Financial Frictions, the Phillips Curve and Monetary Policy

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Abstract

This paper proposes a novel explanation for the missing disinflation after the Global Financial Crisis: The interplay between financial frictions, the Phillips curve and the optimal response by central banks. The structural framework is a tractable financial accelerator New Keynesian DSGE model that allows for closed-form solutions. The presence of financial frictions decreases the slope of the structural Phillips curve via a counter-cyclical credit spread that reduces the pro-cyclicality of marginal costs. This worsens the central bank's trade-off between output gap and inflation stabilization, rendering the former costlier. In this environment, optimal monetary policy is strongly geared towards inflation stabilization, regardless of the policy regime. Following large contractionary shocks, the optimal response by central banks is thus to mitigate disinflation to a large extent.

Keywords: Financial frictions, financial accelerator, Phillips curve, missing disinflation, optimal monetary policy, discretion, commitment, inflation conservatism, inflation targeting.

JEL Classification: E42, E44, E52, E58

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1 Introduction

The missing disinflation in the face of the collapse of output in many advanced economies after the Global Financial Crisis raised a delicate question for macroeconomists: Is the Phillips curve alive and well after all (Coibion and Gorodnichenko, 2015; Hall, 2011; King and Watson, 2012)? This question challenges the idea that inflation and the level of economic activity are inherently linked, a notion that constitutes a fundamental cornerstone of modern thinking about monetary policy. Despite the pressing importance of resolving the missing disinflation puzzle, economists failed to reach a consensus to date.

In this paper, I propose a novel explanation for the missing disinflation puzzle: The interplay between financial frictions, the Phillips curve and the optimal response by central banks. I show that financial frictions – a standard ingredient of many structural macroeconomic models today[1] – alter the Phillips curve and thereby inflation dynamics in three distinct ways. First, they generate a counter-cyclical credit spread that dampens the pro-cyclicality of marginal costs, which in turn decreases the slope of the Phillips curve with respect to the output gap.[2] Second, they amplify the effects of structural shocks by creating endogenous cost-push effects.[3] Third, financial frictions are associated with uncertain future returns and thus render forward-looking behavior by households and firms more relevant to inflation dynamics.[4]

Having established how financial frictions alter the Phillips curve, I analyze how monetary policy should optimally be conducted in this different macroeconomic environment. Broadly speaking, I find that optimal monetary policy is geared towards inflation stabilization in the presence of financial frictions. This is mainly due to the flatter Phillips curve, which worsens the central bank's trade-off between output gap and inflation stabilization, rendering the former costlier. The combination of financial frictions and central banks' optimal response thus constitutes a potential explanation for the missing disinflation puzzle in recent years.

I obtain these findings within an analytically tractable small-scale New Keynesian DSGE model with a labor variant of the financial accelerator by Bernanke et al. (1999). In the model, wages have to be paid before production. Firms are operated by entrepreneurs, who finance the wage bill either by equity or debt financing. The loan contract is subject to a costly state verification problem, which gives rise to a non-zero credit spread that

[1] These models were mainly proposed after the Global Financial Crisis to characterize the interaction between the financial sector and the macroeconomy. Most of them are based on the notion of Bernanke and Blinder (1988) and Bernanke and Gertler (1989, 1995) that financial frictions result from agency costs such that balance sheets of households, firms and/or banks are crucial for macroeconomic dynamics.

[2] This is in line with results obtained by Christiano et al. (2014) and Del Negro et al. (2015), who estimate a very flat Phillips curve using medium-scale financial accelerator models.

[3] See Wieland et al. (2016) and Binder et al. (2017), who document that most financial frictions imply a strong acceleration of macroeconomic shocks on impact relative to models without such frictions.

[4] In the financial accelerator framework by Bernanke et al. (1999) and the workhorse banking model by Gertler and Karadi (2011), expectations of future returns on investing in capital play a key role.

depends on the entrepreneur's leverage. Leverage is counter-cyclical, which translates into a counter-cyclical credit spread that affects marginal costs.

To investigate optimal monetary policy in the context of financial frictions, I proceed in several steps. I first ask: What is the welfare-optimal mandate under financial frictions, i.e. should monetary policy focus on traditional inflation and output gap stabilization and/or stabilize financial variables? I derive the second-order approximation of household utility and show that it gives rise to a mandate for stabilizing inefficient fluctuations in the credit spread and entrepreneur leverage. This mandate is equivalent to closing the output wedge between the flexible-price financial accelerator economy and the efficient economy in the absence of price and financial frictions. With an appropriate redefinition of the output gap, the traditional central bank mandate of inflation and output gap stabilization relative to the efficient allocation thus prevails under financial frictions.

In a second step, I analyze how the presence of financial frictions affects the transmission mechanisms of monetary policy and aggregate shocks. A given change in the nominal interest rate induces counter-cyclical fluctuations in entrepreneur leverage and marginal costs. As a result of this flattening of the Phillips curve, the inflation-output gap trade-off worsens such that output gap stabilization is costlier in terms of inflation. I furthermore demonstrate that financial frictions induce a breakdown of divine coincidence, as shocks are amplified via inefficient credit spread and leverage fluctuations that create endogenous cost-push effects.

Next, I proceed to investigate the ability of monetary policy to stabilize the economy in the face of financial frictions. The tractability of the model allows me to solve the model under optimal discretionary monetary policy in closed form. Under discretion, the targeting rule prescribes a stronger contraction of the output gap as a response to inflation in the presence of financial frictions. This implies a substantial inflationary bias under discretion relative to the standard model, with the bias increasing in the degree of financial frictions. Both biases are amplified by the breakdown of divine coincidence and the higher degree of forward-looking behavior being inherently ignored under discretion.

Having established the sub-optimality of discretion under the welfare-based mandate, I then ask if policy performance can be improved even if the central bank is not able to credibly commit to a future policy. I prove that the stabilization bias relative to first-best policy in the face of financial frictions can be mitigated if society appoints an inflation-conservative central banker in the spirit of Rogoff (1985). If the central banker puts higher weight on inflation stabilization, the public knows that inflation will respond less to any shock, such that expected inflation also reacts less to cost-push shocks. I derive the welfare-maximizing inflation weight analytically and prove that it increases in the degree of financial frictions and shock persistence. I show numerically that discretionary policy with inflation conservatism closely mimics optimal policy under commitment in the financial accelerator economy.

This paper is related to the large literature investigating the missing disinflation puzzle (Hall, 2011; King and Watson, 2012). Within this context, Ball and Mazumder (2011, 2018) and Coibion and Gorodnichenko (2015) explain the missing disinflation by anchored household/firm expectations. Gordon (2013), Watson (2014) and Krueger et al. (2014) propose various different measures of economic slack to reconcile the Phillips curve with the missing disinflation. In line with the paper at hand, Christiano et al. (2015), Del Negro et al. (2015) and Gilchrist et al. (2017) argue that financial frictions are a potential explanation of the missing disinflation puzzle and help to explain inflation dynamics in recent times. These papers use medium-scale New Keynesian DSGE models that are estimated using Bayesian techniques and/or solved numerically. In comparison to these papers, I focus on the effects of financial frictions on the Phillips curve in a small-scale model that can be solved analytically. This enables me to investigate the relationship between structural financial friction parameters and the Phillips curve, in particular with respect to its slope. The closed-form solution also allows to analyze the interplay between the Phillips curve under financial frictions and the optimal response of monetary policy.

In doing so, the explanation for the missing disinflation put forward in this paper complements the literature mentioned above. One main finding of this paper is that monetary policy should be geared towards inflation stabilization in the presence of financial frictions. If central banks follow this optimal policy (at least partly), an anchoring of private inflation expectations should be expected. Moreover, a key implication of the paper at hand is that the definition of output gap as a measure of economic slack is crucial to understand the Phillips curve in the face of financial frictions. The results of this paper should hence be seen as complementary rather than contradictory to other explanations for the disinflation puzzle.

In a broader context, this paper is part of the literature investigating optimal monetary policy in the presence of financial frictions.[5] Carlstrom et al. (2010) introduce agency costs in the spirit of Kiyotaki and Moore (1997) in a small-scale model. De Fiore and Tristani (2013) investigate the financial accelerator in an extension of the basic New Keynesian model. Cúrdia and Woodford (2016) extend the model by a reduced-form link between credit spreads and macroeconomic conditions motivated by household heterogeneity and the need for financial intermediation. Several other papers analyze the performance of simple interest rate rules in models with financial frictions, such as Bernanke and Gertler (2001), Gilchrist and Leahy (2002), Faia and Monacelli (2007) and Boehl (2017). A recurring finding from these papers – although sometimes implicit – is that financial frictions create endogenous additional mark-up effects and/or alter marginal costs. As shown explicitly in the paper at hand, this leads to a breakdown of the canonical "divine

[5]Seminal contributions with respect to optimal monetary policy within the standard New Keynesian DSGE framework encompass Clarida et al. (1999), Rotemberg and Woodford (1999) Woodford (2002), Walsh (2003), Blanchard and Galì (2007) and many others.

coincidence" property of standard models, i.e. financial frictions generate or reinforce the policy trade-offs between stabilizing inflation and the output gap.

The papers that most closely resemble the analysis at hand are the ones by De Fiore and Tristani (2013) and Boehl (2017), who also consider optimal monetary policy in a small-scale financial accelerator model. However, they focus on optimal commitment policy and optimal simple rules, respectively. In contrast, I analyze optimal monetary policy under discretion, when the central bank lacks the ability to commit to future actions. I also provide a tractable variant of the financial accelerator framework that allows for closed-form solutions under discretion. This allows to go beyond the numerical analysis presented in previous papers. On the basis of this analytic characterization, I am subsequently able to investigate the welfare-optimal mandate for discretionary monetary policy in the presence of financial frictions and establish the theoretical optimality of inflation conservatism in this context.

The notion of inflation conservatism follows the seminal contribution by Rogoff (1985). For the standard New Keynesian model, Clarida et al. (1999) find that a central banker with lower weight on output gap stabilization relative to inflation mitigates the stabilization bias of discretionary policy. Adam and Billi (2008), Adam and Billi (2014), and Niemann (2011) analyze inflation conservatism with endogenous fiscal policy. Schmidt and Nakata (2015) show that inflation conservatism is advisable if the zero lower bound on nominal interest rates is explicitly taken into account. In comparison to these papers, I investigate the implications of financial frictions for the optimality of the central bank conservatism. Paoli and Paustian (2017) argue numerically that appointing a conservative central banker may improve outcomes when macroeconomic stabilization is a joint mandate of monetary and macroprudential policy in a banking-type model à la Gertler and Karadi (2011). In contrast to their analysis, I employ the canonical financial accelerator mechanism, focus solely on monetary policy and provide completely analytic results, including conditions under which the degree of inflation conservatism is increasing in the degree of financial frictions.

The paper is structured as follows. Section 2 describes the model setup, derives a tractable three-equation representation and outlines that the model incorporates the three key characteristics of many financial frictions models. Section 3 derives the household welfare approximation to provide a first benchmark central bank mandate. Section 4 investigates optimal discretionary monetary policy. I first provide an analytic solution of the model and characterize the inflationary bias in the financial accelerator economy relative to the standard model. Beyond this, I establish the advisability of inflation conservatism and shows that inflation-conservative discretionary policy is able to substantially reduce the stabilization bias relative to the fully optimal commitment policy. Section 5 concludes and provides ideas for future research.

2 The Model

I propose a small-scale New Keynesian DSGE model with an accelerated cost channel of monetary policy, giving rise to a financial accelerator mechanism. This section describes the model setup, depicts its characteristics and analyzes the featured economic channels.

2.1 The Economy

The model environment is populated by a representative households and a continuum of risk-neutral entrepreneurs, with the latter operating wholesale goods firms. In contrast to the standard model, wages have to be paid before production as in Ravenna and Walsh (2006) such that entrepreneurs need to obtain external financing. The presence of a costly-state-verification problem between financial intermediaries and wholesale firms requires the loan rate to be a mark-up over the safe interest rate, with the mark-up being a function of firm leverage. This generates a financial accelerator mechanism à la Bernanke et al. (1999).

The timing of events is as follows: At the beginning of the period, the aggregate technology shock materializes.[6] Financial markets open, and households decide on consumption and savings. The financial intermediary collects household deposits, and financial traders purchase equity claims from the entrepreneurs. Afterwards, the entrepreneurs obtain external financing via a standard debt contract from financial intermediaries contingent on the amount of available funds raised on the stock market. In the second part of the period, the goods market opens and an idiosyncratic wholesale productivity shock materializes. Wholesale firms produce the homogeneous good subject to their idiosyncratic productivity and sell it to retailers. If the realization of their individual productivity shock is too low, they default and the financial intermediary seizes the remaining production. Otherwise, they repay their debt to the financial intermediary and rebate their profits to stockholders, which in turn rebate them lump-sum to households. Finally, retail firms use the wholesale goods to produce differentiated goods and sell them to households for consumption.

Households: The household sector is completely standard. A representative infinitely lived household maximizes expected present discounted value of utility given by

$$U_t = E_t \sum_{s=0}^{\infty} \beta^s \left\{ \frac{C_{t+s}^{1-\sigma}}{1-\sigma} - \chi \frac{H_{t+s}^{1+\eta}}{1+\eta} \right\}$$

specifying that utility is separable in consumption C_t and labor supply H_t. Consumption

[6] In the baseline setup, this is the only aggregate shock. In Section 4.3, I present an extension of the model with aggregate preference and financial shocks, which is shown in more detail in the Appendix.

C_t is a composite of differentiated goods c_{jt} such that

$$C_t = \left[\int_0^1 C_{jt}^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}$$

where ϵ governs the elasticity of substitution. The representative household holds deposits B_t at a financial intermediary, which yield a safe gross nominal return R_t in the next period. The household also receives real wages W_t from supplying labor H_t and lump-sum aggregate profits Ω_t from financial intermediaries and retail firms. The household's budget constraint in nominal terms is thus given by

$$P_t C_t + B_t \leq R_{t-1} B_{t-1} + P_t W_t H_t + \Omega_t$$

Household optimization gives rise to the following standard Euler equation governing the inter-temporal allocation of consumption

$$C_t^{-\sigma} = \beta E_t \left[\frac{R_t}{\Pi_{t+1}} C_{t+1}^{-\sigma} \right] \tag{1}$$

where $\Pi_t = P_t / P_{t-1}$ is the gross inflation rate. The intra-temporal optimality condition for the trade-off between labor and consumption is given by:

$$\frac{\chi H_t^{\eta}}{C_t^{-\sigma}} = W_t \tag{2}$$

Wholesale Firms: The wholesale sector is populated by a continuum of competitive firms, each being operated by a risk-neutral entrepreneur which are indexed by i. Each wholesale firm produces a homogeneous good according to a production function that is linear in labor

$$Y_{i,t} = A_t \, \omega_{i,t} H_{i,t}$$

where $\omega_{i,t}$ is an idiosyncratic productivity shock, $H_{i,t}$ is firm-specific labor input, and A_t is an aggregate productivity shock which follows an exogenous AR(1) process:

$$\frac{A_t}{A} = \left(\frac{A_{t-1}}{A} \right)^{\rho_a} e^{\varepsilon_{a,t}} \tag{3}$$

with $A = 1$ and $\varepsilon_{a,t}$ being a white-noise shock.

Following Ravenna and Walsh (2006), workers have to be paid before production such that entrepreneurs need to obtain external financing before observing the idiosyncratic productivity shock (but after observing the aggregate shock). At the time of obtaining the external financing, entrepreneurs have available real internal funds of $N_{i,t}$ obtained by equity financing, which is described in more detail below. In order to hire workers at the market-determined wage, entrepreneurs thus need to acquire a loan $L_{i,t}$ given by:

$$L_{i,t} \geq W_t H_{i,t} - N_{i,t}$$

Entrepreneurs borrow at a financial intermediary at the loan rate R_t^L. The banking sector is assumed to be competitive, with banks using collected household deposits to finance the loans to firms. Facing a common wage determined on the labor market, the cost minimization of each wholesale firm is hence given by

$$\begin{aligned} \underset{H_{i,t}}{min} \qquad & W_t H_{i,t} R_t^L \\ s.t. \qquad & \omega_{i,t} A_t H_{i,t} \geq \left(\frac{P_{i,t}}{P_t}\right)^{-\epsilon} Y_t \end{aligned}$$

where the right-hand-side of the constraint is the retailer's demand for good i under monopolistic competition, to be described further below. As the good produced by wholesale firms is homogeneous, aggregating the resulting first-order conditions across firms is straightforward and yields aggregate real marginal costs MC_t given by

$$MC_t = \frac{R_t^L W_t}{A_t} \tag{4}$$

In the cost-channel model by Ravenna and Walsh (2006), the loan rate is simply given by the gross nominal rate as set by the central bank. Here, I model a financial friction that generates a spread between the loan rate and the nominal interest rate. As in Bernanke et al. (1999) and De Fiore and Tristani (2013), the source of the financial friction is a costly state verification problem à la Townsend (1979) between firm's and banks. More specifically, the idiosyncratic productivity shock $\omega_{i,t}$ materializes after production and is assumed to be private information of the entrepreneur, while aggregate technology A_t is publicly observed. The bank can only observe the idiosyncratic output of firms after production by paying monitoring costs ζ proportional to output. As shown by De Fiore and Tristani (2013), the costly state verification problem gives rise to a standard debt contract, which specifies that entrepreneur and financial intermediary share the wholesale profit. In particular, the debt contract is characterized by a threshold value for the idiosyncratic shock $\bar{\omega}_t$ defined by:

$$\bar{\omega}_t A_t H_t = R_t^L \left(W_t H_t - N_t\right) \tag{5}$$

If the realization of $\omega_{i,t} \geq \bar{\omega}_t$, the firm repays its debt and the bank does not monitor the firm. If $\omega_{i,t} < \bar{\omega}_t$, the firm defaults, the bank decides to monitor the firm, pays the monitoring cost and seizes the remaining fraction of output. In the Appendix, I show that the contract implies that the credit spread evolves according to

$$\frac{R_t^L}{R_t} = s\left(\frac{N_t}{W_t H_t}\right) \tag{6}$$

with $s'() < 0$, i.e. the credit spread is positively related to entrepreneur leverage. Intuitively, if the level of available internal funds is low relative to the wage bill, leverage is high and it is more likely that the entrepreneur is not able to repay. As such, higher leverage of the entrepreneur raises the probability of default and hence the riskiness of the loan contract for the financial intermediary. As a compensation, the financial intermediary requires a mark-up such that the loan rate increases in leverage. In particular, it decreases in the amount of internal funds that entrepreneurs have available prior to production.

To conclude the description of the financial contract, note that the share of output accruing to the financial intermediary is given by

$$g(\bar{\omega}_t, \zeta) = \frac{R_t(W_t H_t - N_t)}{A_t H_t} \tag{7}$$

and the entrepreneur's share is:

$$f(\bar{\omega}_t) = 1 - g(\bar{\omega}_t, \zeta) - \zeta \int_0^{\bar{\omega}_t} \omega_t \Phi d\omega \tag{8}$$

Stockholders: I follow the lines of Boehl (2017), who assumes that entrepreneurs issue equity on the stock market. Stocks are priced by financial traders associated with the financial intermediary according to the expected dividend. Keeping in mind that the costs of financing for financial intermediaries are given by the nominal interest rate on deposits and imposing no arbitrage, the stock price S_t is then given by

$$S_t = N_t \frac{E_t[R_{t+1}^S]}{R_t} \tag{9}$$

where R_{t+1}^S denotes the return on equity. In equilibrium, with risk-neutral entrepreneurs being indifferent between increasing or decreasing the loan volume, it must hold that the costs of equity financing equals the cost of external financing:

$$E_t[R_{t+1}^S] = R_t^L \tag{10}$$

To facilitate the analysis, I assume that stockholders can monitor and liquidate wholesale firms without costs (see Boehl, 2017). I furthermore assume that entrepreneur consumption is taxed by the government at an arbitrarily large rate. As a result, entrepreneurs maximize the return on equity and are willing to distribute all their profits to stockholders as dividends, since any profit kept for consumption purposes would be taxed away. In turn, stockholders distribute their profits as lump-sum transfers to households. From the financial contract, the return on equity is given by a share of output $f(\bar{\omega}_t)Y_t$. Accordingly, financial traders attach a price of

$$S_t = \frac{f(\bar{\omega}_t)Y_t}{R_t} \tag{11}$$

In the Appendix, I show that internal funds of entrepreneurs then evolve according to

$$N_t = g\left(Y_t, R_t\right) \tag{12}$$

with $\frac{\partial N_t}{\partial Y_t} > 0$, $\frac{\partial N_t}{\partial R_t} < 0$, i.e. equity financing is pro-cyclical and depends negatively on nominal interest rates.

