} K_{t+1}}\right)\right]\left[1 - \chi_t L \left(\frac{B_{t+1}}{Q_{t+1} K_{t+1}}\right)\right]\right]$$

$$\equiv Q_{t+1} K_{t+1} \Gamma \left(\frac{B_{t+1}}{Q_{t+1} K_{t+1}}\right).$$

Importantly, $\Gamma(B_{t+1}/Q_{t+1} K_{t+1})$ depends only on leverage and not separately on $Q_{t+1} K_{t+1}$. Hence, the FOC for capital can be expressed as

$$1 = \Gamma \left(\frac{B_{t+1}}{Q_{t+1} K_{t+1}}\right)^{-1} \mathbb{E}_t \left(M_{t+1} R^K_{t+1} \lambda_{t+1}\right)$$

(21)

where

$$\lambda_{t+1} = 1 + (\chi_t - 1) \epsilon^*_{t+1} (1 - H(\epsilon^*_{t+1})) - (1 - \zeta \chi_t) \Omega(\epsilon^*_{t+1}).$$

(22)

The (privately) efficient level of leverage is determined by

$$0 = \mathbb{E}_t M_{t+1} \left[(\chi_t - 1)(1 - H(\epsilon^*_{t+1})) - (1 - \chi_t \zeta)\epsilon^*_{t+1} h(\epsilon^*_{t+1}) - (\chi_t - 1)\epsilon^*_{t+1} h(\epsilon^*_{t+1})\right] - \Gamma' \left(\frac{B_{t+1}}{Q_{t+1} K_{t+1}}\right).$$
This expression can be shown to be equivalent to

$$
\mathbb{E}_t \{ M_{t+1} (1 - H (\varepsilon_{t+1}^*)) \left[ \frac{X_t - 1}{X_t} + \gamma \left( \frac{S_t}{Q_t K_{t+1}} \right) + \gamma' \left( \frac{S_t}{Q_t K_{t+1}} \right) \right] \}
$$

$$
= (1 - \zeta_t) \mathbb{E}_t \{ M_{t+1} \varepsilon_{t+1}^* h (\varepsilon_{t+1}^*) \left[ 1 + \gamma \left( \frac{S_t}{Q_t K_{t+1}} \right) + \gamma' \left( \frac{S_t}{Q_t K_{t+1}} \right) \right] \}. \tag{23}
$$

### 3.5 Financial Crises

We now describe how we introduce financial crises into the model. We assume that aggregate technology $Z_t$ evolves over time as the sum of a standard AR(1) shock and a unit root process affected by rare downward jumps:

$$
Z_t = Z_r^t Z_p^t, \quad \log Z_r^t = \rho \log Z_r^{t-1} + \sigma \varepsilon_{Z,t}, \quad \frac{Z_p^{t+1}}{Z_p^t} = e^{-X_{t+1} b c}, \tag{24}
$$

where $X_{t+1}$ is the “financial crisis” shock; specifically $X_{t+1} = 0$ with probability $1 - p_t$ an $X_{t+1} = 1$ with probability $p_t$. When a crisis occurs, the level of technology drops by $b_c$ percent. We assume the following reduced-form law of motion for the probability of a crisis:

$$
\log p_t = b_0 + b_1 \log (B_t / B_t^f) \tag{25}
$$

where $B_t^f$ is the level of credit that prevails in an economy without price distortions and financial shocks. Our specification supposes that the probability of a crisis is an increasing function of the level of inefficient credit. This framework directly implies an “externality” since higher debt increases the probability of a crisis, which is not internalized by financial intermediaries.\(^\text{17}\) We refer to this as “inefficient credit” and hence implicitly assume that the steady-state distortion that favors debt (that, is the steady-state tax subsidy $\chi > 1$) does not create a risk of financial crisis. 

We also assume that the capital accumulation process is affected by the financial crisis in the

\(^{17}\) While this is a convenient short-cut, Cairo and Sim (2016) provides a structural model that delivers the same prediction. In order to study the relationship between price stability and financial stability, Cairo and Sim (2016) endogenize the production and income distribution in the financial crisis model of Kumhof, Ranciere, and Winant (2015). Cairo and Sim (2016) also allows for nominal rigidities and labor market frictions. Cairo and Sim (2016) shows that in this structural model of financial crisis, the correlation between debt and the probability of financial crisis is as high as 0.92. This is one way to justify our reduced form specification for the crisis risk.
same fashion: financial intermediaries invest $I_t$ and “expect” to obtain

$$K^w_t = (1 - \delta)K_t + I_t,$$

but their capital stock that is realized at beginning of time $t + 1$ is actually

$$K_{t+1} = K^w_t e^{-X_{t+1}b_c}.$$

That is, in the (unlikely) event of a financial crisis, the capital stock is not what the intermediaries expected it to be. This amounts to assuming a “capital quality” shock that is perfectly correlated with the productivity shock. This assumption is made largely for technical reasons in our case: it allows using a simpler solution method as we explain below.

Finally, we further assume that the utility function is affected by a crisis realization. We do this because the preferences we use are not compatible with balanced growth, so that a one-time decline in productivity may lead to a change in hours. For tractability, we assume that

$$U(C_t, N_t) = \frac{C_t^{1-\tau}}{1-\tau} - J_t^{1-\tau} \frac{N_t^{1+\nu}}{1+\nu},$$

where $J_t$ is the cumulative disaster effect,

$$J_t = e^{-X_{t}b_c} J_{t-1}.$$

We then redefine variables by detrending by $Z_t$, e.g. $\bar{Y}_t = Y_t/Z_t$, etc. Under the assumptions above, the system of equations of detrended variables does not depend on $X_t$. That is, the detrended system has no jumps. This implies that it can be solved using standard perturbation techniques. For the details of transforming the original system of equations into the detrended system, see the appendix. Also see Gourio (2012), Isoré and Szczerbowicz (2015) and Gabaix (2011) for detailed detrending methodology for this kind of model.\(^{18}\)

\(^{18}\)Note that we also need to assume that financial crisis affects the investment goods production function so that the producer’s adjustment cost is not affected by the disaster realization.
### Table 1: Structural Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Interpretation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>Discount factor</td>
<td>0.99</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Equity issuance cost parameter</td>
<td>0.167</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Capital’s share in production</td>
<td>0.36</td>
</tr>
<tr>
<td>$\tau$</td>
<td>Constant relative risk aversion</td>
<td>2</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>Investment adjustment cost</td>
<td>5</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Depreciation rate</td>
<td>0.025</td>
</tr>
<tr>
<td>$\eta$</td>
<td>Elasticity of substitution between goods</td>
<td>2.0</td>
</tr>
<tr>
<td>$\bar{\chi}$</td>
<td>Steady state tax benefit</td>
<td>1.005</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>Recovery rate on defaulted bonds</td>
<td>0.50</td>
</tr>
<tr>
<td>$\upsilon$</td>
<td>Inverse of the Frisch elasticity of labor supply</td>
<td>1/3</td>
</tr>
<tr>
<td>$\Pi$</td>
<td>Gross inflation rate target</td>
<td>1</td>
</tr>
<tr>
<td>$\varphi$</td>
<td>Price adjustment cost</td>
<td>130</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Idiosyncratic volatility of intermediary returns</td>
<td>0.2007</td>
</tr>
<tr>
<td>$p_{ss}$</td>
<td>Average probability of financial crises</td>
<td>0.005</td>
</tr>
<tr>
<td>$b_1$</td>
<td>Effect of credit deviations on log crisis probability</td>
<td>5</td>
</tr>
<tr>
<td>$b_c$</td>
<td>Size of output drop in financial crises</td>
<td>0.10</td>
</tr>
<tr>
<td>$\rho_Z$</td>
<td>Persistence of the technology shock</td>
<td>0.90</td>
</tr>
<tr>
<td>$\rho_\chi$</td>
<td>Persistence of the financial shock</td>
<td>0.90</td>
</tr>
<tr>
<td>$\rho_{\Xi}$</td>
<td>Persistence of the demand shock</td>
<td>0.90</td>
</tr>
<tr>
<td>$\sigma_Z$</td>
<td>Volatility of the technology shock</td>
<td>0.01</td>
</tr>
<tr>
<td>$\sigma_\chi$</td>
<td>Volatility of the financial shock</td>
<td>0.0097</td>
</tr>
<tr>
<td>$\sigma_{\Xi}$</td>
<td>Volatility of the demand shock</td>
<td>0.0035</td>
</tr>
</tbody>
</table>

### 4 Basic model properties

We first discuss the parameters used for our model, then illustrate the model dynamics using impulse response analysis.

#### 4.1 Calibration

Table 1 summarizes the calibration of the model parameters. Given that we have a quarterly model, the assumed time discount factor of $\beta = 0.99$ implies an annual real rate of 4 percent. Capital’s share in production, $\alpha$, is set equal to 0.36 as is standard in the literature. The depreciation rate, $\delta$, is calibrated equal to 0.025. We set investment adjustment cost $\kappa$ equal to 5 to produce reasonable investment volatility.

We assume risk aversion of 2 and an inverse Frisch elasticity of labor supply of 1/3. The elasticity of substitution between goods, $\eta$, is set to 2, which is consistent with the results in Broda and Weinstein (2006). Given this choice, we set the price adjustment cost, $\varphi$, to be 130 in order to match the fact that micro studies suggest that prices adjust about once a year.

We set the “tax benefit” parameter to a relatively low value of $\bar{\chi} = 1.005$. This reflects the
earlier discussion that debt incurs issuance costs as well as tax benefits. We choose the bankruptcy cost of default, $\zeta$, to be 0.5. This value allows us to match the recovery rate on U.S. corporate bonds that default. For the equity issuance costs, we assume a quadratic form:

$$\gamma \left( \frac{S_t}{Q_t K_{t+1}} \right) = \bar{\gamma} \left( \frac{S_t}{Q_t K_{t+1}} \right)^2.$$  

We next calibrate $\sigma$ and $\bar{\gamma}$ (the volatility of idiosyncratic shocks to firms and the equity issuance cost) to match a probability of default of 15% per year and average value for leverage of around 0.65. This implies that $\sigma = 0.2007$ and $\bar{\gamma} = 0.167$.