In contrast to the standard setup in Bernanke et al. (1999) and the labor-variant used by De Fiore and Tristani (2013) – where entrepreneur net worth is being accumulated internally over time via retained profits – I hence model entrepreneur net worth as stemming from equity financing as in Boehl (2017). I furthermore abstract from entrepreneur consumption by assuming that they are fully taxed and can be liquidated at any time and thus distribute all profits as dividends to stockholders. While these modeling choices may seem as strong assumptions, they allow to keep the model setup analytically tractable by avoiding that equity becomes an endogenous state variable. As shown further below, this setup gives rise to a counter-cyclical entrepreneur leverage being relevant for marginal costs. In turn, this preserves the canonical financial accelerator mechanism.

Retail Firms: A continuum of retailers indexed by j buys wholesale output from entrepreneurs on the competitive wholesale market, taking the wholesale price as given. Wholesale goods are differentiated by retailers at no cost and sold to households. Operating in a monopolistically competitive market, each retailer j has some market power and sets a price $P_{j,t}$. Following Calvo (1983), each retail firm is subject to staggered pricing, i.e. may not change its price with probability θ each period. Retail firms are owned by the representative households, such that the price setting problem is given by:

$$\begin{aligned}
\underset{P_{j,t}}{max} \quad & E_t \sum_{s=0}^{\infty} (\beta\theta)^s \frac{u'(C_{t+s})}{u'(C_t)} \left(\frac{P_{j,t}}{P_{t+s}} (Y_{j,t+s} - MC_{t+s}) \right) \\
s.t. \quad & Y_{j,t+s} = \left(\frac{P_{j,s}}{P_{t+s}} \right)^{-\epsilon} Y_{t+s}
\end{aligned}$$

Each retail firm maximizes the expected discounted stream of profits, subject to the price rigidity and the demand for its individual good, which stems from household cost minimization. The solution to this optimization problem specifies that all retailers that can adjust prices set the same price, which is given by:

$$P_t^* = \frac{\epsilon}{\epsilon - 1} \frac{E_t \sum_{s=0}^{\infty} (\beta\theta)^s u'(C_{t+s}) MC_{t+s} P_{t+s}^{\epsilon} Y_{t+s}}{E_t \sum_{s=0}^{\infty} (\beta\theta)^s u'(C_{t+s}) P_{t+s}^{\epsilon-1} Y_{t+s}} \tag{13}$$

The aggregate price level then follows:

$$P_t^{1-\epsilon} = \theta P_{t-1}^{1-\epsilon} + (1-\theta)(P_t^*)^{1-\epsilon} \tag{14}$$

Market Equilibrium and Monetary Policy: The final output good is a CES composite of individual retail goods:

$$Y_t = \left(\int_0^1 Y_{j,t}^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}}$$

Market clearing in the goods market and in the labor market requires that

$$Y_t = C_t \tag{15}$$

and

$$Y_t = \frac{A_t H_t}{D_t} \tag{16}$$

where D_t is a measure of price dispersion given by:

$$D_t = \int_0^1 \frac{P_{j,t}}{P_t}^{-\epsilon} dj = (1-\theta) \left(\frac{1-\theta \Pi_t^{\epsilon-1}}{1-\theta} \right)^{\frac{\epsilon}{\epsilon-1}} + \theta \Pi_t^{\epsilon} D_{t-1} \tag{17}$$

To close the model, let the central bank set the nominal interest rate R_t, either as a result of an optimal policy optimization problem or following a Taylor-type policy rule. In the latter case, which will be used as a simple benchmark for optimal discretionary policy, the policy rule is simply specified as:

$$\frac{R_t}{R} = \left(\frac{\Pi_t}{\Pi} \right)^{\phi_\pi} \tag{18}$$

To summarize, the model's aggregate dynamics are characterized by Equations (1)-(18) for variables $Y_t, C_t, H_t,\ MC_t, W_t, R_t, P_t, P_t^*, \Pi_t, D_t, R_t^L, R_t^S, N_t, S_t, \bar{\omega}_t, g(\bar{\omega}_t, \zeta), f(\bar{\omega}_t)$ and the sole aggregate shock A_t. Equations (1)-(3) and (13)-(17) are standard and shared with the classic New Keynesian DSGE model, while Equations (4)-(12) describe the financial accelerator.

2.2 Linearized Model

To facilitate the analytic analysis of the model, I consider the linearized version of the model. I log-linearize Equations (1)-(17) around the non-stochastic steady state and denote variables in percentage deviations from steady state with lower case letters ($x_t = log(X_t) - log(X)$). This yields the following linearized equations for the household sector:

$$y_t = -\sigma^{-1} \left(r_t - E_t[\pi_{t+1}] \right) + E_t[y_{t+1}] \tag{19}$$

$$w_t = \eta h_t + \sigma y_t \tag{20}$$

Both the Euler Equation (19) and the intra-temporal trade-off between labor supply and consumption (20) are standard. Moving to the firm sector, the aggregate production function in linear terms is simply given by:

$$y_t = a_t + h_t \tag{21}$$

The Calvo pricing problem gives rise to a standard New Keynesian Phillips curve

$$\pi_t = \kappa\, mc_t + \beta E_t[\pi_{t+1}] \tag{22}$$

where $\kappa = \frac{(1-\theta\beta)(1-\theta)}{\theta}$. Marginal costs are given by

$$mc_t = w_t + \vartheta r_t^L - a_t \tag{23}$$

where I introduce the parameter ϑ as an indicator that governs the presence of the cost channel. With $\vartheta = 1$, firms have to pay the entire wage bill in advance of production such that the loan rate enters marginal costs one-for-one. $\vartheta = 0$ eliminates the cost channel and reverts the model back to the standard framework. This allows a straightforward comparison of the financial accelerator economy and the standard New Keynesian framework in the optimal monetary policy analysis below.

The credit spread specified by the financial contract is given by:

$$r_t^L - r_t = \nu(w_t + h_t - n_t) \tag{24}$$

The sensitivity of the credit spread with respect to leverage in Equation (24) is captured by $\nu > 0$. An increase in leverage by one percent thus triggers an increase in the spread by ν percent. Finally, as shown in the Appendix, equity is given by:

$$n_t = \psi y_t - \mu r_t \tag{25}$$

The elasticities of equity financing with respect to output and the nominal interest rate are governed by ψ and μ, respectively. Lastly, for the reference case where the central bank follows a Taylor rule, this is given in linear terms by:

$$r_t = \phi_\pi \pi_t \tag{26}$$

2.3 Model Properties

This section is devoted to gaining intuition into the dynamic properties of the model, in particular to how the introduction of financial frictions alters the economy in comparison to the standard New Keynesian model. For that purpose, it is possible to reduce the amount of equations to obtain a more parsimonious representation that is more insightful and directly comparable to the standard framework. As a starting point, note that output in the efficient economy, which is the counterfactual economy in which prices are flexible and financial frictions are absent, is given by:

$$y_t^e = \frac{1+\eta}{\sigma+\eta} a_t \tag{27}$$

Let us furthermore denote the output gap with respect to this economy as:

$$x_t = y_t - y_t^e \tag{28}$$

By making use of Equations (27)-(28) and combining Equations (19)-(25), one can rewrite the model as:

$$x_t = -\sigma^{-1}\left(r_t - E_t[\pi_{t+1}]\right) + E_t[x_{t+1}] - \varphi\, a_t \tag{29}$$

$$\pi_t = \mathcal{K}\, x_t + \vartheta\kappa(1+\nu\mu)\, r_t + \beta E_t[\pi_{t+1}] - \vartheta\nu\kappa\phi\, a_t \tag{30}$$

where $\mathcal{K}$, φ and ϕ are parameters described below. The small-scale nature of the model and the assumptions made for tractability purposes thus allow to characterize the model in three equations only: The Euler equation (29) in terms of the output gap, a financial-frictions-augmented Phillips curve (30) and a specification of the nominal interest rate as set by the central bank.

Despite its simplicity, this framework captures three key characteristics of many state-of-the art financial frictions models. First, the macroeconomic effects of structural shocks are amplified, as the financial accelerator alters their transmission channels. In this baseline version of the model, the only aggregate shocks are technology shocks a_t. As in the standard model, positive technology shocks appear negatively in the Euler equation, where the strength is governed by the coefficient

$$\varphi \equiv \frac{(1+\eta)(1-\rho_a)}{\sigma+\eta} \tag{31}$$

A positive realization of the technology shock a_t raises current output from the supply side, thus requiring a fall in the real interest rate to induce a corresponding rise in demand today. Under financial frictions, technology shocks unfold additional effects. As seen in Equation (30), technology shocks also enter in the Phillips curve in the financial accelerator economy, where the coefficient ϕ is given by:

$$\phi \equiv \frac{(1+\eta)}{\sigma+\eta}(\psi-1) \tag{32}$$

To understand the economic interpretation of this result, it is useful to state a mild assumption on the pro-cyclicality of equity financing:

Assumption 1 *The elasticity of equity financing with respect to output is larger than one:* $\psi > 1$.

Lemma 1 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Under Assumption 1, positive technology shocks induce endogenous negative cost-push effects that amplify the expansionary output response.*

The intuition for this finding is straightforward. With financial frictions, a technology shock affects both sides of the entrepreneur's balance sheet. On the one hand, a positive technology shock raises the loan size one-for-one, as labor demand increases for a given wage. On the other hand, the expansionary effect also increases available equity financing via higher expected profits. The total effect on leverage is thus in principle ambiguous, with the size depending on ψ. If ψ is larger than one as specified in Assumption 1, the latter effect of pro-cyclical equity financing dominates. As a result, entrepreneur leverage is counter-cyclical in response to technology shocks, translating into a counter-cyclical credit spread. In turn, technology shocks generate additional negative cost-push effects, which decrease inflation further through lower marginal costs. Finally, the lower marginal costs act as a financial accelerator and increase the expansionary effect of the productivity shock on output.[7]

A second feature of the financial accelerator economy is a change in inflation dynamics. In the financial-frictions-augmented Phillips curve given by Equation (30), the slope with respect to the slope of the Phillips curve with respect to the output gap is given by

$$\mathcal{K} \equiv \kappa(\sigma + \eta + \vartheta\nu(1 + \sigma + \eta - \psi)) \tag{33}$$

Let us state another assumption on the pro-cyclicality of equity financing:

Assumption 2 *The elasticity of equity financing with respect to output satisfies $\psi > 1 + \sigma + \eta$.*

While Assumption (2) is slightly more restrictive than Assumption (1), it is nevertheless a rather mild assumption.[8] With this assumption, we can postulate the following:

Lemma 2 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Under Assumption 2, the Phillips curve with respect to the output gap flattens relative to the standard New Keynesian framework.*

To gain some intuition for this result, consider the standard model first, which implies for $\nu = \vartheta = 0$ such that the slope of the Phillips curve is given by $\mathcal{K} = \kappa(\sigma + \eta)$. In this case, marginal costs are simply given by a function of wages and aggregate productivity (see Equation 23). Suppose that for whatever reason, wholesale firms want to expand production. This requires them to hire more labor and to pay households a higher wage

[7] For $\psi < 1$, the framework can also accommodate the notion that the financial sector may shield the macroeconomy from disturbances, i.e. act as a "financial decelerator" as in Gerali et al. (2010).

[8] For example, under log-utility in consumption such that $\sigma = 1$ and the borderline case of no disutility in labor $\eta = 0$, the elasticity only needs to exceed 2.

(given some level of technology), as seen in Equation (20). This raises marginal costs by $(\sigma+\eta)^{-1}$, depending on the elasticities of labor supply and the degree of inter-temporal consumption smoothing which determine the household's intra-temporal consumption-labor trade-off.

This contrasts to the case where financial frictions are present, in which case the increased labor demand and wages require the entrepreneur to acquire a larger loan to pay workers in advance. This translates into an increase of leverage and a higher loan rate. As a consequence, marginal costs increase by more than in the standard model. However, the higher output also raises expected dividends and thus allows entrepreneurs to raise more equity, thus decreasing leverage, which counteracts the first effect. Under Assumption 2, equity financing is sufficiently pro-cyclical such that the second channel dominates. Accordingly, the slope of the Phillips curve is flatter than in the standard model without financial frictions.

A third characteristic of the financial accelerator economy refers to forward-looking behavior. This can be seen by iterating the Phillips curve given in Equation (30) forward to obtain:

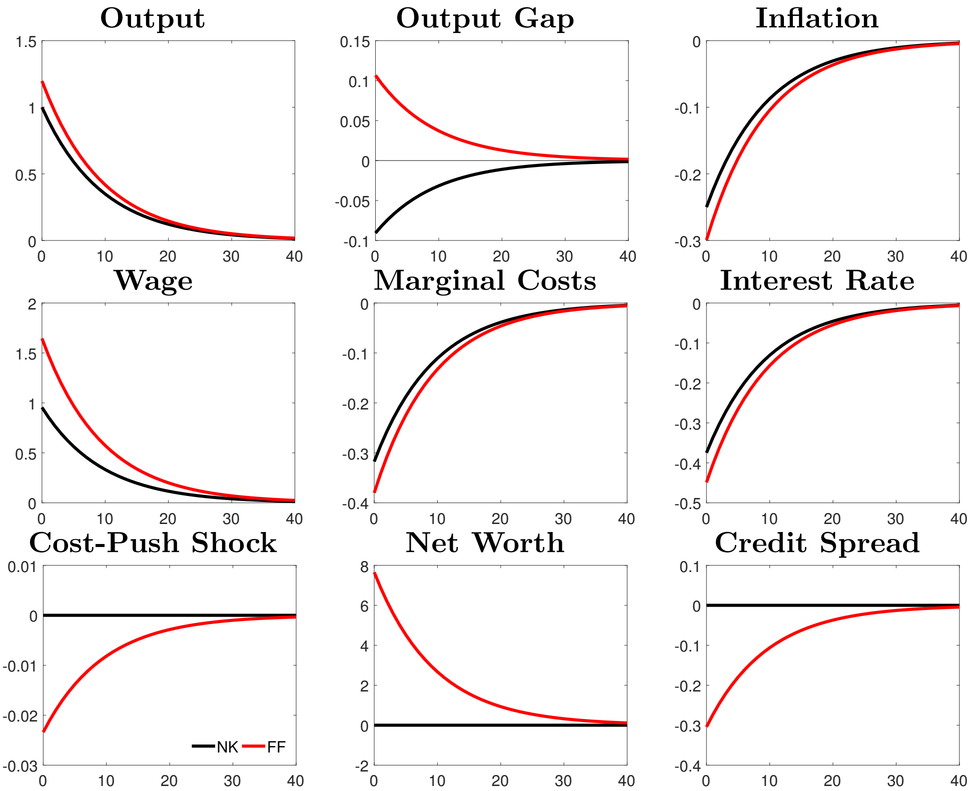
$$\pi_t = \mathcal{K}\sum_{s=0}^{\infty}\beta^s E_t[x_{t+s}] + \vartheta\kappa(1+\nu\mu)\sum_{s=0}^{\infty}\beta^s E_t[r_{t+s}] + \vartheta\nu\frac{\phi}{1-\beta\rho_a}a_t \tag{34}$$

Lemma 3 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Then, expectations of future nominal interest rates matter directly for current inflation dynamics.*

As evident from this equation, financial frictions increases the degree to which forward-looking behavior matters for current period inflation dynamics. In the standard model, nominal interest rates are set by the central bank to influence household behavior via the Euler curve, taking their expectations of future inflation and output gap into account. With the financial accelerator, however, nominal interest rates directly affect marginal costs as well by increasing the loan rate that entrepreneurs have to repay. On the one hand, there is a direct one-to-one increase in the loan rate as the higher nominal interest rate is equivalent to higher funding costs of financial intermediaries via deposits. On the other hand, the increase in nominal interest rates also reduces the available equity financing, such that entrepreneur leverage increases, in turn raising the credit spread by further. As such, retail firms take current and future expected nominal interest rates into account when making their pricing decisions as these constitute important components of current and future expected marginal costs.

Taken together, these three characteristics of the financial accelerator economy imply that macroeconomic dynamics are fundamentally different. As an illustration, consider a positive technology shock, as shown in Figure 1. The impulse responses should be understood as illustrative and are obtained under a standard calibration that satisfies

Figure 1: Technology Shock



Note: Impulse response functions for a technology shock with an autoregressive coefficient of 0.9. The shock size is calibrated to yield a one-percent increase of output under the Taylor rule in the NK model. All variables are in percentage deviations from the non-stochastic steady state, except for inflation and interest rate which are in percentage-point deviations. A period is a quarter, NK is the standard New Keynesian model (in black) and FF (in red) is the financial accelerator economy.

Assumption 2, with the central bank following a Taylor rule.[9] The size of the shock is calibrated such that output expands by one percent in the standard New Keynesian model. In the absence of financial frictions, the technology shock act reduces marginal costs and hence inflation directly. The output gap is negative due to the presence of price stickiness. The central bank reacts to the deflationary pressure by reducing the nominal interest rate.

In the financial accelerator economy, the positive technology shock unfolds endogenous negative cost-push effects, as shown in the lower left panel. The financial accelerator mechanism operates through a pronounced pro-cyclicality of net worth, in turn generating a counter-cyclical credit spread. This leads to a further decrease of marginal costs and inflation. As a result, the output effect is accelerated and the output gap is positive. With financial frictions, inflation and output gap thus move in opposite directions following technology shocks.

Let us summarize the model description. The proposed framework is a small-scale

[9] A more detailed description of the calibration is outlined in Section 4.3 for the numerical comparison of discretionary policy to the case of commitment.

New Keynesian DSGE model with a financial accelerator mechanism. The tractability of the linearized model allows to characterize the economy in three equations only. While the Euler equation and the monetary policy specification are unchanged, financial frictions alter the Phillips curve in three ways. First, technology shocks unfold endogenous cost-push effects, such that their expansionary effects are amplified. Second, the slope of the Phillips curve with respect to the output gap decreases because of a counter-cyclical credit spread. Third, expectations of future nominal interest rate matter for current inflation dynamics as they directly affect marginal costs. While being relatively simplistic, the model hence incorporates the key characteristics of many more complex financial frictions models and implies substantially different macroeconomic dynamics compared to the standard model.

3 Welfare Approximation

As shown above, the presence of financial frictions fundamentally changes the economy's characteristics, which has crucial implications for the optimal behavior of central banks. The predominant and overarching question for the design of optimal monetary policy is the mandate that central banks should pursue. In the present context, this amounts to asking whether financial frictions imply a different welfare-optimal central bank mandate compared to the standard framework. In other words, what is the welfare-optimal mandate in the financial accelerator economy, and (how) is it different from the standard case?