The steady state probability of a financial crisis is set to 2% per year or 0.5% per quarter, corresponding to two crises per century. The size of the output drop is set to 10%. This number is significantly smaller than the values typically used in the asset pricing literature on disasters. This number is also smaller than the recent U.S. experience, as discussed in the introduction. The sensitivity of the financial crisis probability to excess credit is 5, so that a 20% increase in inefficient credit doubles the probability of financial crisis. We study extensively the sensitivity of our results to each of these parameters.

For the aggregate shock processes, we take an agnostic approach and set all the persistence parameters equal to 0.9. We calibrate the standard deviation of technology shock to equal to 0.01. We then choose the other shock volatilities so that the variance decomposition of output can be allocated to technology shock, demand shock and financial shock with 42.5%, 42.5% and 15% shares, respectively. The 15% share for financial shocks is at the lower end of the estimates implied by Christiano, Ilut, Motto, and Rostagno (2010) and Fuentes-Albero (2014). We study the sensitivity of the results to the importance of the financial shocks as well.

### 4.2 Model Properties With a Standard Policy Rule

As a first step, we illustrate how our model economy behaves in response to the three fundamental impulses that we consider - a productivity shock, an aggregate demand shock, and the financial shock. As a further diagnostic we also report the effect of a monetary policy shock. To solve the
model, we assume a standard inertial Taylor (1999) rule:

$$R_t = 0.85 \times R_{t-1} + 0.15 \times (R^* + 1.5 \times (\pi_t - \pi^*) + \tilde{y}_t)$$  \hspace{1cm} (26)$$

where $\tilde{y}_t$ is the output gap,\(^{19}\) and $\pi_t$ is the year-over-year inflation rate. We summarize the main mechanisms in the model by explaining what happens to output, investment, inflation, debt, the policy rate, and the probability of a crisis.

A productivity shock, shown in Figure 2, leads to higher output and lower inflation as is common in New Keynesian models. The policy rule leads the central bank to cut the policy rate but not sufficiently to stabilize inflation or to allow output to rise in line with potential. Put differently, lower inflation reflects the decline in current and future marginal costs that arise from higher productivity and the fact that monetary policy does not bring demand in line with this higher supply.

\(^{19}\)We define this gap to be the difference between the level of output and the one that would prevail in an economy without nominal rigidities and without financial shocks.
The output surge leads to higher borrowing to finance investment, but because output does not keep up with the growth in potential, credit actually rises less than in the frictionless benchmark. As a result, the annualized probability of crisis falls modestly (by 4 basis points, so that the probability drops from 2% per year to 1.96%).

The response to a positive demand shock is shown in Figure 3. The demand shock leads to higher output and inflation; the shock also leads to a higher policy rate, but the assumed policy rule does not respond enough to offset completely the effects of the shock. The output boom leads to higher debt and a higher risk of a financial crisis. Since the shock does not affect the flexible economy and the credit thereof, the increase in the probability of a crisis is sizable.

Next, in Figure 4, we show the effect of a financial shock, which would have no effect on the flexible price economy. This type of shock leads to a large expansion of credit which reduces the user cost of capital and leads to a boom in investment and, to a lesser extent, also in output. The lower user cost feeds through to lower inflation, generating mark-up shock like phenomenon. The spike in debt (that is permitted with this policy rule) significantly increases the risk of financial
crisis, from 2% per year to 2.37% per year.

Finally we illustrate how a “monetary shock” affects this model economy. Although we are most interested in optimal monetary policy rules, showing the impact of a deviation from the rule is informative about certain aspects of the model. Figure 5 displays the responses of our main variables to a 100 basis point (1%) cut in the policy rate. One important takeaway from the figure is that the shock leads to an increase in output and inflation. The output increase leads to a surge in credit and hence the probability of crisis. This suggests that if the central bank is keen on keeping the probability of financial crises low, it may want to raise the monetary policy rate in response to the rise of credit gap after a positive financial shock hits the economy.

An important conclusion from this exercise is that the sensitivity of the risk of crisis to an increase in the policy rate is by no means extreme - this fairly large monetary shock only generates on impact a increase of 8 basis points in the annual probability of crisis, i.e. moving it from 2% to 2.08%. This is magnitude of the change is consistent with the empirical estimates reviewed by IMF (2015). We share the view of IMF (2015) that these estimates are quite uncertain, but it
is important to note that our subsequent conclusions about the desirability of leaning against the
wind are not driven by a presumption that monetary policy has powerful effects on the risk of a
crisis.

5 Optimal simple rules

Having established the basic model properties, we consider policy rules that specify the interest
rate as a function of last period’s interest rate, inflation, the output gap and/or the “credit gap”,
that is, \( B_t / B^f_t \), the deviation of credit from the level that would prevail with only productivity
shocks when prices are flexible.\(^{20}\) Previous research shows that such rules typically perform well
in models like ours. Because real time measurement of the output and credit gaps is difficult, we
also study rules that rely on imperfectly measured version of these variables, namely deviations of

\(^{20}\)Such a policy rule is consistent with Federal Reserve Reform Act of 1977, which states that “the Board of
Governors of the Federal Reserve System and the Federal Open Market Committee shall maintain long run growth
of the monetary and credit aggregates commensurate with the economy’s long run potential to increase production”
output and credit from their steady state values.\textsuperscript{21} Our goal is to establish the conditions when responding to credit is or is not beneficial. The benchmark for comparisons is the welfare of a representative consumer. This consumer cares not only about the usual fluctuations in output and inflation, but also about the risk of a large persistent drop in output and consumption. As we will see, in some configurations of the model, the central bank finds it preferable to respond to credit gap rather than the output gap, even though this leads to higher output and inflation volatility.

Our main result is that leaning against the wind can be beneficial provided that three conditions are met: (1) financial crises have important output effects; (2) financial shocks are important, i.e. the variance of the financial shocks and the associated swing in inefficient credit are large enough, and (3) financial crises are endogenous, i.e. they are caused in part by inefficient credit. In contrast, if there are no financial shocks, even with other financial imperfections present, we obtain the standard result that stabilizing inflation is a sufficient condition for maximizing welfare. In this latter case, a simple Taylor rule that puts enough weight on the output gap can maximize welfare.\textsuperscript{22} If there are financial shocks, but financial crises are exogenous, a simple rule that puts weight on the output gap still outperforms credit-based rules, because targeting the output gap is a more direct way to eliminate undesirable fluctuations in output and inflation.

Obviously, these results depend on parameter choices. For instance, it is clear that if financial crises have small effects, or the variance of financial shocks is small, responding to output may still be preferable to responding to credit. In the results that follow we have calibrated the financial shocks so that they account for 15\% of the variance of output, and demand and productivity shocks equally account for the remainder (i.e., 42.5\% each). We discuss some robustness exercises after we introduce our main findings. However, because we have not estimated the model, we view these results as being indicative rather than dispositive. Put differently, rather than giving a definitive answer to the question of whether leaning against the wind is desirable, we think our framework is useful precisely because it permits us to understand, within a fairly standard DSGE model, which parameters and model features govern whether responding to credit conditions is beneficial.

\textsuperscript{21}See, among many others, Orphanides and Williams (2002) and Edge and Meisenzahl (2011).

\textsuperscript{22}This result is sometimes called “divine coincidence”. The same outcome can be achieved by maximizing the inflation coefficient. Of course, in the presence of price markup shocks, this result breaks down.
5.1 Methodology

We consider policy rules of the following form:

\[ R_t = \rho R_{t-1} + (1-\rho)(R^* + \phi_\pi (\pi_t - \pi^*) + \phi_y \tilde{y}_t + \phi_b b_t) \]  

(27)

where \( \pi_t \) is again the year-over-year inflation rate, \( \tilde{y}_t \) is the output gap and \( b_t \) is the credit gap, i.e. \( \log \left( \frac{B_t}{B_t^f} \right) \). Note that \( b_t \) is the variable which determines the probability of a financial crisis, as given by equation (25). Throughout this exercise we set \( \rho = 0.85 \) and \( \phi_\pi = 1.5 \). Our motivation for imposing these restrictions is to make analysis transparent, and to require that the policy rule resembles the kind that broadly describes actual central bank decisions. We then consider the welfare consequences of policy rules with different coefficients for \( \phi_y \) or \( \phi_b \). Specifically, we rank rules according to the utility they provide to the representative consumer and find the value of \( \phi_y \) and/or \( \phi_b \) that maximizes this expected utility.\(^{23,24}\)

We first consider the simple case where the central bank responds to only one gap so that either \( \phi_b = 0 \) or \( \phi_y = 0 \). We then discuss results when we optimize over \( \phi_b \) and \( \phi_y \) jointly.

One convention that we follow in Table 2 and other tables below is to limit the maximum reported value for \( \phi_b \) to be 100. In some variants of the model that we consider, the divine coincidence property is present so that the optimal policy would have a coefficient equal to infinity on inflation, or equivalently the output gap. This also is consistent with the case of optimal monetary policy without commitment in Clarida, Gali, and Gertler (1999). We have allowed the maximum value to be much higher, say 10,000, and the results are essentially identical.

\(^{23}\)In contrast, many papers minimize a quadratic loss function of inflation and unemployment. In our case this approach would not capture the cost of financial crises, which permanently lower productivity. It is also a priori attractive to use a micro-founded welfare criterion.

\(^{24}\)In practice, we first rewrite the system of equations that determines the equilibrium around the stochastic trend induced by disaster. This system can then be solved using standard perturbation methods since it has no jumps. We then use a second-order approximation of the utility to obtain conditional welfare, that is the utility obtained by the agent if the state variables are at their nonstochastic steady-state values. The result with unconditional welfare (the average utility in the new steady-state) are quite similar however. See appendix for details, and https://sites.google.com/site/fgourio/ for the code used to solve the paper.
Table 2: Benchmark Model

<table>
<thead>
<tr>
<th></th>
<th>Output gap only</th>
<th>Credit gap only</th>
<th>Both gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Welfare</td>
<td>-143.35</td>
<td>-143.15</td>
<td>-143.14</td>
</tr>
<tr>
<td>Consumption equivalent (%)</td>
<td>0</td>
<td>0.177</td>
<td>0.185</td>
</tr>
<tr>
<td>Coefficient $\phi_y$</td>
<td>100</td>
<td>–</td>
<td>80.09</td>
</tr>
<tr>
<td>Coefficient $\phi_b$</td>
<td>–</td>
<td>1.90</td>
<td>100.0</td>
</tr>
<tr>
<td>$400 \times \text{SD}(\Pi)$</td>
<td>1.45</td>
<td>2.41</td>
<td>2.36</td>
</tr>
<tr>
<td>$100 \times \text{SD}(Y)$</td>
<td>2.12</td>
<td>4.38</td>
<td>4.12</td>
</tr>
<tr>
<td>$400 \times \text{E}(P)$</td>
<td>2.06</td>
<td>1.98</td>
<td>1.99</td>
</tr>
<tr>
<td>$400 \times \text{SD}(P)$</td>
<td>0.83</td>
<td>0.29</td>
<td>0.29</td>
</tr>
</tbody>
</table>

Note: The table compares key statistics of the baseline model when monetary policy is set with three different variants of equation (27). In each case, $\rho = 0.85$ and $\phi_\pi = 1.5$. In (1), $\phi_y$ is optimized and $\phi_b$ is zero. In (2), $\phi_b$ is optimized and $\phi_y$ is zero. In (3), both $\phi_b$ and $\phi_y$ are optimized. Consumption equivalent values are calculated relative to (1).

5.2 Main Result

Table 2 summarizes our main finding. When we select the best rule that depends solely on a correctly measured output gap, the optimal sensitivity is very high, around 100, the upper bound in our optimization, so that monetary policy eliminates all inefficient fluctuations of output.

As can be seen, this monetary policy rule generates also a relatively small amount of inflation volatility. The standard deviation of the probability of crises is 0.83 percent. Crises occur about 2.06 percent of the time, which differs from 2 percent owing to Jensen’s inequality. As a result, households face the risk that crises can be more frequent than that. As shown in the second column, when we select the best rule that depends solely on the correctly measured credit gap, we obtain a coefficient of 1.90 on the credit gap.

This rule generates significantly greater volatility of output and inflation than the one based on the output gap. Yet, the credit-gap based rule outperforms the output-gap based rule in terms of welfare. The difference in utility is equivalent to a permanent increase of consumption of 0.18%, a significant number. For comparison, if one were to follow Lucas (1987) and compute the welfare gain of exogenously removing all business cycle volatility of consumption, the benefits amount to 0.058%. In contrast, the same Lucas-style calculation yields a benefit of 5.50% of exogenously

---

25 We set an upper bound of 100, and a lower bound of 0, to ensure that the optimization problem is well-posed. Allowing for values higher than 100 does not materially alter the results.

26 The level of crisis probability is given by $p_t = \exp[b_0 + (B_t/B_f)^{b_1}]$. As a result, the average value of crisis probability is affected by the volatility of excess credit.

27 The reported measure of output volatility does not take into account financial crises.

28 This calculation is based on the benefits of removing consumption volatility starting from the standard Taylor model.
Note: Each panel shows impulse responses for different variables following a one standard deviation financial shock when three different variants of equation (27) are used for monetary policy. In each case, $\rho = 0.85$ and $\phi_\pi = 1.5$. Solid blue is for $\phi_b = 0$ and $\phi_y = 1$. Dotted green is for $\phi_b = 0$ and $\phi_y$ optimized. Dashed red is for LAW with $\phi_b$ optimized and $\phi_y = 0$.

removing all financial crises.\(^{29}\)

In the comparisons that follow, we report the consumption equivalent change between a rule based only on the output gap and those that depend on the credit gap or both gaps; by this convention, the consumption equivalent for the rule that focuses on output gap only is always zero.

The gain in welfare occurs because the LAW policy is sacrificing cyclical volatility in order to limit the financial crisis risk: the probability of a financial crisis is now both smaller and substantially less volatile. The reduction in the mean probability of crisis is driven, in part, by the functional form we use to insure that the crisis probability lies between zero and one.\(^{30}\) While this effect may seem at first mechanical, it reflects the reality that the financial crisis probability is

\(^{28}\)(1999) rule.

\(^{29}\)The benefit obtained from reducing the financial crisis probability exogenously from 2.06ppt to 1.98ppt is 0.23%. Hence our result is in line with the Lucas calculation. We obtain smaller gains because our gains come at a cost of higher business cycle volatility. Moreover, our model incorporates other costs of volatility, including inflation and labor. And, as discussed in Lester, Pries, and Sims (2014), there may be gains from higher volatility as well.

\(^{30}\)We specify a process for the log of the probability and that implies that lower volatility also brings a lower mean.
Figure 7: Impulse Responses to a Demand Shock: Optimal Simple Rules

![Graph of impulse responses to a demand shock for different variables.](image)

Note: Each panel shows impulse responses for different variables following a one standard deviation demand shock when three different variants of equation (27) are used for monetary policy. In each case, $\rho = 0.85$ and $\phi_{\pi} = 1.5$. Solid blue is for $\phi_b = 0$ and $\phi_y = 1$. Dotted green is for $\phi_b = 0$ and $\phi_y$ optimized. Dashed red is for LAW with $\phi_b$ optimized and $\phi_y = 0$.

bounded below (by zero). As such, decreasing the volatility of financial crisis leads to lower mean because the mean is driven by the occasional upswings.

Figures 6, 7 and 8 depict the response of macroeconomic aggregates to the three fundamental shocks under the standard Taylor (the solid blue line), the rule that responds only to the output gap (the dotted green line), and the rule that responds only to the credit gap (the dashed red line). Our main conclusion is best understood by studying Figure 6 to compare what the different rules imply for policy in the aftermath of a financial shock. The credit-gap rule tightens policy, which leads to a much lower debt expansion and consequently a lower risk of a crisis. The cost of this policy is large in terms of the deviation of inflation and output from target. This policy, nevertheless, delivers higher welfare because it meaningfully lowers the probability of a financial crisis. In contrast, the output gap based policy cuts interest rates because inflation is low and lower rates help keep output close to its target. The cost of this choice is a rise in the financial crisis risk.
Note: Each panel shows impulse responses for different variables following a one standard deviation productivity shock when three different variants of equation (27) are used for monetary policy. In each case, $\rho = 0.85$ and $\phi_\pi = 1.5$. Solid blue is for $\phi_b = 0$ and $\phi_y = 1$. Dotted green is for $\phi_b = 0$ and $\phi_y$ optimized. Dashed red is for LAW with $\phi_b$ optimized and $\phi_y = 0$.

Finally, following a standard Taylor rule leads the central bank to gradually cut rates as it trades off inflation undershooting against a modest output boom. In this case, debt also accumulates so that the crisis probability rises even more substantially.

Figures 7 and 8 show the performance of the different rules in face of demand and productivity shocks. Another cost of the credit-gap policy rule is that it does less well than the output-gap based rule in response to standard demand and productivity shocks. While the output-gap based policy offsets completely the demand shock and accommodates almost perfectly the productivity shock, the credit-gap based policy responds less aggressively to both of these shocks. The relatively passive response implied by the optimized credit rule for these shocks is because if it were more aggressive in these cases, it would also be even more responsive to financial shocks: i.e., a higher coefficient on the credit gap would help in responding to these shocks, but would exaggerate even more the output and inflation deviations in response to the financial shock.
5.3 Understanding the results

To confirm the interpretation that we have offered for the main findings, it is instructive to shutdown various features of the model to see how doing so changes the results. A particularly helpful experiment is to turn off the financial shocks (i.e. set $\sigma_{\chi} = 0$) and make the financial crises exogenous ($b_1 = 0$). The environment then amounts to a standard New Keynesian model that includes a debt-equity tradeoff in capital structure and exogenous crises. The main findings are summarized in panel (B) of Table 3.\footnote{For the ease of comparison, we reproduce Table 2 in panel (A) of Table 3.} In this environment, the optimal policy is one that responds enough to either the output or credit gap, and essentially perfectly stabilizes inflation. After a demand shock, monetary policy offsets the shock to fully stabilize output and inflation. On the other hand, when a productivity shock occurs, the policy keeps inflation on target and lets output respond fully to the shock. This result is standard in New Keynesian models - the divine coincidence property (Blanchard and Gali (2007)) applies and so there is no trade-off between output and inflation volatility, and this optimal policy can be (approximately) implemented by either simple rule provided that they are sufficiently aggressive.\footnote{Note that there is no intrinsic reason as to why one simple rule should perform better than the other in terms of welfare in this case; indeed the welfare difference we find is extremely small, about 0.2 basis point. Also note that output and inflation volatility as well as mean and standard deviation of financial crisis probability are quite close.}

To further build intuition, we now relax the assumption that financial crises are exogenous. These results are reported in panel (C) of Table 3. These findings are nearly identical to the prior case. This is because there is no reason to offset the credit fluctuations driven by the productivity shock, which are efficient and do not contribute to financial risk. For demand shocks, the credit fluctuations they create are actually eliminated once output volatility is eliminated. Hence, there is no trade-off between credit stabilization and output/inflation stabilization, and the same policies as in the previous case can implement an efficient allocation without creating any inefficient credit movements.