When thinking about the optimal central bank mandate, it is standard to assume that the central bank is benevolent and thus aims to maximize welfare. Following this notion, one can interpret the maximization of household utility as the relevant mandate for central banks. The seminal contributions by Rotemberg and Woodford (1999) and Benigno and Woodford (2004) show that a second-order approximation of household welfare in the standard New Keynesian model yields a quadratic policy objective in inflation and output. This finding has been widely interpreted as theoretical support for a central bank mandate consisting of stabilizing inflation and economic activity only, and in particular for inflation targeting.[10]

To investigate whether the presence of financial frictions requires a non-standard central bank mandate in the model at hand, I thus first follow the literature and derive a second-order Taylor approximation of household utility around the deterministic steady state. The steady-state output level of the financial accelerator economy Y^{FF} is given

[10] This result also supported the "Jackson Hole consensus" (Bean et al., 2010; Bernanke and Gertler, 1995). According to this view, central banks should not directly be concerned with financial stability, and (systematically) reacting to asset prices and other financial market measures is considered unnecessary at best. Following this notion, maintaining price stability is considered the best a central bank can do to contribute to financial stability.

by:

$$Y^{FF} = \left[\chi^{-1} \left(\frac{\epsilon}{\epsilon - 1} \right)^{-1} \left(R^L\right)^{-\vartheta} \right]^{\frac{1}{\sigma+\eta}} \tag{35}$$

This shows that steady-state output in the financial frictions economy is low because of two inefficiencies. First, as in the standard model, monopolistic competition in the retail market implies that all firms charge a mark-up $\epsilon/(\epsilon-1)$ over marginal costs. Second, the presence of financial frictions means that marginal costs are inefficiently high as entrepreneurs need to lend at the rate R^L to pay workers in advance. The mark-up and the loan rate generate a wedge between household's marginal rate of substitution between leisure and consumption and the marginal product of labor, which is given by aggregate productivity. Following Galí et al. (2007), we can label this wedge as the inefficiency gap.

Lemma 4 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). The inefficiency gap between the marginal rate of substitution and the marginal product of labor is given by*

$$\frac{\chi H^{\eta}}{C^{-\sigma}} A^{-1} = \left(\frac{\epsilon}{\epsilon - 1} \right)^{-1} \left(R^L\right)^{-\vartheta} \tag{36}$$

In the following, however, I assume that there are some steady-state subsidies τ to firm's marginal costs such that the steady-state of the financial accelerator economy is efficient and coincides with the one of the standard model. This is a standard assumption in the literature made to facilitate the analysis.

Assumption 3 *The government issues steady-state subsidies $\tau = \frac{\epsilon}{\epsilon-1}(R^L)^{\vartheta}$ to firm's marginal cost.*

Lemma 5 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Under Assumption 3, the governments corrects for the two steady-state distortions generated by monopolistic competition and financial frictions such that the steady-state is efficient and given by*

$$Y^{FF} = \left[\chi^{-1} \tau \left(\frac{\epsilon}{\epsilon - 1} \right)^{-1} \left(R^L\right)^{-\vartheta} \right]^{\frac{1}{\sigma+\eta}} = \chi^{-\frac{1}{\sigma+\eta}} = Y^{NK} \tag{37}$$

Under this assumption, I derive the second-order approximation of household welfare, which yields the following result:

Proposition 1 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Under Assumption 3, one can approximate household welfare $\mathcal{W}_t$ as*

$$\mathcal{W}_t = E_t \sum_{s=0}^{\infty} \beta^s \left(\frac{U_{t+s} - U}{U_c C} \right) \approx -\frac{1}{2} E_t \sum_{s=0}^{\infty} \beta^s \mathcal{L}_{t+s} \tag{38}$$

where the period-by-period loss function is given by

$$\mathcal{L}_t = \pi_t^2 + \lambda \left(x_t^f - \frac{\vartheta}{\sigma+\eta} r_t^f - \frac{\vartheta \nu}{\sigma+\eta} lev_t^f \right)^2 \tag{39}$$

where

$$\lambda \equiv \frac{\kappa(\sigma+\eta)}{\epsilon} \tag{40}$$

and

$$x_t^f = y_t - y_t^f \tag{41}$$

$$lev_t^f = w_t^f + h_t^f - n_t^f \tag{42}$$

and variables with superscript f refer to the flexible-price financial accelerator economy.

Proof. See Appendix. ■

As in the standard model, household welfare can be approximated by a loss function that looks like a traditional central bank mandate and prescribes inflation and output stabilization. In the financial accelerator economy, the economic stabilization motive consists of stabilizing the output gap with respect to the flexible-price economy (x_t^f) and mitigating fluctuations in the nominal interest rate and entrepreneur leverage. The latter mandate refers to flexible-price variables and is equivalent to the dynamic wedge between flexible-price output and the efficient level of output introduced by the financial accelerator.[11]

Lemma 6 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). The dynamic output wedge between the financial accelerator economy without nominal rigidities and the fully efficient economy is given by:*

$$y_t^f - y_t^e = -\frac{\vartheta}{\sigma+\eta} r_t^f - \frac{\vartheta\nu}{\sigma+\eta} lev_t^f = -\frac{\vartheta}{\sigma+\eta} r_t^{L,f} \tag{43}$$

As outlined above, the presence of financial frictions implies a wedge between wages and the marginal product of labor via the need of entrepreneurs to lend at the rate R_t^L. This wedge is not solely present in the steady-state, but persists when the economy is hit by shocks. Keeping in mind that the loan rate is counter-cyclical under Assumption 2, Lemma 6 shows that the wedge is pro-cyclical, which again underlines the financial accelerator mechanism.

How should one interpret these findings? In particular, do they imply that optimal central bank mandates are fundamentally different in the presence of financial frictions? In the financial accelerator economy at hand, the answer is clearly no. The new mandate elements, relative to the standard model, refer to the wedge between flexible-price economy and the efficient level of output. Yet, a central bank in control of the nominal interest

[11]This dynamic wedge is not covered by the steady-state subsidy to marginal costs. For the price stickiness wedge, it is a well-known result that first-best policy consists of an appropriate dynamic subsidy to marginal costs to eliminate this wedge (see Correia et al., 2008). However, this is not the focus of the paper at hand. Yet, it should be noted that this conveys an interesting notion of dynamic macroprudential policy in the context of the financial accelerator economy. Investigating this issue is left to future research.

rate is only able to influence fluctuations of the economy relative to the flexible-price economy directly. In other words, the new mandate is independent of monetary policy as the nominal rate in the counterfactual flexible-price economy adjusts endogenously.[12]

We can also see this by rewriting the mandate in terms of the output gap with respect to the efficient output prevailing in a counterfactual economy with flexible prices and without financial frictions.

Lemma 7 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). The loss function obtained by approximating household welfare to a second order can be written as*

$$\mathcal{L}_t = \pi_t^2 + \lambda\, x_t^2 \tag{44}$$

where again

$$\lambda = \frac{\kappa(\sigma+\eta)}{\epsilon} \tag{45}$$

and

$$x_t = y_t - y_t^e = y_t - \frac{1+\eta}{\sigma+\eta} a_t \tag{46}$$

In other words, the loss function representing household welfare in the financial accelerator economy is almost identical to the one of the standard small-scale New Keynesian DSGE model. Even the relative weight between inflation and output gap stabilization λ is the same. The only minor difference is the interpretation of the output gap. In the standard model, the relevant output gap is the one between the actual economy and the flexible-price counterpart, as shown by Rotemberg and Woodford (1999) and Benigno and Woodford (2004). As price stickiness is the only source of inefficiency in this model, the flexible-price economy is also efficient. In the financial accelerator economy, the appropriate reference for welfare considerations is again the efficient economy, which is the economy at hand in the absence of nominal rigidities *and* financial frictions.

What is the intuition behind this result? As in the standard New Keynesian model, the first driver of welfare losses is inflation volatility. Variability in inflation causes welfare losses, because the nominal rigidities embodied in the Calvo pricing leads to price dispersion across retail firms. This entails a loss of efficiency in production. The second source of welfare losses are deviations of output from the first-best allocation in the absence of nominal rigidities and further frictions. The presence of the financial accelerator is equivalent to such a further friction and thus drives a wedge between efficient output and output in the counterfactual flexible-price economy. This wedge is, however, independent of monetary policy controlling the nominal interest rate, which only has an effect in the

[12] As such, these mandates may be interpreted as providing a mandate for fiscal or macroprudential policymakers. If these operate instruments that directly affect leverage in the flexible-price economy, they may be able to close the wedge to the efficient level of output. As the focus of the paper is on optimal monetary policy in the presence of financial frictions, I abstract from fiscal or macroprudential policies in the following.

sticky price economy. A monetary policymaker thus may equivalently cast the problem in the canonical form of minimizing the variability of inflation and the output gap with respect to the efficient allocation. This result extends the finding of Ravenna and Walsh (2006) for the cost channel economy to the case of financial frictions.

Before proceeding, it is worthwhile to discuss the similarities and differences of these results to the previous literature. Proposition 1 shows that the loss function can be written as a traditional mandate of stabilizing inflation and the output gap, where in particular the weight on the output gap relative to inflation is not altered by the presence financial frictions. The prevailing traditional monetary policy mandate is in line with findings by Carlstrom et al. (2010), De Fiore and Tristani (2013), Cúrdia and Woodford (2016) and Paoli and Paustian (2017).

However, these papers find that a second-order approximation of household welfare under financial frictions gives rise to additional policy objectives, which one might loosely categorize as financial stability considerations.[13] This difference can be traced back to a different set of modelling assumptions. De Fiore and Tristani (2013) explicitly track entrepreneur consumption, and find that this gives rise to a mandate for smoothing the credit spread. However, this mandate is quantitatively far less important than the traditional mandate for their benchmark calibration. In the model at hand, I abstract entirely from entrepreneur consumption by assuming that they distribute all their profits as dividends to stockholders, which in turn distribute their profits as lump-sum transfers to households. With this assumption, the policy mandate obtained by De Fiore and Tristani (2013) is identical to the one I obtain.

Cúrdia and Woodford (2016) model heterogeneity in the household discount factor, such that the economy is populated by savers and borrowers. The required financial intermediation is assumed to be inefficient and to generate credit spreads. As outlined by Cúrdia and Woodford (2016), additional financial stability considerations vanish from the policy mandate only if one assumes that financial frictions are exogenous. Here, for a different type of financial friction and in a homogeneous agent framework, I obtain a slightly different result: Even with endogenous financial frictions (generated by ν), the policy mandate can be written in canonical form. Lastly, the key differentiating assumption in Carlstrom et al. (2010) and Paoli and Paustian (2017) is the presence of an additional term in household utility in their analysis, which the authors interpret as costs of variable capital utilization. When obtaining the welfare approximation, this gives rise to a financial stability mandate to minimize credit cycles.

[13] These models, like the framework at hand, do not feature a prominent role of financial intermediaries, and are hence silent about the effects of their default and systemic risk within the financial sector. Following Angelini et al. (2014), one may interpret the stabilization of financial market outcomes prescribed in these models as an intermediate target for policymakers. Lowering volatilities of leverage and spreads within financial markets is generally deemed to reduce systemic risk and may therefore be seen as contributing to financial stability.

To summarize, I abstract from entrepreneur consumption and consumer heterogeneity, while at the same time assuming standard household preferences. In the absence of these assumptions made in the previous literature, the presence of financial frictions does not alter the central bank mandate obtained by a second-order household welfare approximation. Even the relative weight on output gap volatility is identical to the standard case. Put differently, without making additional assumptions and taking the conventional view on central banks as controlling the nominal interest rate, stabilization of inflation and output gap prevails as appropriate central bank mandate in the presence of financial frictions. With these finding in mind, the next section turns to optimal discretionary monetary policy.

4 Financial Frictions and the Conduct of Monetary Policy

While the mandate of central banks is not substantially altered in the presence of financial frictions, we have seen in Section 2.3 that the financial accelerator economy implies fundamentally different macroeconomic dynamics. In light of these findings, it is needless to say that one should expect that this requires a different monetary policy stance compared to the standard framework. This is particularly the case if the central bank lacks a credible commitment device, thus operating under discretion and being unable to influence the more relevant forward-looking behavior of agents. Against this backdrop, I investigate the design of optimal discretionary monetary policy within the financial accelerator in the following.

4.1 The Inflationary Bias under Discretion

Discretion constitutes a natural starting point for an analysis of optimal monetary policy, as it imposes minimal requirements on the credibility of the central bank. Under discretion, the monetary policymaker cannot pre-commit to future actions and is hence unable to manipulate private sector expectations. The central bank hence re-optimizes every period, taking private sector expectations as given.

I first solve for optimal discretionary policy under discretion using the mandate obtained from the approximation of household welfare in the previous section. In each period, the central bank's optimization problem under discretion consists of minimizing the loss function by setting the nominal interest rate, taking expectations as given. We can hence write the optimization problem as:

$$\begin{aligned}
\min_{\pi_t, x_t, r_t} \mathcal{L}_t &= \pi_t^2 + \lambda\, x_t^2 && (47)\\
s.t.\ x_t &= -\sigma^{-1}\,(r_t - E_t[\pi_{t+1}]) + E_t[x_{t+1}] - \varphi\, a_t && (48)\\
\pi_t &= \mathcal{K}\, x_t + \vartheta\kappa(1+\nu\mu)\, r_t + \beta E_t[\pi_{t+1}] - \vartheta\nu\kappa\phi\, a_t && (49)
\end{aligned}$$

where the parameters $\lambda, \mathcal{K}, \varphi$ and ϕ are defined as above. The first-order condition for the nominal interest rate yields

$$-\sigma^{-1}\Theta_t = \vartheta\kappa(1+\nu\mu)\Lambda_t \tag{50}$$

where Θ and Λ are the Lagrange multipliers associated with the Euler equation and the Phillips curve, respectively. In contrast to the standard model, this implies that the Euler equation poses a constraint to the policymaker since $\Theta_t \neq 0$ as long as $\Lambda_t = \pi_t \neq 0$. A given change in the nominal interest affects not only the output gap via the Euler equation, but also marginal costs through the Phillips curve. A policymaker facing a trade-off between inflation and output gap stabilization needs to take this into account.[14] This leads us to the following result for the optimal targeting rule under discretion:

Proposition 2 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). The optimal targeting rule for monetary policy under discretion is given by*

$$\pi_t = -\frac{\lambda}{\widetilde{\kappa}} x_t \tag{51}$$

where

$$\widetilde{\kappa} = \kappa[\sigma + \eta - \vartheta\sigma + \vartheta\nu(1 + \sigma + \eta - \psi - \mu\sigma)] \tag{52}$$

Proof. See Appendix. ■

Note that the optimal targeting rule nests the corresponding solution for the standard model ($\vartheta = \nu = 0$), which is given by

$$\pi_t = -\frac{\lambda}{\kappa(\sigma+\eta)} x_t \tag{53}$$

In order to understand the targeting rule, it is worthwhile to investigate the transmission channels of monetary policy in the financial accelerator economy. For the time being, let us thus consider a monetary policy shock.

With financial frictions, a given rise in the nominal interest rate unfolds four effects: First, it raises the real interest rate, such that households want to postpone consumption,

[14] A policymaker who does not care about output fluctuations and thus places a zero weight on the output gap ($\lambda = 0$) will ignore the Euler equation in the financial accelerator economy as well. But as shown in the previous section, the welfare approximation implies $\lambda > 0$.

leading to a fall in the output gap and inflation via the Euler equation. (*Euler channel*). Aside from this standard effect, a second *factor supply channel* arises as households accordingly reduce labor supply to accommodate the lower desired production. This decreases wages and tends to decrease leverage, marginal costs and thus inflation further. Both Euler and factor supply channels are governed by the elasticity of inter-temporal substitution σ and the elasticity of labor supply η, while the factor-supply channel also depends on the sensitivity of loan rate with respect to leverage. Third, marginal costs increase directly via the higher nominal interest rate (*cost channel* governed by σ), even absent changes to labor demand or wages. Fourth, equity financing decreases, both due to the fall in output (ψ) and due to the direct effect of the nominal interest rate ($\mu\sigma$). The latter *equity channel* and the cost channel effect imply an increase in inflation and thus counteract the first two channels.

Let us now return to the targeting rule under discretion. The considerations of a monetary policy shock allows us to rewrite the targeting rule as:

$$-\lambda x_t = \kappa[\underbrace{\sigma+\eta}_{\text{Euler channel}} - \underbrace{\vartheta\sigma}_{\text{cost channel}} + \underbrace{\vartheta\nu(1+\sigma+\eta)}_{\text{factor-supply channel}} - \underbrace{\vartheta\nu(\psi+\mu\sigma)}_{\text{equity channel}}]\,\pi_t \tag{54}$$

In turn, we can postulate the following:

Lemma 8 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Under Assumption 2, the cost channel and the equity channel of monetary policy dominate its factor-supply channel.*

Lemma 9 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Under Assumption 2, the targeting rule for monetary policy under discretion prescribes a more aggressive reaction of the output gap to inflation relative to the standard model.*

These results show that – under a reasonable assumption on the pro-cyclicality of equity financing – the overall power of discretionary monetary policy to influence both inflation and output gap at the same time is limited in the financial accelerator economy. The presence of financial frictions leads to a weaker effect of monetary policy shocks on output, but a larger impact on inflation.In other words, stabilizing inflation is more costly in terms of the output gap because the factor-supply channel is dominated by the cost channel and the equity channel. As a result, the central bank needs to move the nominal interest rate (and thus the output gap) by more than in the standard model for given inflation, which is mirrored in the more aggressive targeting rule under discretion.

The finding of weaker macroeconomic effects of monetary policy shocks is in contrast to the canonical financial accelerator mechanism in Bernanke et al. (1999). In their model, monetary policy shock effects on both output and inflation are amplified. The difference can be traced back to the absence of capital in the model at hand. The factor-supply channel for capital in the original financial accelerator is stronger, because a higher demand for capital increases investment and the price of capital. In turn, this raises entrepreneur net worth, driving down the external finance premium and stimulating further investment, enforcing the factor-supply channel. As a result, the overall effect of monetary policy shocks is amplified. This kind of multiplier effect is substantially weaker if the financial accelerator refers to labor. Accordingly, in the labor financial accelerator economy at hand, the factor-supply channel outweighs the cost channel and the equity channel only for unreasonably low elasticities of substitution, high elasticities of labor supply and a high sensitivity of the credit spread to entrepreneur leverage.

What does the more aggressive targeting rule under discretion imply for macroeconomic dynamics under discretion? The tractability of the framework allows to use the optimal targeting rule to obtain a closed-form solution in terms of shocks only, as shown in the following Proposition.

Proposition 3 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). The dynamics of inflation, output gap and nominal interest rate under optimal discretionary policy are given by*

$$\pi_t = -\lambda\vartheta\kappa \frac{\nu\phi + \sigma\varphi(1+\nu\mu)}{\widetilde{\kappa}^2 + \lambda(1-\rho_a\widetilde{\beta})} a_t \quad (55)$$

$$x_t = \vartheta\kappa\widetilde{\kappa} \frac{\nu\phi + \sigma\varphi(1+\nu\mu)}{\widetilde{\kappa}^2 + \lambda(1-\rho_a\widetilde{\beta})} a_t \quad (56)$$

$$r_t = -\vartheta\kappa\gamma \frac{\nu\phi + \sigma\varphi(1+\nu\mu)}{\widetilde{\kappa}^2 + \lambda(1-\rho_a\widetilde{\beta})} a_t - \sigma\varphi\, a_t \quad (57)$$

where

$$\widetilde{\beta} = \beta + \vartheta\kappa(1+\nu\mu)\left(1 - \frac{\widetilde{\kappa}\sigma}{\lambda}\right) \quad (58)$$

$$\gamma = \lambda\rho_a + (1-\rho_a)\sigma\widetilde{\kappa} \quad (59)$$

Proof. See Appendix. ■

As before, the analytic solution nests the case of the standard model for $\vartheta = \nu = 0$, which serves as a benchmark:

$$\pi_t = \, = 0 \quad (60)$$

$$x_t = \, = 0 \quad (61)$$

$$r_t = -\sigma\varphi\, a_t \quad (62)$$

In the absence of financial frictions, optimal discretionary monetary policy is able to perfectly stabilize both inflation and output gap. This can be achieved by appropriately varying the interest rate in response to the pure demand shock component of technology shocks; this corresponds to the second term in Equation (57) and the one left in Equation (62). In the financial accelerator economy, however, it is straightforward to see that technology shocks have a non-zero effect on inflation and the output gap. In turn, we can postulate:

Lemma 10 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). In the presence of financial frictions, divine coincidence does not hold and discretionary policy fails to perfectly offset technology shocks (inflationary bias).*

The breakdown of divine coincidence is a result of the shock amplification implied by the financial accelerator. As outlined in Lemma 1, positive technology shocks induce endogenous negative cost-push effects that amplify the expansionary output response. These cost-push effects act like mark-up shocks, moving inflation and output gap in opposite directions. As a consequence, monetary policy is not able to stabilize inflation and output gap at the same time, facing a trade-off between stabilizing inflation and output gap (where the output gap fluctuates inefficiently due to the financial accelerator). In turn, this implies that macroeconomic stabilization by the central bank under discretion is sub-optimal relative to the standard model. Because technology shocks then lead to non-zero inflation in the presence of financial frictions, I refer to this sub-optimality as *inflationary bias* of discretionary policy.

Turning to the determinants of the inflationary bias in further detail, let us investigate the components of the analytic solutions in Propositon 3. The dynamics of inflation, output gap and the interest rate all depend on a common coefficient α given by:

$$\alpha \equiv \frac{\nu\phi + \sigma\varphi(1+\nu\mu)}{\widetilde{\kappa}^2 + \lambda(1-\rho_a\widetilde{\beta})} \tag{63}$$

Key components of α are thus the slope of the Phillips curve $\widetilde{\kappa}$ and the degree of forward-looking behavior $\widetilde{\beta}$ under discretionary policy. With respect to the Phillips curve, we can postulate the following:

Proposition 4 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Assume further $\rho_a = 0$ and let Assumption 2 hold. Then it holds that*

$$\frac{\partial\alpha}{\partial\nu} > 0 \tag{64}$$

$$\frac{\partial\alpha}{\partial\psi} > 0 \tag{65}$$

such that the inflationary bias increases in the degree of financial frictions as captured by ν and ψ via the flatter Phillips curve.

Proof. See Appendix. ■

The intuition for this result is straightforward. Under Assumption 2, the financial accelerator leads to a flatter Phillips curve. The slope in the Phillips curve governs the contemporaneous relationship between inflation and output gap. If the slope is lower, discretionary monetary policy faces a more severe trade-off between output gap and inflation stabilization. As argued above, this implies that inflation stabilization is more costly in terms of the output gap. As a result, the inflationary bias of discretionary monetary policy increases in the degree of financial frictions.

In Proposition 4, the assumption $\rho_a = 0$ serves to isolate the effect of the Phillips curve for the conduct of discretionary policy. Another driving factor of the inflationary bias is the degree of forward-looking behavior.

Assumption 4

$$\sigma(1+\nu\mu)(\psi+\mu\sigma-1-\sigma-\eta)+\mu(\lambda-\widetilde{\kappa}\sigma)>0 \tag{66}$$

For general calibrations, Assumption 4 is a slightly more restrictive assumption than Assumption 2. Alternatively, it can be interpreted as a mild constraint on the Frisch labor supply elasticity (η^{-1}).[15] Under no disutility of labor ($\eta = 0$), one can show that Assumption 2 implies that Assumption 4 holds.

Proposition 5 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). It holds that*

$$\frac{\partial\widetilde{\beta}}{\partial\psi}>0 \tag{67}$$

Under Assumption 4, it furthermore holds that

$$\frac{\partial\widetilde{\beta}}{\partial\nu}>0 \tag{68}$$

such that the inflationary bias increases in the degree of financial frictions as captured by ν and ψ via the higher relevance of future expectations for current inflation dynamics. Furthermore, monetary policy reacts more aggressive to technology shocks.

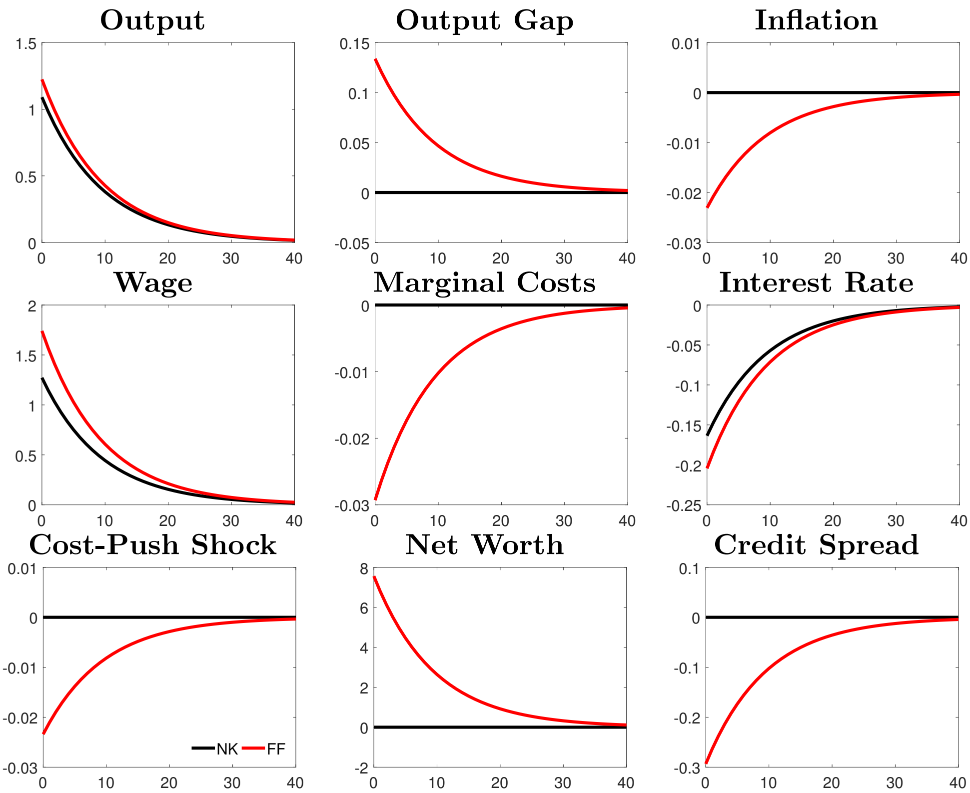
Proof. See Appendix. ■

As shown in Lemma 3, the presence of financial frictions increases the degree to which forward-looking behavior matters for current period inflation dynamics. As nominal interest rates matter for current and future marginal costs, retailers pay more attention to future expected nominal interest rates when making their pricing decisions. The fact that discretion inherently cannot commit to setting future interest rates and hence ignores these more relevant forward-looking elements aggravates the inflationary bias. As with the flatter Phillips curve, this effect on the inflationary bias increases in the degree of financial frictions.

[15] This yields the representation of Assumption 4 as $\eta < \frac{\sigma\mu\kappa+\epsilon[\sigma(1+\nu\mu)+\nu\mu\sigma\kappa)](\psi+\mu\sigma-1-\sigma)}{\mu\kappa(2\sigma\epsilon-1)+\epsilon\sigma(1+\nu\mu)}$, where the right-hand-side is strictly positive under Assumption 2.

An alternative way to illustrate the inflationary bias of discretionary policy is to investigate the impulse responses of technology shocks, shown in Figure 2. In the standard NK model, technology shocks only manifest as demand shocks in the Euler equation, such that it possible and optimal under discretion to fully offset their inflationary effect and close the output gap completely. With financial frictions, technology shocks also generate negative mark-up effects. In turn, divine coincidence breaks down and neither inflation nor output gap are perfectly stabilized. The expansionary effect on output is amplified by the financial accelerator.

Figure 2: Technology Shock under Discretion



Note: Impulse response functions for a technology shock with an autoregressive coefficient of 0.9. The shock size is calibrated to yield a one-percent increase of output under the Taylor rule in the NK model. All variables are in percentage deviations from the non-stochastic steady state, except for inflation and interest rate which are in percentage-point deviations. A period is a quarter, NK is the standard New Keynesian model (in black) and FF (in red) is the financial accelerator economy.

We can thus conclude that discretionary monetary policy suffers from an inflationary bias in the financial accelerator economy relative to the standard model due to three factors. First, the amplification of aggregate shock entailed in the financial accelerator leads to endogenous cost-push effects, in turn resulting in a break-down of divine coincidence. Second, the flatter Phillips curve makes inflation stabilization for discretionary policy more costly in terms of the output gap. Third, the higher degree of forward-looking behavior is inherently ignored under discretion, in turn increasing the inflationary bias.

4.2 Inflation Conservatism

As shown above, discretionary monetary policy suffers from a substantial inflation bias in the financial accelerator economy relative to the standard economy without financial frictions. Clearly, this is undesirable from a policy-maker's perspective. As such, this naturally raises the question whether policy performance can be improved in the presence of financial frictions. Two of the three factors generating the inflationary bias are largely beyond the control of monetary policy: The flatter Phillips curve and the amplification of shocks, the latter leading to a breakdown of divine coincidence.

The third source of the inflationary bias is that discretionary policy inherently fails to take private sector expectations into account. A policy that is able to manipulate private expectations by making credible commitments may thus be advisable and more appropriate than discretionary policy. However, policy commitment places strong requirements on the credibility of central banks. This section hence asks whether the inflationary bias under discretion in the face of financial frictions can be improved upon even if commitment policies are not available.

To evaluate the performance of discretionary policy relative to a policy that takes expectations into account, suppose that the central bank was able to credibly commit to a simple rule of the form:

$$x_t = b_a \, a_t \tag{69}$$

Lemma 11 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Under commitment to a simple rule of the form $x_t = b_a \, a_t$, inflation dynamics are given by*

$$\pi_t = \frac{\widetilde{\widetilde{\kappa}}}{1 - \rho_a \widetilde{\widetilde{\beta}}} b_a \, a_t - \vartheta\kappa \frac{\nu\phi + \sigma\varphi(1 + \nu\mu)}{1 - \rho_a \widetilde{\widetilde{\beta}}} a_t \tag{70}$$

where

$$\widetilde{\widetilde{\kappa}} = \widetilde{\kappa} + \vartheta\kappa\sigma\rho(1 + \nu\mu) \tag{71}$$

$$\widetilde{\widetilde{\beta}} = \beta + \vartheta\kappa(1 + \nu\mu) \tag{72}$$

The solution under commitment to the simple rule can be rewritten by combining Equation (69) and Equation (70) as

$$\pi_t = \frac{\widetilde{\widetilde{\kappa}}}{1 - \rho_a \widetilde{\widetilde{\beta}}} x_t - \vartheta\kappa \frac{\nu\phi + \sigma\varphi(1 + \nu\mu)}{1 - \rho_a \widetilde{\widetilde{\beta}}} a_t \tag{73}$$

which illustrates the benefits from commitment. Under commitment to the simple rule, a contraction of the output gap leads to a contraction of inflation by $\frac{\widetilde{\widetilde{\kappa}}}{1-\rho\widetilde{\widetilde{\beta}}}$, whereas the effect under discretion is only $\widetilde{\kappa}$. By manipulating agent's expectations about its future actions, the central bank is able to improve upon the trade-off between inflation and output gap stabilization that it faces.

The optimal value of b_a can be determined by the central bank by maximizing household welfare. Using the welfare approximation derived in Section 3, the central bank's optimization problem is given by

$$\min_{b_a} \quad E_t \sum_{s=0}^{\infty} \beta^s \left\{\pi_{t+s}^2 + \lambda x_{t+s}^2\right\} \tag{74}$$

$$s.t. \quad \pi_t = \frac{\widetilde{\widetilde{\kappa}}}{1-\rho_a \widetilde{\widetilde{\beta}}} b_a\, a_t - \vartheta\kappa \frac{\nu\phi + \sigma\varphi(1+\nu\mu)}{1-\rho_a\widetilde{\widetilde{\beta}}} a_t \tag{75}$$

$$x_t = b_a\, a_t \tag{76}$$

where two constraints Equation (75) and Equation (76) capture the economic dynamics and the functional form of the simple commitment, respectively.

Lemma 12 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). The optimal policy function with respect to technology shocks under commitment to a simple rule of the form $x_t = b_a\, a_t$ is given by:*

$$b_a = \vartheta\kappa\widetilde{\widetilde{\kappa}} \frac{\nu\phi + \sigma\varphi(1+\nu\mu)}{\widetilde{\widetilde{\kappa}}^2 + \lambda(1-\rho_a\widetilde{\widetilde{\beta}})^2} \tag{77}$$

Proposition 6 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). The dynamics of inflation and the output gap and nominal interest rate under optimal commitment to a simple rule of the form $x_t = b_a\, a_t$ are given by:*

$$\pi_t = -\lambda\vartheta\kappa(1-\rho_a\widetilde{\widetilde{\beta}}) \frac{\nu\phi + \sigma\varphi(1+\nu\mu)}{\widetilde{\widetilde{\kappa}}^2 + \lambda(1-\rho_a\widetilde{\widetilde{\beta}})^2}\, a_t \tag{78}$$

$$x_t = \vartheta\kappa\widetilde{\widetilde{\kappa}} \frac{\nu\phi + \sigma\varphi(1+\nu\mu)}{\widetilde{\widetilde{\kappa}}^2 + \lambda(1-\rho_a\widetilde{\widetilde{\beta}})^2}\, a_t \tag{79}$$

Proof. See Appendix. ■

To put this solution into perspective, the solution for inflation under optimal discretion as derived in the previous section is given by:

$$\pi_t = -\lambda\vartheta\kappa \frac{\nu\phi + \sigma\varphi(1+\nu\mu)}{\widetilde{\kappa}^2 + \lambda(1-\rho_a\widetilde{\beta})}\, a_t \tag{80}$$

Lemma 13 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy) and assume $0 < \rho_a < 1$. Then it holds that $\widetilde{\widetilde{\kappa}} > \widetilde{\kappa}$ and $\widetilde{\widetilde{\beta}} > \widetilde{\beta}$ such that the response of inflation to technology shocks is smaller under optimal commitment to a simple rule of the form $x_t = b_a\, a_t$ compared to optimal discretionary policy.*

Comparing the two solutions in Equations (78) and (80) reveals that for $0 < \rho_a < 1$, commitment under a simple rule achieves lower inflation volatility following technology shocks. This shows that discretionary monetary policy under financial frictions suffers from a *stabilization bias* relative to policies that involve some sort of policy commitment to future actions. Importantly, this stabilization bias is present in the financial accelerator economy even if technology shocks are the only aggregate shocks. This is in contrast to the standard case ($\vartheta = \nu = 0$), where divine coincidence holds such that the stabilization bias non-existent (in the absence of ad-hoc mark-up shocks). The stabilization bias is also not present if shocks do not generate persistent effects in the future, equivalent to $\rho_a = 0$. In this case, private rational expectations of future shocks are zero and the central bank finds it optimal to re-optimize every period anyway, just like under discretion. As a result, there are no benefits from committing to the simple rule.

We have thus established that discretionary monetary policy suffers from a *stabilization bias* relative to optimal commitment policies in the financial accelerator economy. It is important to note that this is different from the *inflationary bias*, which describes the su-boptimal performance of discretionary policy in the presence of financial frictions relative to discretion in the standard model. While the causes of the inflationary bias are largely beyond the control of central banks, the stabilization bias can be partially mitigated by a simple rule commitment, which influences private sector expectations and improves the trade-off between inflation and output gap stabilization.

Notably, the commitment to a simple rule can be operationalized under discretion. As shown by Clarida et al. (1999), this requires society to appoint a central banker that places a relative weight on output gap stabilization that is different from the welfare-based weight.

Proposition 7 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Optimal discretionary monetary policy with relative weight $\widetilde{\lambda}$ on output gap stabilization mimics optimal commitment to a simple rule of the form $x_t = b_a\, a_t$ if*

$$\widetilde{\lambda} = (1 - \rho_a \widetilde{\widetilde{\beta}}) \frac{\widetilde{\kappa}}{\widetilde{\widetilde{\kappa}}} \lambda \tag{81}$$

Proof. See Appendix. ■

Lemma 14 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Under $0 < \rho < 1$, it holds that:*

$$\widetilde{\lambda} < \lambda \tag{82}$$

The required relative weight on output gap stabilization such that discretion mimics the simple commitment is thus lower than the welfare-based weight. In turn, this implies that the relative weight on inflation to improve the performance under discretion has to be higher. In the spirit of Rogoff (1985), we may interpret these results as requiring society to appoint an *inflation-conservative* central banker to mitigate the stabilization bias under discretion. In this context, inflation conservatism means having a strong(er) preference for inflation stabilization, as governed by a higher weight on inflation stabilization. If society appoints such an inflation-conservative central banker operating under discretion, macroeconomic volatility is reduced and household welfare increases.

Assumption 5 *The persistence of technology shocks ρ_a satisfies:*

$$\rho_a \widetilde{\widetilde{\beta}} < 1 \tag{83}$$

Proposition 8 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Under Assumption 2 and Assumption 5, it holds that*

$$\frac{\partial \widetilde{\lambda}}{\partial \nu} < 0 \tag{84}$$

$$\frac{\partial \widetilde{\lambda}}{\partial \psi} < 0 \tag{85}$$

such that the optimal degree of inflation conservatism increases in the degree of financial frictions as captured by ν and ψ.

Proof. See Appendix. ■

Proposition 8 shows that the stronger the financial frictions, the more conservative the central banker must be. Prevailing financial frictions lead to a flattening of the Phillips curve, and a larger degree of forward-looking behavior being relevant for current macroeconomic outcomes. Accordingly, the stabilization bias of discretionary policy (neglecting the forward-looking behavior) increases in the degree of financial frictions. With an inflation-conservative central banker, the public knows that inflation will respond less to a cost-push shock, such that future expected inflation rises less in the face of a positive cost-push shock shock. As a consequence, current inflation can be stabilized, with a smaller fall in the output gap, such that welfare increases. Figure 3 shows the corresponding Rogoff inflation weight as a function of the degree of financial frictions[16]:

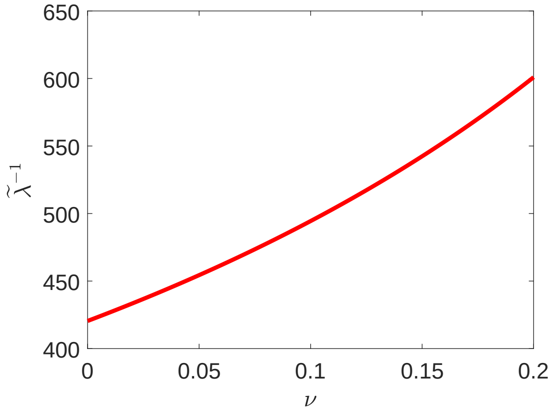
Lemma 15 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Under Assumption 5, it holds that*

$$\frac{\partial \widetilde{\lambda}}{\partial \rho} < 0 \tag{86}$$

such that the optimal degree of inflation conservatism increases in the degree of shock persistence.

[16] The calibration used for this figure is described in more detail in Section 4.3 below.