As a third point of comparison, we now reintroduce financial shocks, though unlike in the benchmark we suppose that crises are exogenous. In this version of the model the output gap rule does slightly better than LAW. These findings are summarized in panel (D) of Table 3. The novelty compared to the previous cases is that the policy response to the output gap is diminished. This occurs because the response that would be required to offset demand and productivity shocks is
<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(A) Benchmark: Financial Shocks, Endogenous Financial Crises</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welfare</td>
<td>-143.35</td>
<td>-143.15</td>
<td>-143.14</td>
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<td>Consumption equivalent (%)</td>
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<td>0.177</td>
<td>0.185</td>
</tr>
<tr>
<td>Coefficient ( \phi_y )</td>
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<td>–</td>
<td>80.09</td>
</tr>
<tr>
<td>Coefficient ( \phi_b )</td>
<td>–</td>
<td>1.90</td>
<td>100.0</td>
</tr>
<tr>
<td>( 400 \times SD(\Pi) )</td>
<td>1.45</td>
<td>2.41</td>
<td>2.36</td>
</tr>
<tr>
<td>( 100 \times SD(Y) )</td>
<td>2.12</td>
<td>4.38</td>
<td>4.12</td>
</tr>
<tr>
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</tr>
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<td>0.29</td>
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<tr>
<td><strong>(B) No Financial Shocks, Exogenous Financial Crises</strong></td>
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<td></td>
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<tr>
<td>Welfare</td>
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<td>-142.99</td>
<td>-142.98</td>
</tr>
<tr>
<td>Consumption equivalent (%)</td>
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<td>-0.002</td>
<td>0</td>
</tr>
<tr>
<td>Coefficient ( \phi_y )</td>
<td>100</td>
<td>–</td>
<td>100</td>
</tr>
<tr>
<td>Coefficient ( \phi_b )</td>
<td>–</td>
<td>96.89</td>
<td>0</td>
</tr>
<tr>
<td>( 400 \times SD(\Pi) )</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>( 100 \times SD(Y) )</td>
<td>2.12</td>
<td>2.11</td>
<td>2.12</td>
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<tr>
<td>( 400 \times E(P) )</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>( 400 \times SD(P) )</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>(C) No Financial Shocks, Endogenous Financial Crises</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welfare</td>
<td>-142.98</td>
<td>-142.98</td>
<td>-142.98</td>
</tr>
<tr>
<td>Consumption equivalent (%)</td>
<td>0.00</td>
<td>-0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Coefficient ( \phi_y )</td>
<td>100</td>
<td>–</td>
<td>100</td>
</tr>
<tr>
<td>Coefficient ( \phi_b )</td>
<td>–</td>
<td>97.28</td>
<td>100</td>
</tr>
<tr>
<td>( 400 \times SD(\Pi) )</td>
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<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>( 100 \times SD(Y) )</td>
<td>2.12</td>
<td>2.11</td>
<td>2.12</td>
</tr>
<tr>
<td>( 400 \times E(P) )</td>
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<td>2.00</td>
</tr>
<tr>
<td>( 400 \times SD(P) )</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>(D) Financial Shocks, Exogenous Financial Crises</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welfare</td>
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<td>-143.14</td>
<td>-143.07</td>
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<tr>
<td>Consumption equivalent (%)</td>
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<td>-0.050</td>
<td>0.017</td>
</tr>
<tr>
<td>Coefficient ( \phi_y )</td>
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<td>–</td>
<td>2.69</td>
</tr>
<tr>
<td>Coefficient ( \phi_b )</td>
<td>–</td>
<td>0.47</td>
<td>0.47</td>
</tr>
<tr>
<td>( 400 \times SD(\Pi) )</td>
<td>1.28</td>
<td>1.97</td>
<td>1.60</td>
</tr>
<tr>
<td>( 100 \times SD(Y) )</td>
<td>2.13</td>
<td>3.07</td>
<td>2.23</td>
</tr>
<tr>
<td>( 400 \times E(P) )</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>( 400 \times SD(P) )</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: The table compares key statistics of the four different versions of the model when monetary policy is set with three different variants of equation (27). The models differ depending on whether financial shocks are set to zero \( (\sigma_\chi = 0) \) or not and whether financial crises are exogenous or not \( (b_1 = 0) \). For the monetary rules, \( \rho = 0.85 \) and \( \phi_\pi = 1.5 \) is always imposed. In (1), \( \phi_y \) is optimized and \( \phi_b \) is zero. In (2), \( \phi_b \) is optimized and \( \phi_y \) is zero. In (3), both \( \phi_b \) and \( \phi_y \) are optimized. Consumption equivalent values are calculated relative to (1).
not consistent with the response needed to stabilize the impact of the financial shock. But the credit gap rule suffers from the same issue and has to trade off the response against the different shocks.\textsuperscript{33} Overall, the LAW policy underperforms because the volatility it induces by stabilizing financial shocks does not lower the crisis risk. However, combining the credit and output gap allows a slightly better outcome.

5.4 When is leaning against the wind desirable?

We next ask how certain parameters or model features affect the desirability of leaning against the wind. For simplicity, in almost all of these comparisons we focus on rules that depend either only on the (correctly measured) output gap or credit gap.

5.4.1 The cost of financial crises

Our benchmark model assumes that a financial crisis leads to a permanent decline in the level of GDP of 10%. Table 4 illustrates how our results change as we vary this cost from 6% to 14% with all other parameters kept constant. Several points emerge. First, the welfare benefit of targeting the credit gap rather than the output gap increases monotonically with the size of the financial crisis. Second, the bigger is the crisis, the stronger is the response to credit, with the coefficient rising from 1.20 to 2.32. As a result, the volatility of inflation and output rise as the responsiveness to credit rises, though the probability of the crisis is hardly moving across the different scenarios. Nevertheless, as the size of the crisis rises, the welfare gains from LAW rise.

5.4.2 The persistence of financial crises

Our model assumes that financial crises have permanent effects on the level of output.\textsuperscript{34} While there is broad agreement that financial crises have very persistent effects, there remains substantial debate on the exact amount of persistence. This section presents two simple calculations that provide some information about how the benefits to LAW change with different implied levels of persistence.

\textsuperscript{33}In some environments where the financial frictions are sufficiently severe, LAW can dominate an output gap rule even if financial crises are exogenous. For such an example, see Kiley and Sim (2017). In our model, this result also seems to be possible.

\textsuperscript{34}In the model, this arises because financial crises affect total factor productivity permanently.
Table 4: The Effect of the Financial Crisis Size on the Benefits of LAW

<table>
<thead>
<tr>
<th>Financial crisis size ($b_c$)</th>
<th>6% (1)</th>
<th>8% (2)</th>
<th>10% (3)</th>
<th>12% (4)</th>
<th>14% (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal coeff. on credit $\phi_b$</td>
<td>1.20</td>
<td>1.58</td>
<td>1.90</td>
<td>2.14</td>
<td>2.32</td>
</tr>
<tr>
<td>Consumption equivalent (%)</td>
<td>0.06</td>
<td>0.115</td>
<td>0.177</td>
<td>0.247</td>
<td>0.324</td>
</tr>
<tr>
<td>SD(Y) under LAW</td>
<td>3.91</td>
<td>4.19</td>
<td>4.38</td>
<td>4.49</td>
<td>4.57</td>
</tr>
<tr>
<td>SD(II) under LAW</td>
<td>2.29</td>
<td>2.37</td>
<td>2.41</td>
<td>2.44</td>
<td>2.46</td>
</tr>
<tr>
<td>Mean(P) under LAW</td>
<td>1.993</td>
<td>1.987</td>
<td>1.980</td>
<td>1.983</td>
<td>1.982</td>
</tr>
<tr>
<td>Mean(P) under output gap rule</td>
<td>2.058</td>
<td>2.059</td>
<td>2.060</td>
<td>2.060</td>
<td>2.061</td>
</tr>
<tr>
<td>SD(P) under LAW</td>
<td>0.39</td>
<td>0.32</td>
<td>0.29</td>
<td>0.26</td>
<td>0.25</td>
</tr>
<tr>
<td>SD(P) under output gap rule</td>
<td>0.82</td>
<td>0.83</td>
<td>0.83</td>
<td>0.83</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Note: The table compares key statistics of the baseline model when $b_c$ (the size of the financial crisis) varies and monetary policy is set according to two variants of equation (27). Under each variant $\rho = 0.85$ and $\phi_y = 1.5$. The rows labeled “output gap rule” optimize over $\phi_y$ and set $\phi_b = 0$. The rows labeled LAW optimize over $\phi_b$ and set $\phi_y = 0$. Consumption equivalent values are calculated as the difference between LAW outcome and the output gap rule outcome.

One approach to modeling recoveries is simply to assume that a fraction of financial crises are immediately reversed. Hence, it amounts to assuming a lower baseline probability of financial crisis. Table 5 shows how the results vary with this baseline probability. Recall that our baseline is one crisis every 50 years. Perhaps surprisingly, even with a crisis every 125 years, LAW still (barely) out performs the output gap rule. In this sense, even if more than half of all crisis are transitory, the results from the baseline model carry over. The lesson here is what matters is not the absolute value of the financial crisis probability but by how much it is reduced by following LAW rather than an output gap rule. In our baseline, the reduction in this probability is 8 basis points. If the crisis occurs once every 125, the reduction in crisis risk is 2 basis points, which makes welfare nearly identical to that of an output gap rule in welfare terms. If the crisis probability is once every 250 years, the reduction in crisis risk is only 1 basis point or so, which is sufficiently low that the output gap rule dominates.

An alternative explored in Table 6 involves adjusting the size of the financial crisis drop so that the present value of output loss is the same in our model as it would be in a model where the initial drop remains 10%, but then the shock dies out. To compare different possibilities, we assume that the shocks decay with different half-lives. For instance, if the half-life is 3 years, then the initial

35Our model solution exploits the “scaling property” - all variables adjust by the same amount following a financial crisis. Extending the model to make the shocks persistent rather than permanent makes it difficult to maintain this scaling property. Without the scaling property, the model would be untractable to analyze.
Table 5: The Effect of the Probability of Financial Crises on the Benefits of LAW

<table>
<thead>
<tr>
<th>Frequency of Crises (yrs)</th>
<th>250</th>
<th>125</th>
<th>83</th>
<th>70</th>
<th>50</th>
<th>33</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td>(benchmark)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal coeff. on credit</td>
<td>φ₀</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b₀</td>
<td>0.643</td>
<td>0.899</td>
<td>1.250</td>
<td>1.464</td>
<td>1.904</td>
<td>2.353</td>
</tr>
<tr>
<td>Consumption equivalent (%)</td>
<td></td>
<td>-0.135</td>
<td>0.024</td>
<td>0.068</td>
<td>0.097</td>
<td>0.177</td>
</tr>
<tr>
<td>SD(Y) under LAW</td>
<td></td>
<td>3.286</td>
<td>3.601</td>
<td>3.946</td>
<td>4.112</td>
<td>4.379</td>
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<tr>
<td>SD(Π) under LAW</td>
<td></td>
<td>2.073</td>
<td>2.193</td>
<td>2.299</td>
<td>2.344</td>
<td>2.414</td>
</tr>
<tr>
<td>Mean(P) under LAW</td>
<td></td>
<td>0.403</td>
<td>0.801</td>
<td>1.195</td>
<td>1.422</td>
<td>1.984</td>
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<tr>
<td>Mean(P) under output gap rule</td>
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<td>0.415</td>
<td>0.823</td>
<td>1.235</td>
<td>1.472</td>
<td>2.060</td>
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<tr>
<td>SD(P) under LAW</td>
<td></td>
<td>0.111</td>
<td>0.185</td>
<td>0.228</td>
<td>0.245</td>
<td>0.287</td>
</tr>
<tr>
<td>SD(P) under output gap rule</td>
<td></td>
<td>0.169</td>
<td>0.329</td>
<td>0.495</td>
<td>0.590</td>
<td>0.826</td>
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</table>

Note: The table compares key statistics of the baseline model when \( p_{ss} \) (the unconditional probability of a financial crisis) varies and monetary policy is set according to two variants of equation (27). Under each variant \( \rho = 0.85 \) and \( \phi_{pc} = 1.5 \). The rows labeled “output gap rule” optimize over \( \phi_p \) and set \( \phi_y = 0 \). The rows labeled LAW optimize over \( \phi_b \) and set \( \phi_y = 0 \). Consumption equivalent values are calculated as the difference between LAW outcome and the output gap rule outcome.