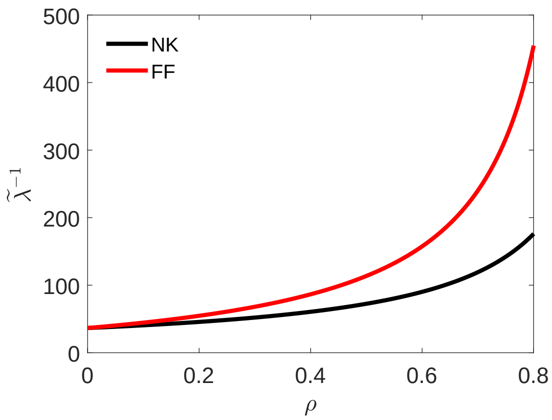
Figure 3: Rogoff Inflation Weight and Financial Frictions



Note: The required inflation weight $\widetilde{\lambda}^{-1}$ relative to the weight on output gap such that discretionary policy mimics the solution under commitment to a simple rule, as a function of the degree of financial frictions.

The optimal Rogoff-weight decreases in the degree of shock persistence. The more persistent the shocks, the lower is the optimal weight on output gap stabilization, as seen in Figure 4, confirming the results by Clarida et al. (1999) for the financial accelerator model at hand. As with the degree of financial frictions, a larger shock persistence amplifies the stabilization bias of discretionary policy, such that a Rogoff-conservative central banker is more advisable if shocks are more persistent.

Figure 4: Rogoff Inflation Weight and Persistence



Note: The required inflation weight $\widetilde{\lambda}^{-1}$ relative to the weight on output gap such that discretionary policy mimics the solution under commitment to a simple rule, as a function of shock persistence parameter. NK is the standard New Keynesian model (in black) and FF (in red) is the financial accelerator economy.

Comparing the discretionary policy with simple commitment thus suggests that inflation conservatism can improve welfare in the face of financial frictions. This result may come at a surprise given the previous finding that the financial accelerator induces inefficient output gap fluctuations. At first glance, the resulting additional output gap volatility may hence call for a stronger focus on stabilizing economic activity. However, as the approximated household welfare reveals, the welfare-based relative weight on inflation stabilization remains high in the financial accelerator model. Moreover, stabilizing inflation is more costly in terms of the output gap for discretionary policy because of the flattening of the Phillips curve. Against this backdrop, the stabilization of inflation emerges as the more important central bank mandate. Society can ensure that the central bank minimizes the stabilization bias relative to optimal commitment policy by appoint an inflation-conservative central banker. At the same this, this also reduces the inflationary bias in the financial accelerator economy relative to the standard model.

While inflation-conservative discretion mimicks commitment to a simple rule is thus favorable over discretion using the welfare-based weight, it is not the fully optimal policy. The benchmark first-best policy is optimal commitment policy. The next section thus analyzes optimal commitment policy and compares macroeconomic stabilization and welfare implications under the different policy regimes.

4.3 Optimal Commitment Policy

The advisability of inflation conservatism in the presence of financial frictions stems from the inherent stabilization bias of discretionary policy. While discretion constitutes a natural benchmark as discussed by Clarida et al. (1999), it may be argued that central banks increasingly (try to) rely on commitment policy.[17] However, the commitment to a simple rule considered in the previous section restricts the central bank's action to be a simple rule with respect to the shocks. This section derives the implementation of monetary policy under commitment, serving as a the welfare-optimal benchmark to evaluate the gains from discretionary policy under inflation conservatism.

To derive the optimal commitment policy, suppose that the central bank was able to credibly commit to an entire path for current and future inflation and the output gap. In that case, the central bank optimization problem is to maximize household welfare or the expected current and future weighted volatilities of inflation and output gap. We can write the optimization problem as:

$$\underset{\{\pi_{t+s},x_{t+s}\}_{s=0}^{\infty}}{min} E_t \sum_{s=0}^{\infty} \beta^s \left\{\pi_{t+s}^2 + \lambda x_{t+s}^2\right\} \tag{87}$$

$$\text{s.t.} \quad E_t[\pi_{t+s}] = E_t[\widetilde{\kappa} x_{t+s} + \widetilde{\widetilde{\beta}}\pi_{t+1+s} + \vartheta\kappa\sigma(1+\nu\mu)x_{t+1+s} - \vartheta\kappa(\nu\phi + \sigma\varphi(1+\nu\mu)a_{t+s}] \tag{88}$$

where Equation 88 combines both Euler equation and Phillips curve. Denoting the associated Lagrange multiplier by Λ_t, the first-order conditions under the timeless perspective

[17] In particular, the prevailing use of forward guidance and projected paths for the nominal interest rate among major central banks in the aftermath of the Great Recession and in the zero lower bound period may be considered as being closer to commitment than to discretion.

(Woodford, 2003a,b) imply:

$$\pi_t + \Lambda_t - \frac{\widetilde{\widetilde{\beta}}}{\beta}\Lambda_{t-1} = 0 \tag{89}$$

$$\lambda x_t - \widetilde{\kappa}\Lambda_t - \frac{\mathcal{K} - \widetilde{\kappa}}{\beta}\Lambda_{t-1} = 0 \tag{90}$$

Rearranging and eliminating Lagrange multipliers Λ_t yields the targeting rule under commitment.

Lemma 16 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). The optimal targeting rule under commitment is given by:*

$$\pi_t + \vartheta \upsilon \pi_{t-1} = -\frac{\lambda}{\widetilde{\widetilde{\kappa}}}\left(x_t - \frac{\widetilde{\widetilde{\beta}}}{\beta}x_{t-1}\right) \tag{91}$$

with

$$\upsilon = \frac{\kappa\sigma(1 + \nu\mu)}{\beta\widetilde{\kappa}} \tag{92}$$

As a comparison, the (nested) equivalent targeting rule in the standard New Keynesian model is:

$$\pi_t = -\frac{\lambda}{\kappa(\sigma + \eta)}\left(x_t - x_{t-1}\right). \tag{93}$$

As discussed above, financial frictions make private expectations of the future more important for current dynamics. As a response, the fully optimal commitment policy hence follows a targeting rule with more inertia by additionally considering lagged inflation, and responds stronger to the output gap. In contrast to the standard model, the optimal targeting rule considers the deviation of current output to the scaled past output gap, which results from explicitly taking the increasing degree of forward-looking behavior into account.

Lemma 17 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Under Assumption 2, it holds that*

$$\frac{\partial \upsilon}{\partial \nu} > 0 \tag{94}$$

$$\frac{\partial \upsilon}{\partial \psi} > 0 \tag{95}$$

such that the degree to which optimal commitment policy responds to lagged inflation increases in the degree of financial frictions as captured by ν and ψ.

This highlights again that, as forward-looking behavior becomes more important, a commitment to more inertia becomes more pressing. Accordingly, the optimal commitment policy is more persistent under financial frictions than in the standard model. This allows the central bank to better influence the public's expectations, improving the trade-off between output gap and inflation stabilization.

Unfortunately, the case of commitment does not allow for a convenient analytic solution. Hence, I solve the model under commitment numerically to compare the fully optimal policy with discretion and the case of Rogoff-conservatism. For this purpose, I also augment the model by two additional shocks: A preference shock ε_t^c to household's marginal utility of consumption, and a financial shock ε_t^r that shifts the required loan rate.[18] The corresponding linearized Euler equation can then be written as:

$$y_t = -\sigma^{-1}(r_t - E_t[\pi_{t+1} + E_t[\varepsilon_{t+1}^c - \varepsilon_t^c]) + E_t[y_{t+1}] \tag{96}$$

The spread is then given by

$$r_t^L = r_t + \nu(w_t + h_t - n_t) + \varepsilon_t^r \tag{97}$$

The model parametrization follows conventional values in the literature. For the standard New Keynesian parameters, I largely adopt the parameter values from Ravenna and Walsh (2006). Accordingly, the quarterly household discount rate β is calibrated to 0.99, implying a steady state quarterly interest rate of 1%. For the inverse elasticity of intertemporal substitution, I set $\sigma = 1.5$ and the Frisch elasticity of labor supply with respect to the real wage $\eta = 2$.[19] The Calvo parameter of non-adjusting firms in each period is calibrated to $\theta = 0.75$, such that the average duration of prices is four quarters and the slope of the Phillips curve with respect to marginal costs is approximately $\kappa = 0.086$. The elasticity of substitution between intermediate goods is set to $\epsilon = 11$, implying a steady-state mark-up of 10%. The welfare-based weight on the output gap is then given by $\lambda = 0.027$.

The cost channel requires $\vartheta = 1$.[20] For the elasticity of the loan rate to leverage, I follow Bernanke et al. (1999) by setting $\nu = 0.05$. As demonstrated in the Appendix, this implies an elasticity of equity to the nominal interest rate of approx. $\mu = 1.05$. The elasticity of equity to output is calibrated at $\psi = 6$. As shown in Section 2.3, this implies that the financial accelerator generates an amplification of technology shocks by 20%, roughly in line with the original financial accelerator by Bernanke et al. (1999). The calibration is then also in line with Assumptions 1, 2 and 4. With respect to monetary policy, I assume that the central bank follows the simplest version of the Taylor rule with

[18] None of the results of the previous sections hinges on the assumption that the technology shock is the only aggregate shock. The corresponding closed-form solutions in the extension with the two additional shocks are shown in the Appendix.

[19] This is higher than in Ravenna and Walsh (2006), who set $\eta = 1$, but is more in line with empirical estimates, see for example Smets and Wouters (2007) or Del Negro et al. (2015).

[20] As discussed in Ravenna and Walsh (2006), intermediate values $0 < \vartheta < 1$ imply that households pay the remainder of the interest tax on wages. In the absence of financial frictions, the mapping between marginal costs and the output gap is thus unaffected relative to the case where $\vartheta = 1$. To disentangle the effect of the cost channel and financial frictions, I just consider the polar cases of $\vartheta = 1$ and $\vartheta = 0$.

Table 1: Calibration

Parameter	Description	Value
β	Household discount factor	0.99
σ	Inverse elasticity of intertemporal substitution	1.5
η	Frisch labor supply elasticity	2
θ	Calvo pricing fraction non-adjusting firms	0.75
ϵ	Good elasticity of substitution	11
ϑ	Cost channel	1
ν	Sensitivity of loan rate to leverage	0.05
ψ	Elasticity of equity to output	6
μ	Elasticity of equity to interest rate	1.05
ϕ_π	Taylor rule response to inflation	1.50
$100\sigma_a$	Std. dev. technology shock	0.585
$100\sigma_c$	Std. dev. preference shock	1.470
$100\sigma_r$	Std. dev. financial shock	0.845

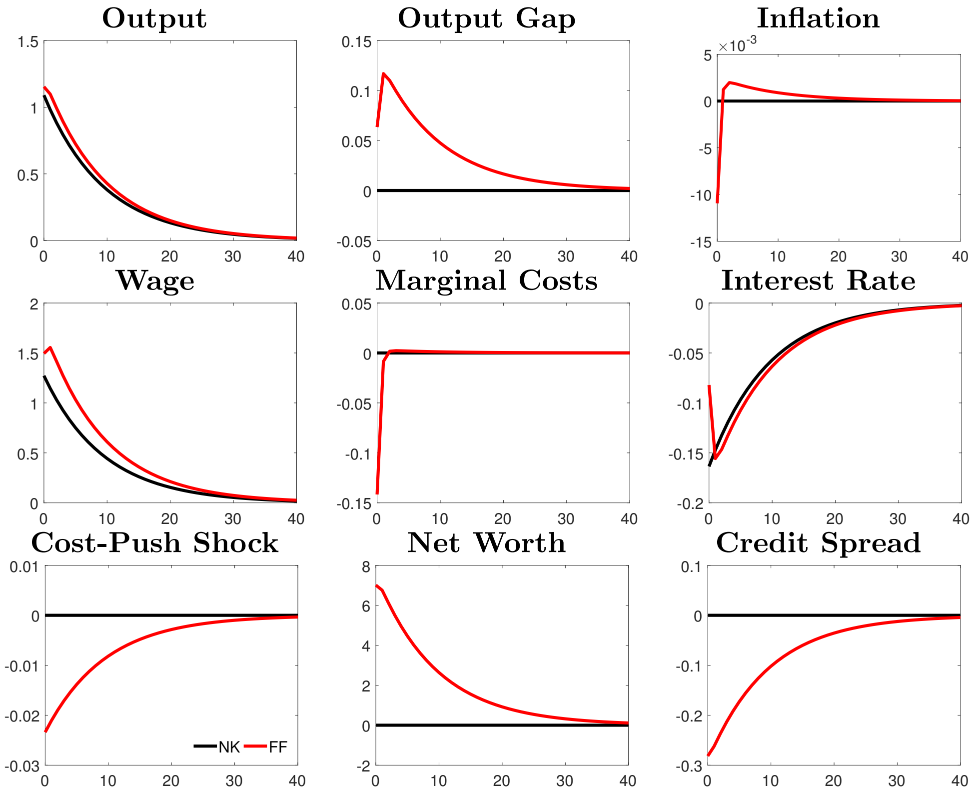
coefficient $\phi_\pi = 1.5$. The autocorrelation coefficients of all shocks are set to 0.90, and the shock variances are calibrated to match the empirically observed variances of quarterly GDP-deflator inflation and quarterly output per capita growth for the U.S. 1964-2008.

Using this calibration, Figure 5 illustrates optimal monetary policy under commitment from a timeless perspective following a technology shock.[21] In the standard model, technology shocks only appear as demand shocks in the Euler equation. As under discretion, optimal commitment perfectly offsets their effect on inflation and the output gap by appropriately adjusting the nominal interest rate. Under financial frictions, the breakdown of divine coincidence implies that also optimal commitment policy fails to completely stabilize technology shocks and has to allow for some fluctuation in the output gap and inflation. In particular, the central bank initially does not increase the nominal interest rate to the same extent as it does in the standard model. Accordingly, this generates some deflation and a positive output gap on impact. Afterwards, however, the path of nominal interest rates is slightly more contractionary compared to the standard model, such that the output gap follows a hump-shaped path and inflation stays positive for a prolonged period of time. Overall, the central bank sacrifices some output gap volatility in favor of a more favorable stabilization of inflation under commitment.

After having solved for the optimal policies under discretion using the welfare-based mandate, under discretion with inflation conservatism and under commitment, we are now able to compare the stabilization performance across policy regimes. In particular, the aim is to evaluate the performance of the inflation-conservative central banker relative

[21] The graph shows optimal commitment policy based on the first order approximated equations of the economy subject to the quadratic objective. As I assume that the steady state of the model is efficient due to the presence of some appropriate subsidies, the second-order terms of the Ramsey planner's FOCs evaluate to zero (Woodford, 2002). This avoids spurious welfare rankings that can in principal arise if one does not assume an efficient steady state and fails to compute the FOCs of the Ramsey planner's problem subject to the nonlinear equations characterizing the economy and then approximate these FOCs to first order (Kim and Kim, 2003).

Figure 5: Technology Shock under Commitment



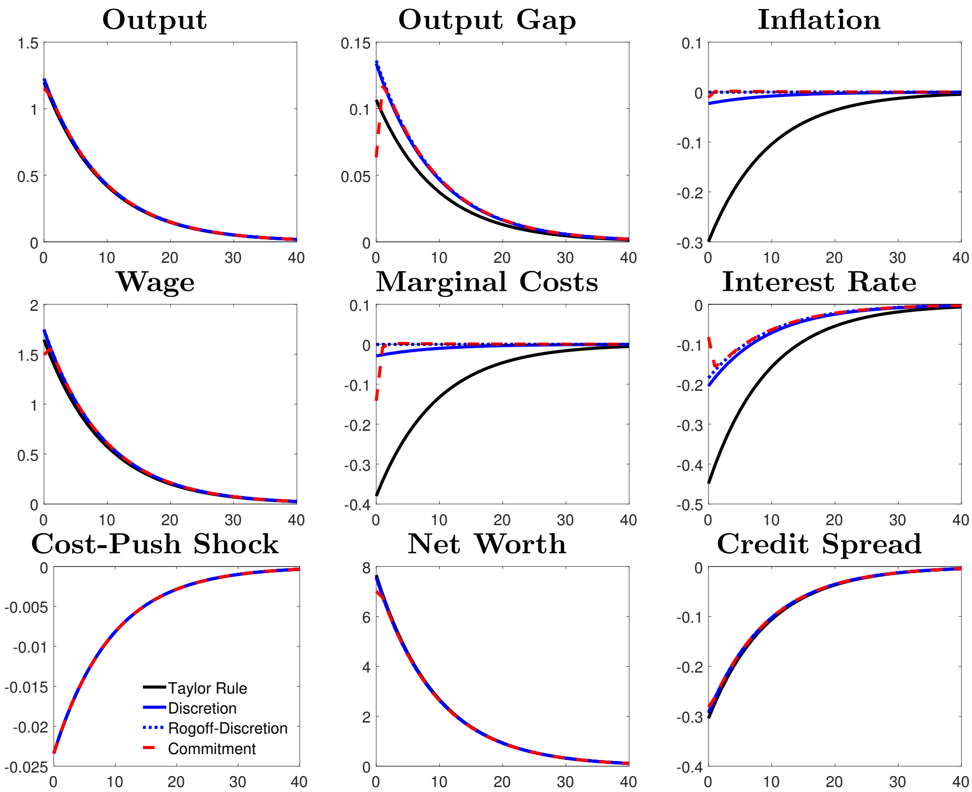
Note: Impulse response functions for a technology shock with an autoregressive coefficient of 0.9. The shock size is calibrated to yield a one-percent increase of output under the Taylor rule in the NK model. All variables are in percentage deviations from the non-stochastic steady state, except for inflation and interest rate which are in percentage-point deviations. A period is a quarter, NK is the standard New Keynesian model (in black) and FF (in red) is the financial accelerator economy.

to the optimal commitment policy. As a first step, consider Figure 6, which shows how a technology shock is propagated under full commitment compared to inflation-conservative discretion. For the purpose of comparison, the standard discretion solution and the simple Taylor rule solution are plotted as well.

Focusing first on commitment relative to discretion and Taylor rule, one can see that output responses are almost identical under the different regimes. This mirrors the low prominence of output stabilization in the central bank mandate. Put differently, it is evident from the figure that the main benefits from discretion and commitment stem from the improved stabilization of inflation. The response of inflation is substantially lower for all policy regimes relative to the Taylor rule, which is thus far from optimal in this context.

Comparing the full commitment policy to discretion using the welfare-based weight shows that the former is able to achieve both lower output gap and inflation variability. As discussed above, the optimal commitment policy implies some inertia in adjusting the nominal interest rate, such that inflation initially falls by a bit more and the output gap increases by less than under inflation-conservative discretionary policy. This reflects the

Figure 6: Technology Shock across Monetary Policy Regimes



Note: Impulse response functions for a technology shock with an autoregressive coefficient of 0.9. The shock size is calibrated to yield a one-percent increase of output under the Taylor rule in the model. All variables are in percentage deviations from the non-stochastic steady state, except for inflation and interest rate which are in percentage-point deviations. A period is a quarter, and all impulse responses are for the financial accelerator economy.

improved output gap to inflation trade-off that a policymaker faces if he is able to fully commit to complete paths of the output gap and inflation.

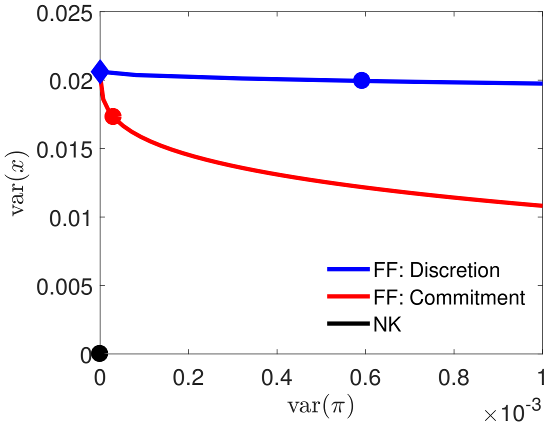
In contrast to the other policy regimes, Rogoff-conservative central banker stabilizes inflation almost completely, mirroring his large preference for stable inflation. As such, inflation is even less volatile than under optimal commitment. This comes at the expense of a larger volatility of the output gap, even higher than under the standard Taylor rule. This highlights that the gains from appointing an inflation-conservative central banker may be substantial in the face of financial frictions, but that inflation conservatism may at the same time lead to slightly higher volatility of economic activity.

An alternative way to see this result is to consider policy frontiers following technology shocks.[22] These combinations of efficient inflation and output gap volatilities are shown in Figure 7 below. While the achievable combinations of inflation and output gap volatility under discretionary policy cannot be altered by the inflation-conservative central banker, he chooses a different point on the policy frontier. As such, the solution under Rogoff-conservatism comes closer to the policy frontier under commitment and thus reduces the

[22]The policy frontiers for preference shocks and financial shocks are very similar and shown in the Appendix.

stabilization bias.

Figure 7: Policy Frontiers



Note: Efficient policy frontiers under discretion following a one-standard-deviation technology shock in σ_π^2, σ_x^2 space. Points to the right of the frontiers are inefficient, points to the left infeasible. The circles show the optimal solutions under discretion and commitment given the welfare-based relative weight on the output gap λ. The diamond is the solution under Rogoff-discretion with weight λ.

Note furthermore that the efficient solution in the standard NK model is zero inflation and output gap volatility for both discretion and commitment. Therefore, the Rogoff-conservative central banker also reduces the inflationary bias of discretion in the financial accelerator economy relative to the economy without financial frictions.

Finally, we can measure welfare gains from inflation conservatism quantitatively, as displayed in Table 2. It shows the standard deviations of inflation and output gap following a one-standard-deviation technology shock in all policy regimes, for both the standard NK model and the financial accelerator economy, and the associated inflationary bias and the stabilization bias.[23] Both are measured in terms of the implied inflation gap premium, which follows Kuester and Wieland (2010) by translating welfare losses into corresponding increases in the standard deviation of inflation.

In terms of overall stabilization of macroeconomic dynamics and associated welfare losses, the table shows that Rogoff-discretionary policy comes close to mirroring the full commitment solution. Under inflation-conservatism, the inflation gap premia are very small, substantially lower than under conventional discretion and the Taylor rule. The conservative central banker thus substantially reduces both the inflation bias and the stabilization bias.

[23]The corresponding tables for preference shocks and financial shocks feature the same results and are shown in the Appendix.

Table 2: **Policy Performance Under Different Regimes**

Policy	Financial Accelerator			Standard NK			Infl.
	sd(π)	sd(x)	Stab. Bias	sd(π)	sd(x)	Stab. Bias	Bias
Commitment	0.0055	0.1316	0	0	0	0	0.0224
Rogoff-Discretion	0.0004	0.1436	0.0078	0	0	0	0.0237
Discretion	0.0243	0.1412	0.0252	0	0	0	0.0337
Taylor Rule	0.3157	0.1125	0.3155	0.2637	0.0957	0.264	0.1739

Note: Standard deviations of inflation and output gap in response to one-standard-deviation technology shocks for alternative monetary policy regimes. The stabilization bias is measured as inflation gap premium (IGP), i.e. the increase in the standard deviation of inflation that is equivalent to the loss relative to full commitment policy. The inflation bias is measured as the IGP in the financial accelerator economy relative to the standard NK model.

5 Conclusion

The link between inflation and economic activity as prescribed by the Phillips curve is at the core of most modern thinking about monetary policy. Yet, the applicability of the Phillips curve has been called into question after the Global Financial Crisis, given the missing disinflation in the face of collapsing output. Against this background, this paper analyzes the implications of financial frictions for the Phillips curve.

I first propose a small-scale New Keynesian DSGE model with a financial accelerator. The tractability of the framework allows me to show analytically that the presence of financial frictions (a) reduces the slope of the New Keynesian Phillips curve with respect to the output gap as the counter-cyclical credit spread dampens the pro-cyclicality of marginal costs, (b) amplifies shocks via endogenous cost-push shock effects and (c) renders forward-looking behavior more important for inflation dynamics. These are characteristics that are present in many structural New Keynesian DSGE models with financial frictions.

A second-order approximation of household welfare shows that fluctuations in the credit spread generate inefficient fluctuations in marginal costs, in turn creating an additional inefficiency wedge in the economy. I show analytically that a central bank operating under discretion incurs a substantial deterioration of policy performance if financial frictions prevail in the economy. The endogenous mark-up effects induced by the financial accelerator lead to a breakdown of divine coincidence. The resulting inflationary bias relative to the standard economy is aggravated by a flattening of the Phillips curve and the higher relevance of forward-looking behavior for current inflation dynamics. The inflationary bias is increasing in the degree of financial frictions.

I prove that welfare under discretionary policy can be improved by appointing a conservative central banker in the spirit of Rogoff (1985). If the central banker is more inflation-conservative than society, i.e. if he places a larger relative weight on inflation stabilization, he is able to improve upon the trade-off between output gap and inflation. I show that the welfare-maximizing degree of inflation conservatism increases in the degree to which financial frictions are present.

Based on these findings, the interplay between financial frictions, the Phillips curve and the optimal response by central banks emerge as a potential explanation for the missing disinflation puzzle. The results suggest that monetary policy should be geared towards inflation stabilization in the presence of financial frictions. This notion is complementary to other explanations put forward in the literature, such as the anchoring of inflation expectations.

From a broader perspective, the findings of this paper reiterate a key result of the New Keynesian DSGE literature: Welfare costs of business cycles are mainly incurred via inflation volatility, which generates dispersion of intermediate goods prices under Calvo pricing and thus a suboptimal allocation of consumption. These high welfare costs of inflation volatility are hard-wired into the New Keynesian DSGE framework, and tend to dominate other sources of welfare costs. This includes considerations of financial frictions and the stabilization of leverage cycles. A prescription for future research is hence to investigate the circumstances under which the presence of financial frictions generates financial cycle stabilization motives with a larger role relative to inflation and output gap stabilization for household welfare. One possible avenue is to focus on (non-linear) models featuring systemic risk.

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Appendix

A Details on the Financial Friction

This section provides a more detailed description of the loan contract and of equity financing. These constitute the two funding opportunities that are available to entrepreneurs, who operate the intermediate goods-producing firms. As in Christiano et al. (2005), Ravenna and Walsh (2006) and De Fiore et al. (2011), wages have to be paid in advance of production. Entrepreneurs can obtain the required funds to pay wages either by equity financing on stock markets or by borrowing from a financial intermediary. As in Bernanke et al. (1999) and De Fiore et al. (2011), I assume the existence of a costly-state verification problem between firm's and banks. This gives rise to entrepreneur leverage being relevant for marginal costs, in turn leading to the canonical financial accelerator mechanism.

Let's first consider the financial contract, and drop all indices indexing firms for the sake of plain notation. Suppose that the entrepreneurs operating the intermediate goods-producing have available equity financing of N_t, which is described in more detail below. In order to hire H_t workers and pay them the market-determined wage w_t before production, entrepreneurs need to borrow

$$L_t = W_t H_t - N_t \tag{A1}$$

from a financial intermediary. Intermediate goods are produced according to a production function that is linear in labor. In addition to aggregate technology, assume that there are additional firm-specific idiosyncratic productivity shocks ω. Production is thus given by

$$Y_t = \omega_t A_t H_t$$

The idiosyncratic productivity shocks are assumed to be private information of the firm, while aggregate technology is commonly observed. The bank can only observe the idiosyncratic output of firms after production by paying monitoring costs proportional to output. This costly state verification problem gives rise to a contract specifying a loan amount L_t, a loan rate R_t^L and a threshold value for the idiosyncratic shock $\bar{\omega}_t$ defined by:

$$\bar{\omega}_t A_t H_t = R_t^L L_t \tag{A2}$$

If the realization of $\omega_t \geq \bar{\omega}_t$, the firm repays $R_t^L L_t$ and the bank does not monitor the firm. If $\omega_t < \bar{\omega}_t$, the firm defaults, the bank decides to monitor the firm, pays the monitoring cost and seizes the remaining fraction of output $(1-\zeta)\omega_t A_t H_t$.

The optimal contract maximizes the entrepreneur's expected return (A3), i.e. the share of output accruing to the entrepreneur, subject to the borrowing constraint (A4), the entrepreneur's incentive compatibility constraint (A5), the participation constraint of the financial intermediary (A6) and the repayment threshold (A7). Equations (A8) - (A9) define the shares of output accruing to the entrepreneur and the financial intermediary, respectively. Total output is split between entrepreneur, the financial intermediary and monitoring costs, as defined in (A10).

The contract can then be written as:

$$\max_{L_t, R_t^L, \bar{\omega}_t, H_t} \quad f(\bar{\omega}_t)A_tH_t \tag{A3}$$

$$s.t. \quad W_tH_t \leq L_t + N_t \tag{A4}$$

$$f(\bar{\omega}_t)A_tH_t \geq R_tN_t \tag{A5}$$

$$g(\bar{\omega}_t, \zeta)A_tH_t \geq R_tL_t \tag{A6}$$

$$\bar{\omega}_tA_tH_t = R_t^L L_t \tag{A7}$$

$$f(\bar{\omega}_t) = \int_{\bar{\omega}}^{\infty} (\omega_t - \bar{\omega_t})\Phi d\omega \tag{A8}$$

$$g(\bar{\omega}_t, \zeta) = \int_0^{\infty} (1-\zeta)\omega_t\Phi d\omega_t + \int_{\bar{\omega_t}}^{\infty} \bar{\omega_t}\Phi d\omega_t \tag{A9}$$

$$f(\bar{\omega}_t) + g(\bar{\omega}_t, \zeta) + \zeta \int_0^{\bar{\omega_t}} \omega_t\Phi d\omega = 1 \tag{A10}$$

De Fiore et al. (2011) provide conditions under which the borrowing constraint (A4) holds with equality, and show that the entrepreneur's incentive compatibility constraint (A5) is slack given the optimal contract, while the financial intermediary participation constraint (A6) is binding. Defining

$$v_t = \frac{A_t}{W_t} \tag{A11}$$

as auxiliary variables capturing terms that are exogenous to the contract, we can thus rewrite the maximization problem as

$$\max_{L_t, R_t^L, \bar{\omega}_t} \quad f(\bar{\omega}_t)v_t(L_t + N_t) \tag{A12}$$

$$s.t. \quad g(\bar{\omega}_t, \zeta)v_t(L_t + N_t) = R_tL_t \tag{A13}$$

where the threshold and the shares are given by Equations (A7)- (A10). Denoting the Lagrange multiplier on (A13) by ξ_t, the FOCs with respect to L_t and $\bar{\omega}_t$ are given by:

$$f(\bar{\omega}_t)v_t - \xi_t(g(\bar{\omega}_t, \zeta)v_t - R_t) = 0 \tag{A14}$$

$$f'(\bar{\omega}_t)(L_t + N_t) - \xi_t(g'(\bar{\omega}_t, \zeta)v_t(L_t + N_t)) = 0 \tag{A15}$$

where $f'(.)$ and $g'(.)$ denote the derivatives of f and g with respect to $\bar{\omega}_t$. Combining these equations yields:

$$\frac{f(\bar{\omega}_t)v_t}{g(\bar{\omega}_t,\zeta)v_t - R_t} = \frac{f'(\bar{\omega}_t)}{g'(\bar{\omega}_t,\zeta)} \tag{A16}$$

Equation (A16), together with (A13) and (A7), defines the optimal contract $\{L_t, R_t^L, \bar{\omega}_t\}$. We can rearrange these equations to:

$$R_t^L = \frac{\bar{\omega}_t}{f(\bar{\omega}_t)} \frac{f'(\bar{\omega}_t)}{g'(\bar{\omega}_t,\zeta)} \frac{N_t}{w_t H_t - N_t} R_t \tag{A17}$$

This equation can be rewritten as

$$\frac{R_t^L}{R_t} = s\left(\frac{N_t}{W_t H_t}\right) \tag{A18}$$

with $s'(.) < 0$. As in Bernanke et al. (1999), we can approximate this relationship linearly around the steady state by

$$r_t^L = r_t + \nu(w_t + h_t - n_t) + \varepsilon_t^r \tag{A19}$$

with $0 < \nu < 1$ and where an ad-hoc financial shock to the loan-rate is added. Hence, the costly state verification problem between entrepreneurs and banks implies a mapping of structural parameters into the elasticity of the credit spread with respect to entrepreneur leverage. This is Equation (24) shown in the main part. Intuitively speaking, higher entrepreneur leverage increases the probability of firm default, such that the financial intermediary requires a higher loan rate as a compensation for taking the higher risk.

With respect to equity, Equation (12) postulates that it depends positively on output and negatively on the nominal interest rate. Similar to Boehl (2017), I assume that entrepreneurs can issue equity in the stock market. Imposing no arbitrage, equity needs to satisfy

$$S_t = N_t \frac{E_t[R_{t+1}^S]}{R_t} \tag{A20}$$

where S_t is the stock price S_t and R_{t+1}^S denotes the return on equity. In equilibrium, with (risk-neutral) entrepreneurs being indifferent between increasing or decreasing the loan volume, it must furthermore hold that

$$E_t[R_{t+1}^S] = R_t^L \tag{A21}$$

Stocks are priced by risk-neutral financial traders associated with the financial intermediary according to the expected dividend on the stocks. I assume that entrepreneur consumption is fully taxed. As a result, they pay out the whole return left after repaying the loan as dividend at the end of each period. From the financial contract, this return is given by $f(\bar{\omega_t})Y_t$. Accordingly, financial traders attach a price of

$$S_t = \frac{f(\bar{\omega_t})Y_t}{R_t} \tag{A22}$$

to stocks. Combining Equations (A20)-(A22) and using (A18) yields

$$N_t = \frac{f(\bar{\omega_t})Y_t}{R_t} s^{-1}\left(\frac{N_t}{W_t H_t}\right) \tag{A23}$$

where $s^{-1}(.)$ is the inverse function of $s(.)$. This is what Equation (12) in the main text captures, noting that wages and labor supply can be written as a function of output using household's intratemporal optimality condition and the production function. Log-linearizing this equation yields

$$n_t = \psi y_t - \mu r_t \tag{A24}$$

with $\psi > 0, \mu = \frac{1}{1-\nu} > 0$ which means that entrepreneurs can raise more equity if (expected) output is higher, but less equity if the nominal interest rate is higher (due to higher opportunity costs for financial traders). The financial accelerator hence entails the well-known result by Bernanke et al. (1999) that equity is pro-cyclical, while at the same time depending directly on central bank interest rates.

B Linearized Equations Characterizing Equilibrium

Sticky-Price Economy

Euler equation:

$$y_t = -\sigma^{-1}(r_t - E_t[\pi_{t+1}) + E_t[y_{t+1}] \tag{A25}$$

Intratemporal consumption-labor trade-off:

$$w_t = \eta h_t + \sigma y_t \tag{A26}$$

Production function:

$$y_t = a_t + h_t \tag{A27}$$

Marginal costs:

$$mc_t = w_t + \vartheta r_t^L - a_t \tag{A28}$$

Phillips curve:

$$\pi_t = \kappa mc_t + \beta E_t[\pi_{t+1}] \tag{A29}$$

Credit spread:

$$r_t^L = r_t + \nu(w_t + h_t - n_t) \tag{A30}$$

Equity:

$$n_t = \psi y_t - \mu r_t \tag{A31}$$

Taylor rule:

$$r_t = \phi_\pi \pi_t + \eta_t^m \tag{A32}$$

Flexible-Price Economy

Euler equation:

$$y_t^f = -\sigma^{-1}\left(r_t^f\right) + E_t[y_{t+1}^f] \tag{A33}$$

Intratemporal consumption-labor trade-off:

$$w_t^f = \eta h_t^f + \sigma y_t^f \tag{A34}$$

Production function:

$$y_t^f = a_t + h_t^f \tag{A35}$$

Marginal costs:

$$0 = w_t^f + \vartheta r_t^{L,f} - a_t \tag{A36}$$

Credit spread:

$$r_t^{L,f} = r_t^f + \nu(w_t^f + h_t^f - n_t^f) \tag{A37}$$

Equity:

$$n_t^f = \psi y_t^f - \mu r_t^f \tag{A38}$$

Auxiliary Variables and Shocks

Efficient output:

$$y_t^e = \frac{1+\eta}{\sigma+\eta} a_t \tag{A39}$$

Output gap:

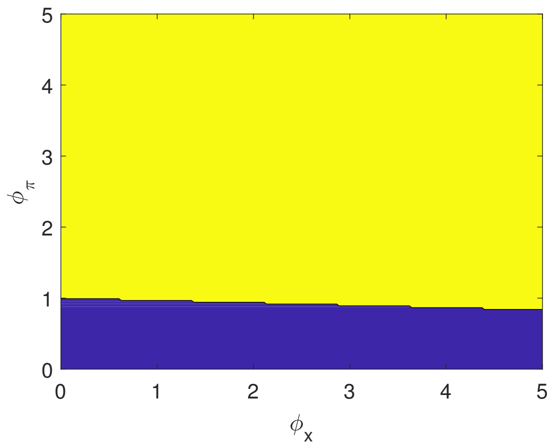
$$x_t = y_t - y_t^e \tag{A40}$$

Technology shock:

$$a_t = \rho_a \, a_{t-1} + \eta_t^a \tag{A41}$$

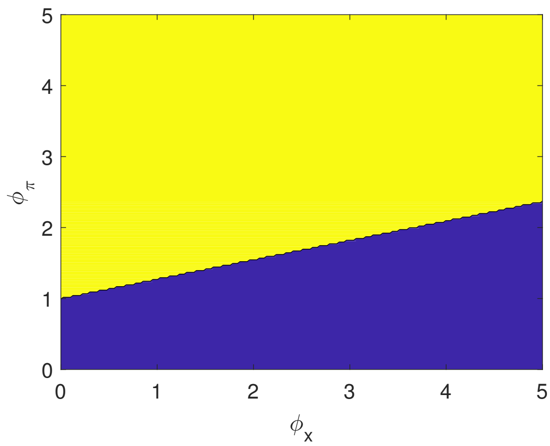
C Determinacy Regions

Figure A1: Determinacy Region NK Model



Note: The determinacy (yellow) and indeterminacy (blue) regions of the standard New Keynesian model ($\vartheta = 0$) for a standard Taylor rule responding to inflation and output gap. The x-axis shows the output gap coefficient and the y-axis the coefficient on inflation.

Figure A2: Determinacy Region Financial Accelerator Model



Note: The determinacy (yellow) and indeterminacy (blue) regions of the financial frictions model ($\vartheta = 1, \nu = 0.05, \psi = 6, \mu = \frac{1}{1-\nu}$) for a standard Taylor rule responding to inflation and output gap. The x-axis shows the output gap coefficient and the y-axis the coefficient on inflation.