A drop of 10% is followed by a recovery so that after 3 years GDP is only 5% below its pre-crisis trend. This scenario would imply that the annual persistence is about 0.79, and the present value of total loss would be that same as if there had been a 1.5% permanent shock. When we solve the model with a 1.5% permanent shock, LAW is out-performed by the output gap rule. This result can be interpreted as meaning that with this degree of persistence our baseline finding is overturned.\(^{36}\)

The table shows that for a half-life of 9 years or longer, LAW again is preferred.

### 5.4.3 The sensitivity of crises to excess credit

Another key parameter for our results is \( b_1 \), which measures how much excess credit affects the likelihood of financial crises. A large value of \( b_1 \) means that excess credit has a strong effect on the risk of crises and hence on welfare. This naturally gives rise to a stronger motive to lean against excess credit. Table 7 confirms this intuition. First, for low values of \( b_1 \), LAW is outperformed by the output gap rule. Second, the optimal coefficient on credit rises with \( b_1 \). This change in the coefficient partially offsets the increase in the volatility of financial crisis probability that would otherwise occur mechanically. Third, this policy is chosen despite a clear cost in terms of higher output and inflation volatility.

\(^{36}\)Note, however, that reasoning in present value neglects the effect of risk aversion on the implied size for welfare purpose. These effects are relatively small given our assumed risk aversion and financial crisis size, however.
### Table 6: Mapping of Transitory Financial Crises into Equivalent Permanent Crises

<table>
<thead>
<tr>
<th>Half Life of the Shock (Annual)</th>
<th>3yrs</th>
<th>6yrs</th>
<th>9yrs</th>
<th>12yrs</th>
<th>15yrs</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Underlying Persistence (Annual)</td>
<td>0.794</td>
<td>0.891</td>
<td>0.926</td>
<td>0.944</td>
<td>0.955</td>
</tr>
<tr>
<td>Equivalent Crisis Size (%)</td>
<td>1.50</td>
<td>2.60</td>
<td>3.50</td>
<td>4.10</td>
<td>4.70</td>
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<tr>
<td>Optimal coeff. on credit $\phi_b$</td>
<td>0.584</td>
<td>0.687</td>
<td>0.787</td>
<td>0.880</td>
<td>0.965</td>
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<tr>
<td>Consumption equivalent (%)</td>
<td>-0.025</td>
<td>-0.005</td>
<td>0.010</td>
<td>0.022</td>
<td>0.033</td>
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<tr>
<td>SD(Y) under LAW</td>
<td>3.210</td>
<td>3.344</td>
<td>3.469</td>
<td>3.508</td>
<td>3.675</td>
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<td>SD(II) under LAW</td>
<td>2.036</td>
<td>2.098</td>
<td>2.148</td>
<td>2.187</td>
<td>2.218</td>
</tr>
<tr>
<td>Mean(P) under LAW</td>
<td>2.020</td>
<td>2.012</td>
<td>2.007</td>
<td>2.003</td>
<td>1.999</td>
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<td>Mean(P) under output gap rule</td>
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<td>2.073</td>
<td>2.058</td>
<td>2.058</td>
<td>2.058</td>
</tr>
<tr>
<td>SD(P) under LAW</td>
<td>0.586</td>
<td>0.538</td>
<td>0.500</td>
<td>0.469</td>
<td>0.444</td>
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<tr>
<td>SD(P) under output gap rule</td>
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<td>0.844</td>
<td>0.823</td>
<td>0.823</td>
<td>0.824</td>
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</tbody>
</table>

Note: The table compares key statistics of the baseline model when smaller financial crises are considered. The size of the financial crisis is chosen so that the total present value of crisis is equivalent to one where the initial decline is 10 percent, but then the shock decays with differing half-lives shown in the first row. The equivalent permanent size is shown in row 3 and the model is solved for permanent shocks of that size with monetary policy being set according to two variants of equation (27). Under each variant $\rho = 0.85$ and $\phi_\pi = 1.5$. The rows labeled “output gap rule” optimize over $\phi_y$ and set $\phi_b = 0$. The rows labeled LAW optimize over $\phi_y$ and set $\phi_b = 0$. Consumption equivalent values are calculated as the difference between LAW outcome and the output gap rule outcome.

#### 5.4.4 Functional forms for financial crisis probability

We assume in our benchmark a particular functional form that links the probability of a financial crisis to excess credit (Equation (25)). Of course this reduced form is simply an assumption, and there are various other reasonable alternative functional forms. Table 8 shows how the results differ for several natural alternatives. The first column reproduces the baseline results. Columns 2 and 3 report the results if one uses the “gap” for B/K or B/Y rather than B in (25). Columns 4 and 5 assume instead that the level of debt or growth rate of debt affect probability of crisis. In all cases, we adjust the monetary policy rule so that it responds to the variable that affects the probability of a financial crisis.37

The key message that emerges from this table is that the gains from LAW are robust to changing the precise functional form that governs the crisis. In all cases, the same basic trade-off operates: LAW generates a small but significant reduction in the average probability of financial crisis, and hence a positive welfare gain, despite more inflation and output gap volatility. In fact, the gains in welfare are at least as high as in the baseline for each of the alternatives in Table 8.

---

37 We also recalibrate the parameter $b_1$ to keep the volatility of the financial crisis probability the same in the case where monetary policy follows a standard Taylor (1999) Rule.
Table 7: The Effect of the Changing Sensitivities to Financial Crises on the Benefits of LAW

<table>
<thead>
<tr>
<th>Sensitivity of crisis to excess credit ($b_1$)</th>
<th>2</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>(benchmark)</td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Optimal coeff. on credit $\phi_b$</td>
<td>0.42</td>
<td>1.13</td>
<td>1.90</td>
<td>2.69</td>
<td>4.06</td>
</tr>
<tr>
<td>Consumption equivalent (%)</td>
<td>-0.05</td>
<td>0.04</td>
<td>0.17</td>
<td>0.37</td>
<td>0.91</td>
</tr>
<tr>
<td>SD($Y$) under LAW</td>
<td>3.03</td>
<td>3.84</td>
<td>4.38</td>
<td>4.69</td>
<td>5.00</td>
</tr>
<tr>
<td>SD($\Pi$) under LAW</td>
<td>1.94</td>
<td>2.28</td>
<td>2.41</td>
<td>2.49</td>
<td>2.55</td>
</tr>
<tr>
<td>Mean($P$) under LAW</td>
<td>1.987</td>
<td>1.989</td>
<td>1.984</td>
<td>1.982</td>
<td>1.979</td>
</tr>
<tr>
<td>Mean($P$) under output gap rule</td>
<td>1.987</td>
<td>2.019</td>
<td>2.060</td>
<td>2.115</td>
<td>2.271</td>
</tr>
<tr>
<td>SD($P$) under LAW</td>
<td>0.27</td>
<td>0.32</td>
<td>0.29</td>
<td>0.27</td>
<td>0.26</td>
</tr>
<tr>
<td>SD($P$) under output gap rule</td>
<td>0.34</td>
<td>0.66</td>
<td>0.83</td>
<td>0.99</td>
<td>1.33</td>
</tr>
</tbody>
</table>

Note: The table compares key statistics of the baseline model when $b_1$ (the sensitivity of a financial crisis to excess credit) varies and monetary policy is set according to two variants of equation (27). Under each variant $\rho = 0.85$ and $\phi_\pi = 1.5$. The rows labeled "output gap rule" optimize over $\phi_y$ and set $\phi_b = 0$. The rows labeled LAW optimize over $\phi_b$ and set $\phi_y = 0$. Consumption equivalent values are calculated as the difference between LAW outcome and the output gap rule outcome.