D Welfare Approximation

This section shows the proof for Proposition 1. Start from the per-period household utility function, which is given by

$$U_t = U(C_t, H_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \chi \frac{H_t^{1+\eta}}{1+\eta} \tag{A42}$$

and is thus separable in consumption and hours worked. A second-order Taylor expansion of U_t around a steady state (C, H) yields

$$U_t - U \simeq U_c C \left(\frac{C_t - C}{C}\right) + U_h H \left(\frac{H_t - H}{H}\right) + \frac{1}{2} U_{cc} C^2 \left(\frac{C_t - C}{C}\right)^2 + \frac{1}{2} U_{hh} H^2 \left(\frac{H_t - H}{H}\right)^2 + tip \tag{A43}$$

where variables without a time subscript denote steady state values, U_x denotes the derivative with respect to x and tip stands for terms independent of policy. Rewriting this equation in log deviations by replacing $\frac{X_t - X}{X} \approx x_t + \frac{1}{2} x_t^2$ where $x_t = log\left(\frac{X_t}{X}\right)$ gives

$$U_t - U \simeq U_c C \left(c_t + \left(\frac{1}{2} + \frac{U_{cc} C}{2 U_c}\right) c_t^2\right) + U_h H \left(h_t + \left(\frac{1}{2} + \frac{U_{hh} H}{2 U_h}\right) h_t^2\right) + tip \tag{A44}$$

Noting that $\frac{U_{cc} C}{U_c} = -\sigma$ and $\frac{U_{hh} H}{U_h} = \eta$, as well as making use of the ressource constraint $c_t = y_t$ we can rewrite this as

$$U_t - U \simeq U_c C \left(y_t + \frac{1-\sigma}{2} y_t^2\right) + U_h H \left(h_t + \frac{1+\eta}{2} h_t^2\right) + tip \tag{A45}$$

From the production function, we have that

$$h_t = y_t - a_t + d_t \tag{A46}$$

where $d_t = log \int_0^1 \left(\frac{P_{j,t}}{P_t} dj\right)^{-\epsilon}$ is capturing price dispersion. It can be shown that

$$d_t = \frac{\epsilon}{2} var_j\{p_{j,t}\} \tag{A47}$$

or in other words price dispersion is proportional to the cross-sectional variance of relative prices in a neighborhood of a symmetric steady state up to a second-order approximation. We can use this to rewrite utility as

$$U_t - U = U_c C \left(y_t + \frac{1-\sigma}{2} y_t^2\right) + U_h H \left(y_t + \frac{\epsilon}{2} var_j\{p_{j,t}\} + \frac{1+\eta}{2} (y_t - a_t)^2\right) + tip \tag{A48}$$

Dividing by $U_c C$ and rearranging terms yields

$$\frac{U_t - U}{U_c C} = \left(1 + \frac{U_h H}{U_c C}\right) y_t + \frac{1-\sigma}{2} \widehat{y}_t^2 + \frac{1}{2} \left[\frac{U_h H}{U_c C} \left(\epsilon \, var_j\{p_{j,t}\} + (1+\eta)(y_t - a_t)^2\right)\right] + tip \tag{A49}$$

The steady-state of the flexible-price equilibrium is given by

$$Y^f = \left(\frac{1}{\chi \tau \frac{\epsilon}{\epsilon-1} \vartheta R^L} \right)^{\frac{1}{\sigma+\eta}} \tag{A50}$$

which shows that it is distorted by the presence of monopolistic competition via the mark-up $\frac{\epsilon}{\epsilon-1} > 1$ and the financial friction via the non-negative credit spread that implies $R^L \geq R = \beta^{-1} > 1$. As described in the main text, I assume that there are some steady-state subsidies τ on firm's marginal costs such that $\tau \frac{\epsilon}{\epsilon-1} R^L = 1$ and the steady-state is efficient. Imposing efficiency of the steady state through appropriate subsidies, we have

$$-\frac{U_h}{U_c} = MPN = \frac{Y}{H} \tag{A51}$$

such that

$$\frac{U_h H}{U_c C} = -1 \tag{A52}$$

and the linear term involving y_t drops out. We are left with

$$\frac{U_t - U}{U_c C} = -\frac{1}{2} \left[(\sigma - 1) y_t^2 + \epsilon\, var_j\{p_{j,t}\} + (1+\eta)\left(y_t - a_t\right)^2 \right] + tip \tag{A53}$$

The efficient allocation is given by

$$y_t^e = \frac{1+\eta}{\sigma+\eta} a_t \tag{A54}$$

which we can use to replace a_t and get

$$\frac{U_t - U}{U_c C} = -\frac{1}{2} \left[(\sigma - 1) y_t^2 + \epsilon\, var_j\{p_{j,t}\} + (1+\eta)\left(y_t - \frac{\sigma+\eta}{1+\eta} y_t^e\right)^2 \right] + tip \tag{A55}$$

which can be rearranged to

$$\frac{U_t - U}{U_c C} = -\frac{1}{2} \left[(\sigma+\eta)(y_t - y_t^e)^2 + \epsilon\, var_j\{p_{j,t}\} \right] + tip \tag{A56}$$

Defining the output gap with respect to efficient output as $x_t = y_t - y_t^e$, we can write the second-order approximation of household welfare losses as a fraction of steady state consumption (ignoring additive terms independent of policy) as

$$\begin{aligned} \mathcal{W}_t &= E_t \sum_{s=0}^{\infty} \beta^s \left(\frac{U_{t+s} - U}{U_c C} \right) && \text{(A57)} \\ &= -\frac{1}{2} E_t \sum_{s=0}^{\infty} \beta^s \left(\epsilon\, var_j\{p_{j,t+s}\} + (\sigma+\eta) x_{t+s}^2 \right) && \text{(A58)} \end{aligned}$$

Following Woodford (2003a), we can rewrite

$$\sum_{s=0}^{\infty}\beta^s var_j\{p_{j,t+s}\} = \frac{\theta}{(1-\beta\theta)(1-\theta)}\sum_{s=0}^{\infty}\beta^s\pi_{t+s}^2 \tag{A59}$$

Using $\kappa = \frac{(1-\beta\theta)(1-\theta)}{\theta}$, we can write

$$\mathcal{W}_t = -\frac{1}{2}E_t\sum_{s=0}^{\infty}\beta^s\left(\frac{\epsilon}{\kappa}\pi_{t+s}^2 + (\sigma+\eta)x_{t+s}^2\right) \tag{A60}$$

Finally, we can postulate a per-period loss function for policymakers with a normalized unit weight on inflation:

$$\mathcal{L}_t = \pi_t^2 + \lambda x_t^2 \tag{A61}$$

where $\lambda = \frac{\kappa(\sigma+\eta)}{\epsilon}$. This is what Proposition 1 in the main text states. At first glance, this seems identical to the solution obtained in the standard model without a cost channel and financial frictions. However, note that the wedge between flexible-price output and the efficient level of output is given by

$$y_t^f = y_t^e - \vartheta r_t^L \tag{A62}$$

such that we can write the loss function as

$$\mathcal{L}_t = \pi_t^2 + \lambda\left(y_t - y_t^f - \vartheta r_t^L\right)^2 \tag{A63}$$

or alternatively using

$$r_t^L = r_t^f + \nu(w_t^f + h_t^f - n_t^f) \tag{A64}$$

as

$$\mathcal{L}_t = \pi_t^2 + \lambda\left(x_t^f - \frac{\vartheta}{\sigma+\eta}r_t^f - \frac{\vartheta\nu}{\sigma+\eta}lev_t^f\right)^2 \tag{A65}$$

where all variables with superscript f refer to the flexible-price economy, $x_t^f = y_t - y_t^f$ is the output gap with respect to the flexible-price economy with financial frictions and $lev_t^f = w_t^f + h_t^f - n_t^f$. Ignoring covariance terms, the loss function is approximately equal to

$$\mathcal{L}_t \approx \pi_t^2 + \lambda\left(x_t^f\right)^2 + \frac{\lambda\vartheta^2}{(\sigma+\eta)^2}\left(r_t^f\right)^2 + \frac{\lambda\vartheta^2\nu^2}{(\sigma+\eta)^2}\left(lev_t^f\right)^2 \tag{A66}$$

We may interpret the first two terms as representing the traditional central bank mandate of stabilizing inflation and economic activity. The latter two terms are mandates for stabilizing the volatility of interest rate and leverage, as these are crucial for loan terms and hence marginal costs. These represent the additional wedge that emerges between flexible-price economy and efficient economy due to the presence of financial frictions.

E Proofs

This section shows the proofs of Propositions 2-8.

Proposition 2 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). The optimal targeting rule for monetary policy under discretion is given by*

$$\pi_t \;=\; -\frac{\lambda}{\widetilde{\kappa}} x_t \tag{A67}$$

where

$$\widetilde{\kappa} = \kappa[\sigma + \eta - \vartheta\sigma + \vartheta\nu(1 + \sigma + \eta - \psi - \mu\sigma)] \tag{A68}$$

Proof. Let us combine the Euler equation and the Phillips curve to one constraint given by:

$$\pi_t = \widetilde{\kappa}\, x_t + \widetilde{\widetilde{\beta}}\, E_t[\pi_{t+1}] + \vartheta\kappa\sigma(1 + \nu\mu)E_t[x_{t+1}] - \vartheta\kappa(\nu\phi + \varphi\sigma(1 + \nu\mu))\, a_t \tag{A69}$$

Let us denote the Lagrange multiplier associated with this constraint as Ξ_t. The first-order conditions for inflation and output gap under discretion are given by:

$$\pi_t = \Xi_t \tag{A70}$$

$$-\lambda x_t - \widetilde{\kappa}\, \Xi_t = 0 \tag{A71}$$

Combining the first-order conditions yields:

$$\pi_t \;=\; -\frac{\lambda}{\widetilde{\kappa}} x_t \tag{A72}$$

■

Proposition 3 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). The dynamics of inflation, output gap and nominal interest rate under optimal discretionary policy are given by*

$$\pi_t \;=\; -\lambda\vartheta\kappa\, \frac{\nu\phi + \sigma\varphi(1 + \nu\mu)}{\widetilde{\kappa}^2 + \lambda(1 - \rho_a\widetilde{\beta})}\, a_t \tag{A73}$$

$$x_t \;=\; \vartheta\kappa\widetilde{\kappa}\, \frac{\nu\phi + \sigma\varphi(1 + \nu\mu)}{\widetilde{\kappa}^2 + \lambda(1 - \rho_a\widetilde{\beta})}\, a_t \tag{A74}$$

$$r_t \;=\; -\vartheta\kappa\gamma\, \frac{\nu\phi + \sigma\varphi(1 + \nu\mu)}{\widetilde{\kappa}^2 + \lambda(1 - \rho_a\widetilde{\beta})}\, a_t - \sigma\varphi\, a_t \tag{A75}$$

where

$$\widetilde{\beta} = \beta + \vartheta\kappa(1 + \nu\mu)\left(1 - \frac{\widetilde{\kappa}\sigma}{\lambda}\right) \tag{A76}$$

$$\gamma = \lambda\rho_a + (1 - \rho_a)\sigma\widetilde{\kappa} \tag{A77}$$

Proof. Given the targeting rule under optimal discretion, the economy can be characterized by two equations:

$$\pi_t = \widetilde{\kappa}\, x_t + \widetilde{\widetilde{\beta}}\, E_t[\pi_{t+1}] + \vartheta\kappa\sigma(1+\nu\mu)E_t[x_{t+1}] - \vartheta\kappa(\nu\phi + \varphi\sigma(1+\nu\mu))\, a_t \tag{A78}$$

$$\pi_t \;=\; -\frac{\lambda}{\widetilde{\kappa}} x_t \tag{A79}$$

Inserting the targeting rule in Equation (A78) and rearranging yields

$$\pi_t = \frac{\lambda}{\lambda + \widetilde{\kappa}} \widetilde{\beta}\, E_t[\pi_{t+1}] - \frac{\lambda}{\lambda + \widetilde{\kappa}} \vartheta\kappa(\nu\phi + \sigma\varphi(1+\nu\mu))a_t \tag{A80}$$

Iterating forward yields the solution for inflation. The solution for the output gap then follows directly from the targeting rule. The dynamics of the nominal interest rate can be obtained by inserting the solutions for inflation and output gap in the Euler equation.
■

Proposition 4 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Assume further $\rho_a = 0$ and let Assumption 2 hold. Then it holds that*

$$\frac{\partial \alpha}{\partial \nu} > 0 \tag{A81}$$

$$\frac{\partial \alpha}{\partial \psi} > 0 \tag{A82}$$

such that the inflationary bias increases in the degree of financial frictions as captured by ν and ψ via the flatter Phillips curve.

Proof. Under $\rho_a = 0$, we have that:

$$\alpha \equiv \frac{\nu\phi + \sigma\varphi(1+\nu\mu)}{\widetilde{\kappa}^2 + \lambda} \tag{A83}$$

The derivative of α with respect to ν is given by:

$$\frac{\partial \alpha}{\partial \nu} = \frac{(\phi + \varphi\sigma\mu)(\widetilde{\kappa}^2 + \lambda) - (\nu\phi + \sigma\varphi(1+\nu\mu))\frac{\partial \widetilde{\kappa}^2}{\partial \nu}}{[\widetilde{\kappa} + \lambda(1-\widetilde{\beta})]^2} \tag{A84}$$

The denominator is positive, so the sign of the derivative is determined by the numerator. The first term is strictly positive. The derivative in the second term is negative under Assumption 2. We hence have that:

$$\frac{\partial \alpha}{\partial \nu} > 0 \tag{A85}$$

For the second part, the derivative of α with respect to ψ is given by:

$$\frac{\partial\alpha}{\partial\psi} = \frac{\nu(\widetilde{\kappa}^2 + \lambda)\frac{\partial\phi}{\partial\psi} - (\nu\phi + \sigma\varphi(1+\nu\mu))\frac{\partial\widetilde{\kappa}^2}{\partial\psi}}{[\widetilde{\kappa} + \lambda(1-\widetilde{\beta})]^2} \tag{A86}$$

Again, the sign is determined by the numerator. The first derivative in the numerator is positive in any case. The second derivative is also negative in the financial accelerator economy. We thus have that:

$$\frac{\partial\alpha}{\partial\psi} > 0 \tag{A87}$$

■

Proposition 5 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). It holds that*

$$\frac{\partial\widetilde{\beta}}{\partial\psi} > 0 \tag{A88}$$

Under Assumption 4, it furthermore holds that

$$\frac{\partial\widetilde{\beta}}{\partial\nu} > 0 \tag{A89}$$

such that the inflationary bias increases in the degree of financial frictions as captured by ν and ψ via the higher relevance of future expectations for current inflation dynamics. Furthermore, monetary policy reacts more aggressive to technology shocks.

Proof. Note that $\widetilde{\beta}$ is given by:

$$\widetilde{\beta} = \beta + \vartheta\kappa(1+\nu\mu)\left(1 - \frac{\widetilde{\kappa}\sigma}{\lambda}\right) \tag{A90}$$

We thus have that:

$$\frac{\partial\widetilde{\beta}}{\partial\psi} = -\vartheta\kappa(1+\nu\mu)\frac{\sigma}{\lambda}\frac{\partial\widetilde{\kappa}}{\partial\psi} = \vartheta^2\nu\kappa(1+\nu\mu)\frac{\sigma}{\lambda} > 0 \tag{A91}$$

For the second part, we have that:

$$\frac{\partial\widetilde{\beta}}{\partial\nu} = \vartheta\kappa\mu - \vartheta\kappa\frac{\sigma}{\lambda}\left[\mu\widetilde{\kappa} + (1+\nu\mu)\frac{\partial\widetilde{\kappa}}{\partial\nu}\right] \tag{A92}$$

Rearranging and plugging in the derivative of $\widetilde{\kappa}$ shows that the sign of the derivative is determined by:

$$\mu(\lambda - \sigma\widetilde{\kappa}) - \sigma(1+\nu\mu)(1+\sigma+\eta-\psi-\mu\sigma) \tag{A93}$$

This term is positive under Assumption 4. ■

Proposition 6 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). The dynamics of inflation and the output gap and nominal interest rate under optimal commitment to a simple rule of the form $x_t = b_a\, a_t$ are given by:*

$$\pi_t = -\lambda\vartheta\kappa(1-\rho_a\tilde{\tilde{\beta}})\frac{\nu\phi+\sigma\varphi(1+\nu\mu)}{\tilde{\tilde{\kappa}}^2+\lambda(1-\rho_a\tilde{\tilde{\beta}})^2}\,a_t \tag{A94}$$

$$x_t = \vartheta\kappa\tilde{\tilde{\kappa}}\frac{\nu\phi+\sigma\varphi(1+\nu\mu)}{\tilde{\tilde{\kappa}}^2+\lambda(1-\rho_a\tilde{\tilde{\beta}})^2}\,a_t \tag{A95}$$

Proof. As seen in Lemma 12, the optimal policy function is given by:

$$b_a = \vartheta\kappa\tilde{\tilde{\kappa}}\frac{\nu\phi+\sigma\varphi(1+\nu\mu)}{\tilde{\tilde{\kappa}}^2+\lambda(1-\rho_a\tilde{\tilde{\beta}})^2} \tag{A96}$$

The dynamics of inflation are in Lemma 11 for general b_a as:

$$\pi_t = \frac{\tilde{\tilde{\kappa}}}{1-\rho_a\tilde{\tilde{\beta}}}b_a\,a_t - \vartheta\kappa\frac{\nu\phi+\sigma\varphi(1+\nu\mu)}{1-\rho_a\tilde{\tilde{\beta}}}a_t \tag{A97}$$

Combining these two equations yields:

$$\pi_t = \vartheta\kappa\tilde{\tilde{\kappa}}\frac{\tilde{\tilde{\kappa}}}{1-\rho_a\tilde{\tilde{\beta}}}\frac{\nu\phi+\sigma\varphi(1+\nu\mu)}{\tilde{\tilde{\kappa}}^2+\lambda(1-\rho_a\tilde{\tilde{\beta}})^2}\,a_t - \vartheta\kappa\frac{\nu\phi+\sigma\varphi(1+\nu\mu)}{1-\rho_a\tilde{\tilde{\beta}}}\,a_t \tag{A98}$$

This can be rearranged to yield the representation shown in the main text. ■

Proposition 7 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Optimal discretionary monetary policy with relative weight $\widetilde{\lambda}$ on output gap stabilization mimics optimal commitment to a simple rule of the form $x_t = b_a\, a_t$ if*

$$\widetilde{\lambda} = (1-\rho_a\tilde{\tilde{\beta}})\frac{\tilde{\kappa}}{\tilde{\tilde{\kappa}}}\lambda \tag{A99}$$

Proof. Discretion with a Rogoff-conservative weight yields the following inflation dynamics:

$$\pi_t^{\text{Rogoff}} = -\widetilde{\lambda}\vartheta\kappa\,\frac{\nu\phi+\sigma\varphi(1+\nu\mu)}{\tilde{\kappa}^2+\lambda(1-\rho_a\tilde{\beta}(\widetilde{\lambda}))}\,a_t \tag{A100}$$

Under commitment to a simple rule (CSR), inflation is given by:

$$\pi_t^{\text{CSR}} = -\lambda\vartheta\kappa(1-\rho_a\tilde{\tilde{\beta}})\frac{\nu\phi+\sigma\varphi(1+\nu\mu)}{\tilde{\tilde{\kappa}}^2+\lambda(1-\rho_a\tilde{\tilde{\beta}})^2}\,a_t \tag{A101}$$

Setting these two equations equal shows that inflation dynamics are identical if

$$\frac{\widetilde{\lambda}}{\tilde{\kappa}^2+\lambda(1-\rho_a\tilde{\beta}(\widetilde{\lambda}))} = \frac{\lambda(1-\rho_a\tilde{\tilde{\beta}})}{\tilde{\tilde{\kappa}}^2+\lambda(1-\rho_a\tilde{\tilde{\beta}})^2} \tag{A102}$$

The solution for $\widetilde{\lambda}$ follows after some algebraic manipulations, noticing that $\widetilde{\beta}$ is a function of $\widetilde{\lambda}$. ■

Proposition 8 *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Under Assumption 2 and Assumption 5, it holds that*

$$\frac{\partial \widetilde{\lambda}}{\partial \nu} < 0 \tag{A103}$$

$$\frac{\partial \widetilde{\lambda}}{\partial \psi} < 0 \tag{A104}$$

such that the optimal degree of inflation conservatism increases in the degree of financial frictions as captured by ν and ψ.