Table 8: The Effect of Alternative Determinants of Financial Crises on the Benefits of LAW

<table>
<thead>
<tr>
<th>Debt variable (B, BK and BY)</th>
<th>B GAP</th>
<th>BK GAP</th>
<th>BY GAP</th>
<th>B Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Optimal coefficient on credit $\phi_b$</td>
<td>1.906</td>
<td>1.017</td>
<td>6.472</td>
<td>1.772</td>
</tr>
<tr>
<td>Consumption equivalent (%)</td>
<td>0.177</td>
<td>0.231</td>
<td>0.266</td>
<td>0.184</td>
</tr>
<tr>
<td>SD($Y$) under LAW</td>
<td>4.380</td>
<td>4.775</td>
<td>12.00</td>
<td>1.305</td>
</tr>
<tr>
<td>SD($Y$) under output gap rule</td>
<td>2.117</td>
<td>2.098</td>
<td>2.117</td>
<td>2.116</td>
</tr>
<tr>
<td>SD($\Pi$) under LAW</td>
<td>2.415</td>
<td>3.181</td>
<td>4.162</td>
<td>2.399</td>
</tr>
<tr>
<td>SD($\Pi$) under output gap rule</td>
<td>1.454</td>
<td>1.362</td>
<td>1.461</td>
<td>1.454</td>
</tr>
<tr>
<td>Mean($P$) under LAW</td>
<td>1.984</td>
<td>1.960</td>
<td>1.904</td>
<td>1.986</td>
</tr>
<tr>
<td>Mean($P$) under output gap rule</td>
<td>2.060</td>
<td>2.071</td>
<td>2.091</td>
<td>2.063</td>
</tr>
<tr>
<td>SD($P$) under LAW</td>
<td>0.287</td>
<td>0.588</td>
<td>0.273</td>
<td>0.320</td>
</tr>
<tr>
<td>SD($P$) under output gap rule</td>
<td>0.827</td>
<td>0.905</td>
<td>0.926</td>
<td>0.838</td>
</tr>
</tbody>
</table>

Note: The table compares key statistics of the models that differ according to which debt variable determines the probability of a financial crisis. B, BK and BY stand for credit, credit to capital and credit to GDP, respectively. For B Gap, BK Gap and BY Gap the probability is computed relative to the levels for each variable that would obtain without price stickiness and financial shocks. To facilitate comparisons, the coefficient $b_1$ (the sensitivity of a financial crisis to the debt variable) is adjusted so that volatility of the probability of a crisis is the same as when monetary policy is set according to equation (26). Monetary policy is set according to two variants of equation (27). Under each variant $\rho = 0.85$ and $\phi_\pi = 1.5$. The rows labeled "output gap rule" optimize over $\phi_y$ and set $\phi_b = 0$. The rows labeled LAW optimize over $\phi_b$ and set $\phi_y = 0$. Consumption equivalent values are calculated as the difference between LAW outcome and the output gap rule outcome.

5.4.5 The magnitude of financial shocks

Perhaps most basically, the magnitude of the (inefficient) financial shocks is critical for our results. We already illustrated that if there are no financial shocks, leaning against the wind brings no benefits relative to standard policies. Table 9 provides more details on the importance of this...
Table 9: The Effect of Financial Shock Volatility on the Benefits of LAW

<table>
<thead>
<tr>
<th>Standard dev. of financial shocks (relative to benchmark)</th>
<th>33%</th>
<th>66%</th>
<th>100%</th>
<th>133%</th>
<th>166%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Optimal coeff. on credit $\phi_b$</td>
<td>4.97</td>
<td>2.35</td>
<td>1.90</td>
<td>1.74</td>
<td>1.67</td>
</tr>
<tr>
<td>Consumption equivalent (%)</td>
<td>0.01</td>
<td>0.07</td>
<td>0.18</td>
<td>0.32</td>
<td>0.51</td>
</tr>
<tr>
<td>SD($Y$) under LAW</td>
<td>2.61</td>
<td>3.44</td>
<td>4.38</td>
<td>5.38</td>
<td>6.43</td>
</tr>
<tr>
<td>SD($\Pi$) under LAW</td>
<td>0.87</td>
<td>1.65</td>
<td>2.41</td>
<td>3.18</td>
<td>4.96</td>
</tr>
<tr>
<td>Mean($P$) under LAW</td>
<td>1.999</td>
<td>1.992</td>
<td>1.980</td>
<td>1.974</td>
<td>1.962</td>
</tr>
<tr>
<td>Mean($P$) under output gap rule</td>
<td>2.007</td>
<td>2.027</td>
<td>2.060</td>
<td>2.106</td>
<td>2.165</td>
</tr>
<tr>
<td>SD($P$) under LAW</td>
<td>0.09</td>
<td>0.19</td>
<td>0.29</td>
<td>0.38</td>
<td>0.48</td>
</tr>
<tr>
<td>SD($P$) under output gap rule</td>
<td>0.28</td>
<td>0.55</td>
<td>0.83</td>
<td>1.01</td>
<td>1.38</td>
</tr>
</tbody>
</table>

Note: The table compares key statistics of the baseline model when $\sigma_x$ (the standard deviation of financial shocks) varies and monetary policy is set according to two variants of equation (27). Under each variant $\rho = 0.85$ and $\phi_\pi = 1.5$. The rows labeled “output gap rule” optimize over $\phi_\pi$ and set $\phi_b = 0$. The rows labeled LAW optimize over $\phi_b$ and set $\phi_\pi = 0$. Consumption equivalent values are calculated as the difference between LAW outcome and the output gap rule outcome.

Consideration. Here too, we see that the welfare difference between the best credit gap policy and the best output gap policy is increasing in the variance of financial shocks. The effects on output and inflation volatility as well as the financial crisis probability are more subtle because they result both from (i) the higher variance of financial shocks and (ii) the change in policy rule in response to this higher variance. Nevertheless, when the financial shocks are more important, the LAW policy delivers more volatility for output and inflation than the output gap rule and a lower probability of a crisis.

5.4.6 The role of risk aversion

We next explore how the willingness of households to bear macroeconomic risk affects our results. On one side, higher risk aversion makes agents more fearful of financial crises. On the other hand, higher risk aversion also makes agents less willing to tolerate the higher business cycle volatility implied by LAW. Moreover, with our assumed preferences, a higher risk aversion implies a lower elasticity of substitution, which affects the response of the economy to monetary policy (as well as the dynamics of the model more generally). Table 8 reveals that the first effect seems to dominate - the higher is risk aversion, the larger are the benefits from leaning against the wind. With a risk aversion of 0.5, an output-gap rule outperforms a credit-gap rule, but the benefits of using the credit gap rule rise with risk aversion. The optimal policy largely stabilizes fluctuations in financial

38
Table 10: The Effect of Risk Aversion on the Benefits of LAW

<table>
<thead>
<tr>
<th>CRRA</th>
<th>0.5</th>
<th>1.5</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Optimal coeff. on credit $\phi_b$</td>
<td>0.74</td>
<td>1.35</td>
<td>1.90</td>
<td>3.23</td>
<td>4.76</td>
</tr>
<tr>
<td>Consumption equivalent (%)</td>
<td>-0.30</td>
<td>0.12</td>
<td>0.18</td>
<td>0.27</td>
<td>0.35</td>
</tr>
<tr>
<td>SD(Y) under LAW</td>
<td>8.61</td>
<td>4.88</td>
<td>4.38</td>
<td>3.75</td>
<td>3.35</td>
</tr>
<tr>
<td>SD(Π) under LAW</td>
<td>2.60</td>
<td>2.41</td>
<td>2.41</td>
<td>2.40</td>
<td>2.39</td>
</tr>
<tr>
<td>Mean(P) under LAW</td>
<td>1.92</td>
<td>1.98</td>
<td>1.98</td>
<td>1.99</td>
<td>1.99</td>
</tr>
<tr>
<td>Mean(P) under output gap rule</td>
<td>2.084</td>
<td>2.066</td>
<td>2.060</td>
<td>2.049</td>
<td>2.041</td>
</tr>
<tr>
<td>SD(P) under LAW</td>
<td>0.49</td>
<td>0.36</td>
<td>0.29</td>
<td>0.20</td>
<td>0.15</td>
</tr>
<tr>
<td>SD(P) under output gap rule</td>
<td>0.89</td>
<td>0.84</td>
<td>0.83</td>
<td>0.80</td>
<td>0.78</td>
</tr>
</tbody>
</table>

Note: The table compares key statistics of the baseline model when $\tau$ (the level of risk aversion) varies and monetary policy is set according to two variants of equation (27). Under each variant $\rho = 0.85$ and $\phi_{\pi} = 1.5$. The rows labeled “output gap rule” optimize over $\phi_y$ and set $\phi_b = 0$. The rows labeled LAW optimize over $\phi_b$ and set $\phi_y = 0$. Consumption equivalent values are calculated as the difference between LAW outcome and the output gap rule outcome.

Figure 9 summarizes many of the central findings of the paper. On the horizontal axis, we vary the size of the financial crisis. On the vertical axis we vary risk aversion. The lines that are drawn trace out isoquants in units of equivalent consumption between the best LAW policy (that responds only to the credit gap and inflation) and the best monetary policy rule that responds only to the output gap (and inflation). The zero consumption equivalence curve traces out all the combinations of the size of the crisis and the representative household’s level of risk aversion where the two policies deliver equivalent welfare. Points to the right and above the zero curve show the regions where LAW delivers higher welfare and below and to the left show combinations where the output gap rule performs better. The outcome for the benchmark model, described in Table 2 with risk aversion of two and a crisis that brings a permanent ten percent output loss, is indicated by the red dot. The results from Table 4 described how welfare varied when we fixed risk aversion at two and varied the size of the crisis. This figure fills in the rest of the parameter space. Not surprisingly, as risk aversion rises, LAW’s relative performance improves. For most combinations, LAW is advantageous. However, if risk aversion is lower, say one, then a crisis that drops output by 10 percent is not enough to justify a LAW policy.

---

38 Each policy is optimized with respect to the coefficient on the credit gap or output gap, as in the exercises above.
Note: Each line shows pairs of values for the size of the financial crisis ($b_c$) and risk aversion ($\tau$) lead to different values of consumption equivalent differences when monetary policy is set using two different monetary policy rules. Each rule is a variant of equation (27) with $\rho = 0.85$ and $\phi_{\pi} = 1.5$. One rule optimizes over $\phi_y$ and sets $\phi_b = 0$ and the other optimizes over $\phi_y$ and sets $\phi_b = 0$.

### 5.4.7 Habit Formation

The results thus far indicate that the LAW may improve the welfare of the representative agent in various environments. The results also indicate that such welfare gains may come with costs of increased volatility in output and inflation.

It is, therefore, likely that the size of welfare gains may depend on the specification of the representative agent’s utility function. In particular, the agent’s tolerance of additional consumption volatility due to implementing the LAW should be important. As demonstrated in Table 10, we know that the level of risk aversion is an important parameter. The more general consideration will be how much the representative consumers weighs business cycle risk as opposed to financial crisis risk.

To test this possibility, in this subsection, we suppose that the agents are subject to habit
### Table 11: Habit Formation and the Benefits of LAW

<table>
<thead>
<tr>
<th>$a = 0.70$</th>
<th>$a = 0.75$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta^H$</td>
<td>$\delta^H$</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>0.50</td>
<td>0.50</td>
</tr>
</tbody>
</table>

| Optimal coeff. on credit $\phi_b$ | 2.505 | 1.893 | 1.679 | 1.550 | 1.462 | 1.398 |
| Consumption equivalent (%) | 0.108 | 0.031 | 0.027 | 0.027 | 0.028 | 0.029 |
| SD($Y$) under LAW | 2.209 | 2.566 | 2.774 | 2.915 | 3.012 | 3.084 |
| SD($H$) under LAW | 1.966 | 1.895 | 2.002 | 2.065 | 2.103 | 2.217 |
| Mean($P$) under LAW | 2.006 | 2.005 | 2.003 | 2.003 | 2.003 | 2.003 |
| Mean($P$) under output gap rule | 2.058 | 2.066 | 2.072 | 2.076 | 2.079 | 2.082 |
| SD($P$) under LAW | 0.237 | 0.287 | 0.308 | 0.322 | 0.333 | 0.342 |
| SD($P$) under output gap rule | 0.692 | 0.715 | 0.732 | 0.746 | 0.757 | 0.765 |

Note: The table compares key statistics of the baseline model when the utility function is (28) and the habit stock evolves according to (29). The two panels report different values for the key habit parameters. Monetary policy is set according to two variants of equation (27). Under each variant $\rho = 0.85$ and $\phi_\pi = 1.5$. The rows labeled “output gap rule” optimize over $\phi_y$ and set $\phi_b = 0$. The rows labeled LAW optimize over $\phi_b$ and set $\phi_y = 0$. Consumption equivalent values are calculated as the difference between LAW outcome and the output gap rule outcome.

The parameters $a$ and $\delta^H$ measure the strength of habit formation and the decay rate of habit stock $S_t^H$. To ensure that the scaling property of the model remains, we assume that the habit stock is...
destroyed in a financial crisis.\footnote{To see this, one can express the law of motion for the habit stock in a detrended form: \[ \ddot{S}^H_t = e^{-X_t b_c} \left( \frac{Z^I_t}{Z^H_{t-1}} \right)^{-1} [(1 - \delta^H)\dot{S}^H_{t-1} + \delta^H \dot{C}_{t-1}] = (1 - \delta^H)\dot{S}^H_{t-1} + \delta^H \dot{C}_{t-1}. \] } This assumption amounts to assuming that following a large shock such as a financial crisis, habits are adjusted faster than in normal times, perhaps because of the saliency of the crisis or because of all the other adjustments required by the crisis. We make it for tractability to preserve the scaling property but we note that this assumption creates an important bias against LAW by making crises relatively less painful.

Table 11 presents the results for various values of $a$ and $\delta^H$. The cutoff values for $a$ are chosen so that in some instances, LAW continues to dominate the output gap rule, while in others it does not. When $a$ is below 0.7, then LAW always outperforms the output gap rule. \textit{Havranek, Rusnak, and Sokolova (2017)} survey 597 estimates of habit formation reported in 81 published studies. The mean reported value for $a$ is 0.4, but the estimates vary widely both within and across studies.

The mechanisms at work in this alternative are the same as in the baseline. LAW reduces the average probability of financial crisis and hence creates some benefits. But run-off-the-mill business cycle fluctuations are now significantly more costly for the representative consumer given the habits preferences. So when habit persistence (or the habit strength) is low, the business cycle costs are lower and LAW performs better, but when these parameters are larger, the output gap rule can be preferred.

### 5.4.8 Other monetary policy rules

Our comparisons thus far focus on simple monetary policy rules with a fixed weight on inflation of 1.5, optimizing either the output or credit gap. Alternatively one can imagine optimizing over the inflation coefficient. Inflation is easier to measure than either the output gap or credit gap so one might think that this kind of policy is appealing on those grounds. Table 12 reports the results from this experiment. The first column reports the result of optimizing over inflation while keeping the output gap and credit gap coefficients at zero.\footnote{As we verify in the appendix, in the model with exogenous crises and no financial shocks this policy is equivalent to optimizing over the output gap - a reflection of the divine coincidence result.} Perhaps surprisingly, inflation stabilization substantially reduces welfare compared even with output gap stabilization (Column 2). This is because inflation stabilization leads to even more loosening of policy in response to financial shocks.
<table>
<thead>
<tr>
<th></th>
<th>PG</th>
<th>OG</th>
<th>CG</th>
<th>PG &amp; CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opt Taylor rule coefficient</td>
<td>100.0</td>
<td>100.0</td>
<td>0.000</td>
<td>100.0</td>
</tr>
<tr>
<td>Opt LAW coefficient $\phi_b$</td>
<td>0.000</td>
<td>0.000</td>
<td>1.904</td>
<td>92.28</td>
</tr>
<tr>
<td>Welfare</td>
<td>-143.8</td>
<td>-143.3</td>
<td>-143.1</td>
<td>-143.1</td>
</tr>
<tr>
<td>Consumption equivalent</td>
<td>0.000</td>
<td>0.375</td>
<td>0.553</td>
<td>0.630</td>
</tr>
<tr>
<td>SD(II)</td>
<td>0.065</td>
<td>1.454</td>
<td>2.414</td>
<td>2.408</td>
</tr>
<tr>
<td>SD(Y)</td>
<td>2.965</td>
<td>2.117</td>
<td>4.379</td>
<td>4.700</td>
</tr>
<tr>
<td>Mean($P$)</td>
<td>2.222</td>
<td>2.060</td>
<td>1.984</td>
<td>1.934</td>
</tr>
<tr>
<td>SD($P$)</td>
<td>1.124</td>
<td>0.826</td>
<td>0.287</td>
<td>0.226</td>
</tr>
</tbody>
</table>

Table 12: The Effect of Different Monetary Policy Rules on the Benefits of LAW

Note: The table compares key statistics of the baseline model is solved with four different monetary policy rules that are each special cases of equation (27). Under each variant $\rho = 0.85$. In (1), $\phi_\pi$ is optimized and $\phi_y$ and $\phi_b$ are set to 0. In (2), $\phi_\pi$ is 1.5, $\phi_y$ is optimized and $\phi_b$ is set to 0. In (3), $\phi_\pi$ is 1.5, $\phi_b$ is optimized and $\phi_y$ is set to 0. In (4) $\phi_\pi$ and $\phi_y$ are optimized and $\phi_b$ is set to 0. Consumption equivalent values are calculated as the difference between each model and (1).

because financial shocks are similar to markup-like shocks in a standard DSGE model. As a result, LAW outperforms significantly a pure inflation targeting policy. When we optimize over both inflation and credit gap, further gains can be obtained, not surprisingly.

5.5 Trading off financial stability vs. macroeconomic stability

Our model results demonstrate a significant trade-off between the traditional mandates of monetary policy – output and inflation stability – and financial stability - stabilizing, and if possible reducing the probability of financial crisis.

To illustrate this trade-off, we present a “policy frontier” in Figure 10. The policy frontier depicts the range of outcomes that can be implemented by a LAW policy. The frontier is obtained by solving the model for many possible values of $\phi_b$. In particular, in the left panel of Figure 10, we change the LAW coefficient from 0 to 100 to see what happens to the mean probability of financial crises (on the vertical axis) and the standard deviation of the inflation rate (on the horizontal axis). In the right panel, we show the relationship between the mean probability of financial crisis and the stability of economic activity as measured by the standard deviation of output. In a standard New Keynesian DSGE model, it is common to represent the policy frontier as the pairs of volatility of output and inflation that can be obtained. Here, we show how these measures vary with the average probability of a financial crisis.

41 The figure is nearly identical when one uses the output gap instead of output.
The two panels indicate that for low values of the LAW coefficient, there can be a region where the central bank can improve upon both financial stability and traditional monetary policy objectives. This is possible because a rule that sets interest rates based only on inflation is sub-optimal and putting a little weight on the credit gap unambiguously improves outcomes. The panels also show that after a certain point, the central bank can reduce the probability of financial crises only by tolerating higher inflation and/or output volatility. The LAW coefficient where the tradeoff begins differs for output and inflation. This is not surprising since the distortionary effects of responding to financial shocks differs for inflation and output. Nonetheless, the cost of a crisis is large enough that utility is maximized (at $\phi_b = 1.90$) by driving down the probability of a crisis even though doing so substantially raises both inflation and output volatility. This choice reflects the improvement in the distribution of outcomes due to the lower risk of crisis. The welfare maximization challenge is to balance these gains against the losses from the increased volatility of the economy. The analysis suggests that this is an important potential consideration that is often omitted from stabilization discussions.
5.6 Mismeasurement

An important practical consideration is that neither the output gap nor the credit gap is actually observable. In practice efficient movements in credit cannot easily be separated from inefficient ones. In our model, inefficient movements come from demand or financial shocks while efficient ones come from technology shocks. In reality deregulation, changes in property rights and many other factors could also lead to a benign surge in credit and a central bank would need to be able to separate those swings from the inefficient ones. However our model economy does not face this type of mismeasurement problem. Consequently, we might underestimate the issue of real time mismeasurement problem in reality.

To quantify this, we search again for the best policy rules in our baseline specification where the central bank is restricted to just observing actual output and credit - that is, it uses the deviation from the steady-state rather than the deviation from the efficient benchmark. The results are shown in Table 13 (and these should be compared to the findings in Table 2). The mismeasured output gap rule now eliminates all fluctuations in output, including the efficient ones. This leads to higher inflation volatility and noticeably lower welfare. Relying on the mismeasured credit gap still leads to a similar tradeoff as in the baseline model. The central bank delivers less frequent crises, in exchange for higher inflation and output volatility. The relative performance of the rule based on mismeasured credit is bigger in this scenario than in the one with both gaps are perfectly measured. In fact, the best rule when both gaps are considered puts almost no weight on the output gap (and the welfare is about the same as when only the credit gap is used).

The welfare level is actually slightly higher when the mismeasured credit gap is used instead of the perfectly measured output gap; this conclusion depends on all the foregoing factors that have been shown to determine the relative attractiveness of leaning against the wind. For instance, in parameter configurations where the gains from leaning against the wind are low to begin with, then tying the policy rate to mismeasured credit gap would not necessarily lead to higher welfare than a rule that can be set based on a perfectly measured output gap. In these cases, however, the mismeasured credit gap rule would still outperform the mismeasured output gap rule.

One caveat is that in our simple model, most of the credit variation is inefficient, so that the mismeasurement problem is not very significant. This is because credit does not move very
significantly in response to the efficient productivity shocks. We conjecture that if the structure of the model was such that credit was driven either by an efficient financial shock (such as lower real bankruptcy costs) or if the elasticity of credit to productivity shocks were larger (e.g. because the shocks were very persistent), this result might be overturned.

6 Conclusion

Conventional discussions about the links between monetary policy and financial stability typically start by saying that one can appeal to different tools for different jobs. Macro-prudential regulation can address stability concerns, while monetary policy can attend to managing inflation. We agree that this would be the ideal arrangement, however, in practice in many countries this is easier said than done. Macro-prudential policymaking is in its infancy and for some countries the tools barely exist. These practical concerns motivate our analysis.

On the question of whether central banks should alter monetary policy to contain financial stability risks IMF staff study (IMF (2015)) says “Based on our current knowledge, and in present circumstances, the answer is generally no.” We believe this conclusion is premature.

The model we have presented is highly stylized and the parameters are not estimated. Nonetheless, we believe it does capture the ingredients that many of the advocates, and opponents, of leaning

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Table 13: Optimal Policy Rules with Mismeasured Gaps

<table>
<thead>
<tr>
<th></th>
<th>Output gap only (1)</th>
<th>Credit gap only (2)</th>
<th>Both gaps (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welfare</td>
<td>-143.54</td>
<td>-143.25</td>
<td>-143.25</td>
</tr>
<tr>
<td>Consumption equivalent (%)</td>
<td>-0.17</td>
<td>0.09</td>
<td>0.09</td>
</tr>
<tr>
<td>Coefficient $\phi_y$</td>
<td>100</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Coefficient $\phi_b$</td>
<td>0</td>
<td>1.61</td>
<td>1.61</td>
</tr>
<tr>
<td>$400 \times SD(\Pi)$</td>
<td>1.77</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>$100 \times SD(Y)$</td>
<td>0.09</td>
<td>3.82</td>
<td>3.82</td>
</tr>
<tr>
<td>$400 \times E(P)$</td>
<td>2.10</td>
<td>2.01</td>
<td>2.01</td>
</tr>
<tr>
<td>$400 \times SD(P)$</td>
<td>0.90</td>
<td>0.42</td>
<td>0.42</td>
</tr>
</tbody>
</table>

Note: The table compares key statistics of the baseline model when monetary policy is set with three different variants of equation (27). In each case, $\rho = 0.85$ and $\phi_\pi = 1.5$. In (1), the output gap is the deviation from output from its steady state value, $\phi_y$ is optimized and $\phi_b$ is zero. In (2), the credit gap is the deviation from credit from its steady state value, $\phi_b$ is optimized and $\phi_y$ is zero. In (3), both $\phi_b$ and $\phi_y$ are optimized and the output gap is the deviation of output from its steady state value and the credit gap is the deviation from credit from its steady state value. Consumption equivalent values are calculated relative to (1) in Table 2.
against the wind accept as important. In particular, the model presumes that financial crises are very costly, and are partly driven by credit conditions which monetary policy can affect, but attempting to manage credit entails costs in terms of traditional inflation and output objectives. The model can easily uncover circumstances where leaning against the wind is welfare improving.

The model points to a number of factors that will determine the efficacy of leaning against the wind. Our main hesitations in endorsing the conclusion of IMF staff study (IMF (2015)) are that many of these factors are difficult to measure and that existing empirical work still do not provide much guidance about how to calibrate certain of these key elasticities. Perhaps subsequent work will confirm the IMF conclusion but for now we believe it is too early to say that the question is settled.

While we have tried to delineate the key factors determining the desirability of LAW, our model cannot address all factors that are likely relevant. This calls for several straight-forward extensions of our analysis. For instance, one question is whether LAW is still worth the cost if an imperfect (for instance slow moving) macro-prudential policy exists. Another question open for debate is whether the conclusions would still hold if financial shocks affected the economy mostly through a demand channel, so that they do not generate a sharp trade-off between inflation and output.

One powerful conclusion from the model is that the case for leaning against the wind likely rests on accepting higher volatility of inflation and output, in exchange for reducing the risk of crises. If central banks are going to embrace this policy, they will need to invest substantially in explaining this tradeoff to the public and to legislatures.

References


Cairo, I., and J. Sim (2016): “Income Inequality, Financial Crisis and Monetary Policy,” working paper, Federal Reserve Board.


Appendices

A System of Equations

A.1 Non-detrended system of equations

The system has 31 variables:

\[
Y_t = \begin{bmatrix}
       \nu_t & \lambda_t^K & \mu_t & C_t & L_t & \Pi_t & l_t & \Omega_t & M_{t-1,t} & \Lambda_t \\
       N_t & w_t & \Xi_t & R_t & Q_t & K_t & I_t & Y_t & R^K_t & S^K_t \\
       q_t & B_t & \varepsilon_t^* & \chi_t & K^K_t & \tau^K_t & Z_t & h_t & z_t^* & H_t \\
       \Gamma_t & & & & & & & & & 
\end{bmatrix}
\]

The corresponding system of equations are:

\[\nu_t = 1 - \mu_t \quad (A.1)\]

\[0 = 1 - \varphi \Pi_t (\Pi_t - 1) - \eta \nu_t + \varphi E_t \left[ M_{t,t+1} \Pi_{t+1} (\Pi_{t+1} - 1) \frac{Y_{t+1}}{Y_t} \right] \quad (A.2)\]

\[M_{t-1,t} = \beta \frac{\Lambda_t}{\Lambda_{t-1}} \quad (A.3)\]

\[\Lambda_t = C_t^{-\gamma} \quad (A.4)\]

\[\Lambda_t w_t = N_t^\nu \quad (A.5)\]

\[1 = E_t \left( M_{t,t+1} \Xi_t \frac{R_t}{\Pi_{t+1}} \right) \quad (A.6)\]

\[K^K_t = (1 - \delta) K_t + I_t \quad (A.7)\]

\[K_{t+1} = e^{X_t + b} K^K_t \quad (A.8)\]

\[C_t + I_t = Y_t - \frac{\psi}{2} (\Pi_t - \Pi)^2 Y_t \quad (A.9)\]

\[w_t = (1 - \alpha) \mu_t \frac{Y_t}{N_t} \quad (A.10)\]

\[r^K_t = \alpha \mu_t \frac{Y_t}{K_t} \quad (A.11)\]

\[Y_t = Z_t K^K_t N_t^{1-\alpha} \quad (A.12)\]

\[R^K_t = \frac{(1 - \delta) Q_t + r^K_t}{Q_{t-1}} \quad (A.13)\]
\[ S^K_t = Q_t K^w_t - \chi_t q_t B_{t+1} \]  
(A.14)

\[ \varepsilon^*_t = \frac{B_t}{R^K_t Q_{t-1} K_t} \]  
(A.15)

\[ z^*_t = \sigma^{-1}(\log \varepsilon^*_t + 0.5\sigma^2) \]  
(A.16)

\[ H_t = \Phi(z^*_t) \]  
(A.17)

\[ h_t = \phi(z^*_t) \]  
(A.18)

\[ \Omega_t = \Phi(z^*_t - \sigma_t) \]  
(A.19)

\[ q_t = E_t \left( M_{t+1} \left( 1 - H(\varepsilon^*_t+1) + \frac{\zeta}{B_t} R^K_{t+1} Q_t K_{t+1} \Omega(\varepsilon^*_t+1) \right) \right) \]  
(A.20)

\[ \Gamma_t = E_t \left( M_{t+1} R^K_{t+1} \chi^*_t \right) \]  
(A.21)

\[ \chi^K_t = 1 + (\chi_t - 1) \varepsilon^*_t (1 - H(\varepsilon^*_t)) \]  
(A.22)

\[ \Gamma_t = 1 + \gamma (1 - \chi_t L(l_t)) (1 - \chi_t L(l_t)) \]  
(A.23)

\[ L(l_t) = E_t M_{t+1} [\Omega(\varepsilon^*_t+1) \zeta R^K_{t+1} + (1 - H(\varepsilon^*_t+1)) \varepsilon^*_t R^K_{t+1}] \]  
(A.24)

\[ E_t \left\{ M_{t+1} (1 - H(\varepsilon^*_t+1)) \left[ \frac{\chi_t - 1}{\chi_t} + \gamma \left( \frac{S^K_t}{Q_t K_{t+1}} \right) + \gamma^* \left( \frac{S^K_t}{Q_t K_{t+1}} \right) \right] \right\} \]  
(A.25)

\[ = (1 - \zeta) E_t \left\{ M_{t+1} \varepsilon^*_t+1 h(\varepsilon^*_t+1) \left[ 1 + \gamma \left( \frac{S^K_t}{Q_t K_{t+1}} \right) + \gamma^* \left( \frac{S^K_t}{Q_t K_{t+1}} \right) \right] \right\} \]  
(A.26)

\[ Q_t = 1 + \kappa \left( \frac{I_t}{I_{t-1}} - 1 \right) - E_t \left\{ M_{t,t+1} \frac{\kappa}{2} \left( \left( \frac{I_{t+1}}{I_t} \right)^2 - 1 \right) \right\} \]  
(A.27)

\[ l_t = \frac{B_t}{Q_t K^K_w} \]  
(A.28)

\[ \log R_t = (1 - \rho_R) \log R_{t-1} + \rho_R [\log R + \rho_{\Pi} \log (\Pi_t/\bar{\Pi}) + \rho_Y \log (Y_t/Y^F_t)] \]  
(A.29)

\[ \log \chi_t = (1 - \rho_\chi) \log \chi + \rho_\chi \log \chi_{t-1} + \sigma_\chi \epsilon_{\chi,t} \]  
(A.30)

\[ Z_{t+1} = e^{X_{t+1}^b} e^{\varepsilon^*_t Z_t} \]  
(A.31)