Proof. The first derivative is given by:

$$\begin{aligned} \frac{\partial \widetilde{\lambda}}{\partial \nu} &= -\rho_a \frac{\widetilde{\kappa}}{\widetilde{\widetilde{\kappa}}} \frac{\partial \widetilde{\widetilde{\beta}}}{\partial \nu} + (1 - \rho_a \widetilde{\widetilde{\beta}}) \frac{\partial \frac{\widetilde{\kappa}}{\widetilde{\widetilde{\kappa}}}}{\partial \nu} && \text{(A105)} \\ &= -\rho_a \frac{\widetilde{\kappa}}{\widetilde{\widetilde{\kappa}}} \vartheta \kappa \nu + (1 - \rho_a \widetilde{\widetilde{\beta}}) \vartheta \frac{\widetilde{\widetilde{\kappa}} - \widetilde{\kappa}}{\widetilde{\kappa}^2} \frac{\partial \widetilde{\kappa}}{\partial \nu} && \text{(A106)} \end{aligned}$$

We have that $\widetilde{\widetilde{\kappa}} > \widetilde{\kappa}$ for $0 < \rho < 1$. Under Assumption 5, we have that $(1 - \rho_a \widetilde{\widetilde{\beta}}) > 0$ and $\frac{\partial \widetilde{\kappa}}{\partial \nu} < 0$ under Assumption 2. This implies that:

$$\frac{\partial \widetilde{\lambda}}{\partial \nu} < 0 \tag{A107}$$

For the second part of the proposition, note that the derivative is given by:

$$\begin{aligned} \frac{\partial \widetilde{\lambda}}{\partial \nu} &= (1 - \rho_a \widetilde{\widetilde{\beta}}) \frac{\partial \frac{\widetilde{\kappa}}{\widetilde{\widetilde{\kappa}}}}{\partial \psi} && \text{(A108)} \\ &= (1 - \rho_a \widetilde{\widetilde{\beta}}) \frac{\widetilde{\widetilde{\kappa}} - \widetilde{\kappa}}{\widetilde{\kappa}^2} \frac{\partial \widetilde{\kappa}}{\partial \psi} && \text{(A109)} \end{aligned}$$

We have that $\widetilde{\widetilde{\kappa}} > \widetilde{\kappa}$ for $0 < \rho < 1$. Under Assumption 5, we have that $(1 - \rho_a \widetilde{\widetilde{\beta}}) > 0$ and $\frac{\partial \widetilde{\kappa}}{\partial \psi} = -\vartheta \nu < 0$ in the financial accelerator economy. This implies that:

$$\frac{\partial \widetilde{\lambda}}{\partial \psi} < 0 \tag{A110}$$

■

F Model Extension

F.1 Model Equations

This section shows the model extension with two additional aggregate shocks: A preference shock ε_t^c to household's marginal utility of consumption, and a financial shock ε_t^r that shifts the required loan rate. The utility function of households is given by:

$$U_t = E_t \sum_{s=0}^{\infty} \beta^s \left\{ e^{\varepsilon_{t+s}^c} \frac{C_{t+s}^{1-\sigma}}{1-\sigma} - \chi \frac{H_{t+s}^{1+\eta}}{1+\eta} \right\}$$

The resulting optimality conditions are:

$$e^{\varepsilon_t^c} C_t^{-\sigma} = \beta E_t \left[\frac{R_t}{\pi_{t+1}} e^{\varepsilon_{t+1}^c} C_{t+1}^{-\sigma} \right] \tag{A111}$$

$$\frac{\chi H_t^{\eta}}{e^{\varepsilon_t^c} C_t^{-\sigma}} = W_t \tag{A112}$$

The corresponding linearized equations describing household behavior can then be written as:

$$y_t = -\sigma^{-1} \left(r_t - E_t[\pi_{t+1}] + E_t[\varepsilon_{t+1}^c] - \varepsilon_t^c \right) + E_t[y_{t+1}] \tag{A113}$$

$$w_t = \eta h_t + \sigma y_t - \varepsilon_t^c \tag{A114}$$

The linearized equation for the credit spread is then given by:

$$r_t^L = r_t + \nu(w_t + h_t - n_t) + \varepsilon_t^r \tag{A115}$$

Note that preference shocks lead to efficient output fluctuations:

$$y_t^e = \frac{1+\eta}{\sigma+\eta} a_t + \frac{1}{\sigma+\eta} \varepsilon_t^c \tag{A116}$$

The model can be written compactly as

$$x_t = -\sigma^{-1} \left(r_t - E_t[\pi_{t+1}] \right) + E_t[x_{t+1}] + u_t \tag{A117}$$

$$\pi_t = \mathcal{K} x_t + \vartheta \kappa (1 + \nu\mu) r_t + \beta E_t[\pi_{t+1}] + e_t \tag{A118}$$

where u_t is a composite demand shock given by:

$$u_t = \frac{\eta(1-\rho_c)}{\sigma(\sigma+\eta)} \varepsilon_t^c - \frac{(1+\eta)(1-\rho_a)}{\sigma+\eta} a_t \tag{A119}$$

and e_t is a composite cost-push shock:

$$e_t = \kappa \vartheta \varepsilon_t^r + \kappa \nu \vartheta \left(\frac{1-\psi}{\sigma+\eta} \varepsilon_t^c - (\psi - 1) \frac{1+\eta}{\sigma+\eta} a_t \right) \tag{A120}$$

The structure of the economy is hence similar to the one in the baseline model. The two extra shocks alter efficient output and unfold additional demand shocks and cost-push effects. Notably, the financial shock is inefficient and appears as a pure mark-up shock in the Phillips curve only.

F.2 Optimal Discretionary Monetary Policy

The analytic solutions are presented in terms of the composite shocks for the sake of illustrative exposition. Following the same steps as in the main analysis, the solution under optimal discretionary policy is given by

$$\pi_t = \frac{\lambda}{\widetilde{\kappa}^2 + \lambda(1-\rho_e\widetilde{\beta})} e_t + \lambda\vartheta\kappa \frac{\sigma(1+\nu\mu)}{\widetilde{\kappa}^2 + \lambda(1-\rho_u\widetilde{\beta})} u_t \tag{A121}$$

$$x_t = -\frac{\widetilde{\kappa}}{\widetilde{\kappa}^2 + \lambda(1-\rho_e\widetilde{\beta})} e_t - \vartheta\kappa\widetilde{\kappa} \frac{\sigma(1+\nu\mu)}{\widetilde{\kappa}^2 + \lambda(1-\rho_u\widetilde{\beta})} u_t \tag{A122}$$

$$r_t = \frac{\gamma_e}{\widetilde{\kappa}^2 + \lambda(1-\rho_e\widetilde{\beta})} e_t + \frac{\gamma_u(1+\vartheta\kappa(1+\nu\mu))}{\widetilde{\kappa}^2 + \lambda(1-\rho_u\widetilde{\beta})} u_t \tag{A123}$$

where

$$\gamma_i = \lambda\rho_i + (1-\rho_i)\sigma\widetilde{\kappa} \quad \text{for } i = u, e \tag{A124}$$

and all remaining parameters are defined as in the main text.

In line with the main analysis, this shows that optimal discretionary policy can be perfectly stabilize preference shocks and financial shocks in the absence of financial frictions ($\vartheta = 0$, such that the second terms disappear, and $e_t = 0$). This is equivalent to saying that divine coincidence continues to hold in this model extension without financial frictions. If, however, financial frictions are present, preference and financial shocks generate endogenous cost-push effects. The mechanism is the same as the one for technology shocks discussed in the main text. This leads to a breakdown of divine coincidence, and an inflationary bias of discretionary monetary policy relative to the standard NK model.

F.3 Mimicking Commitment to Simple Rule

Let the simple rule be of the form:

$$x_t = b_e e_t + b_u u_t \tag{A125}$$

Inserting this in the Phillips curve yields

$$\pi_t = \frac{1+\widetilde{\widetilde{\kappa}} b_e}{1-\rho_e\widetilde{\widetilde{\beta}}} e_t + \frac{(\mathcal{K}-\widetilde{\kappa}) + \widetilde{\widetilde{\kappa}} b_u}{1-\rho_u\widetilde{\widetilde{\beta}}} u_t \tag{A126}$$

where all parameters are defined as in the main text. The optimal values of b_e and b_u are the solution to the central bank's optimization problem given by

$$\min_{b_e,b_u} \frac{1}{2}E_t\sum_{s=0}^{\infty}\beta^s\left\{\left[\left(\frac{1+\widetilde{\widetilde{\kappa}}b_e}{1-\rho_e\widetilde{\widetilde{\beta}}}\right)^2+\lambda b_e^2\right]e_{t+s}^2+\left[\left(\frac{(\mathcal{K}-\widetilde{\kappa})+\widetilde{\widetilde{\kappa}}b_u}{1-\rho_u\widetilde{\widetilde{\beta}}}\right)^2+\lambda b_u^2\right]u_{t+s}^2\right\} \tag{A127}$$

From the first order condition, it follows that the optimal policy functions with respect to demand and cost-push shocks are given by:

$$b_e = -\frac{\widetilde{\widetilde{\kappa}}}{\widetilde{\widetilde{\kappa}}^2+\lambda(1-\rho_e\widetilde{\widetilde{\beta}})^2} \tag{A128}$$

$$b_u = -\frac{(\mathcal{K}-\widetilde{\kappa})\widetilde{\widetilde{\kappa}}}{\widetilde{\widetilde{\kappa}}^2+\lambda(1-\rho_u\widetilde{\widetilde{\beta}})^2} \tag{A129}$$

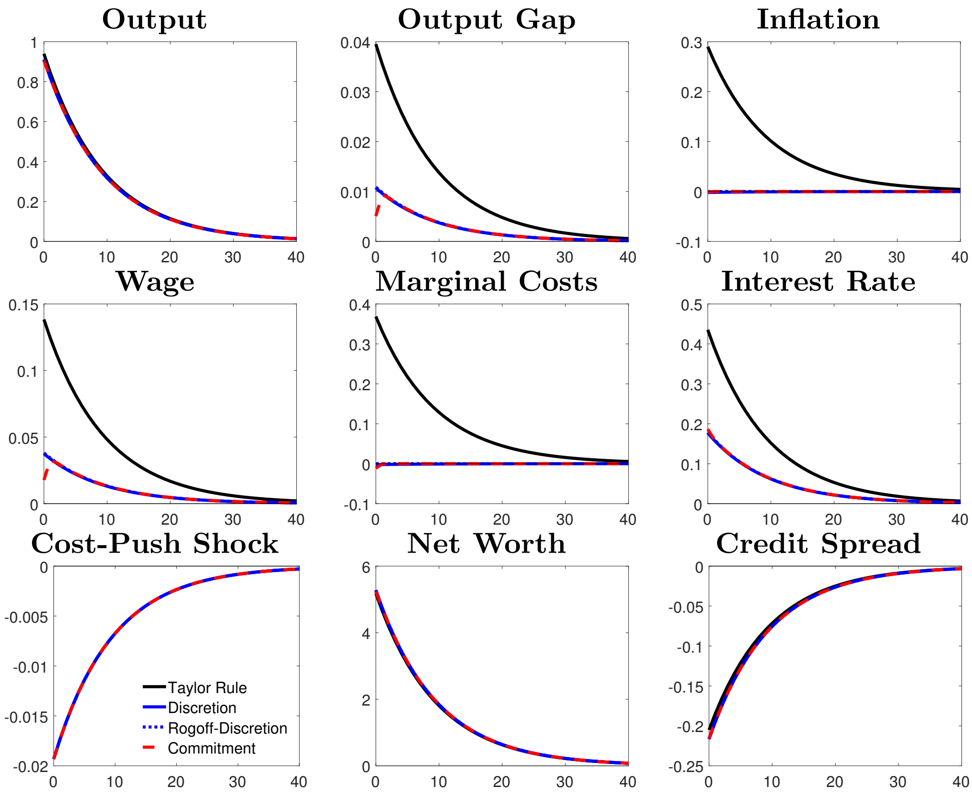
Using this result in the Phillips curve yields the solution for inflation:

$$\pi_t = \frac{\lambda(1-\rho_e\widetilde{\widetilde{\beta}})}{\widetilde{\widetilde{\kappa}}^2+\lambda(1-\rho_e\widetilde{\widetilde{\beta}})^2}e_t+\lambda\vartheta\kappa\frac{\sigma(1+\nu\mu)(1-\rho_u\widetilde{\widetilde{\beta}})}{\widetilde{\widetilde{\kappa}}^2+\lambda(1-\rho_u\widetilde{\widetilde{\beta}})^2}u_t \tag{A130}$$

Given the previous result that preference shocks and financial shocks unfold similar demand and cost-push effects as technology shocks, the results obtained for the baseline model hold as well.

F.4 Policy Regime Comparison

Figure A3: Preference Shock across Monetary Policy Regimes



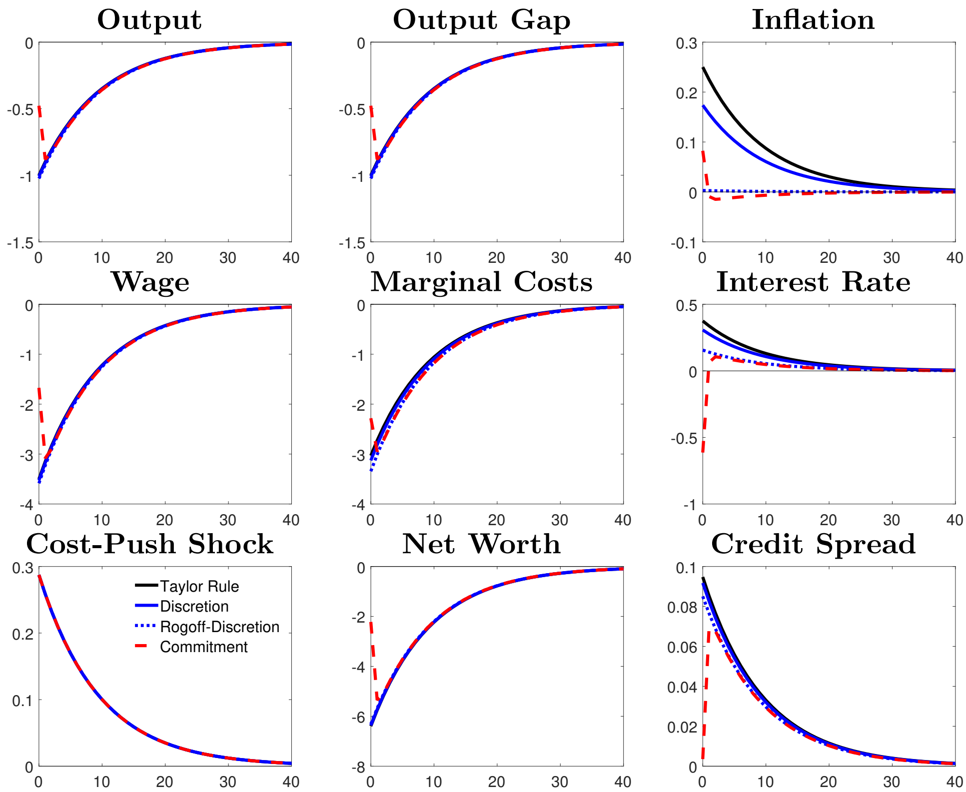
Note: Impulse response functions for a technology shock with an autoregressive coefficient of 0.9. The shock size is calibrated to yield a one-percent increase of output under the Taylor rule in the model. All variables are in percentage deviations from the non-stochastic steady state, except for inflation and interest rate which are in percentage-point deviations. A period is a quarter, and all impulse responses are for the financial accelerator economy.

Table A1: Policy Performance Preference Shock

Policy	Financial Accelerator			Standard NK			Infl.
	sd(π)	sd(x)	Stab. Bias	sd(π)	sd(x)	Stab. Bias	Bias
Commitment	0.0004	0.0107	0	0	0	0	0.0018
Rogoff-Discretion	0.0000	0.0116	0.0006	0	0	0	0.0019
Discretion	0.0020	0.0114	0.0020	0	0	0	0.0027
Taylor Rule	0.3106	0.0423	0.3107	0.2945	0.1068	0.2950	0.0975

Note: Standard deviations of inflation and output gap in response to one-standard-deviation preference shocks for alternative monetary policy regimes. The stabilization bias is measured as inflation gap premium (IGP), i.e. the increase in the standard deviation of inflation that is equivalent to the loss relative to full commitment policy. The inflation bias is measured as the IGP in the financial accelerator economy relative to the standard NK model.

Figure A4: Financial Shock across Monetary Policy Regimes



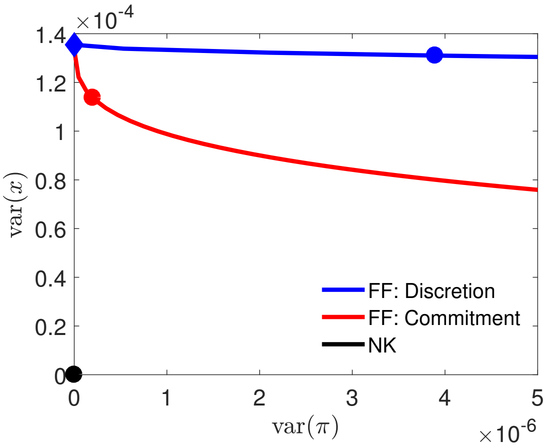
Note: Impulse response functions for a contractionary financial shock with an autoregressive coefficient of 0.9. The shock size is calibrated to yield a one-percent decrease of output under the Taylor rule in the FF model. All variables are in percentage deviations from the non-stochastic steady state, except for inflation and interest rate which are in percentage-point deviations. A period is a quarter, and all impulse responses are for the financial accelerator economy.

Table A2: Policy Performance Financial Shock

Policy	Financial Accelerator			Standard NK			Infl.
	sd(π)	sd(x)	Stab. Bias	sd(π)	sd(x)	Stab. Bias	Bias
Commitment	0.0425	1.0158	0	0	0	0	0.1732
Rogoff-Discretion	0.0030	1.1087	0.0599	0	0	0	0.1832
Discretion	0.1879	1.0904	0.1944	0	0	0	0.2604
Taylor Rule	4.9604	0.7318	4.9588	4.4434	1.6122	4.4513	2.1921

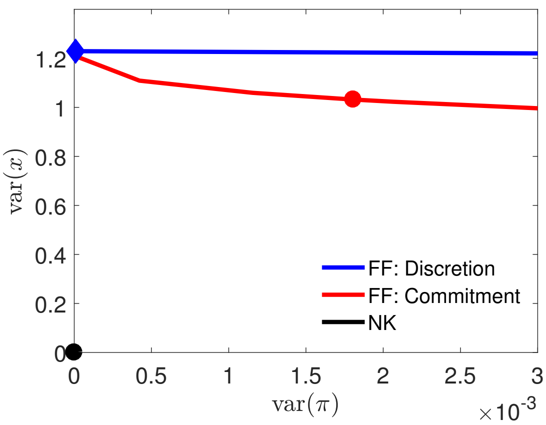
Note: Standard deviations of inflation and output gap in response to one-standard-deviation financial shocks for alternative monetary policy regimes. The stabilization bias is measured as inflation gap premium (IGP), i.e. the increase in the standard deviation of inflation that is equivalent to the loss relative to full commitment policy. The inflation bias is measured as the IGP in the financial accelerator economy relative to the standard NK model.

Figure A5: Policy Frontiers Preference Shock



Note: Efficient policy frontiers under discretion following a one-standard-deviation preference shock in σ_π^2, σ_x^2 space. Points to the right of the frontiers are inefficient, points to the left infeasible. The circles show the optimal solutions under discretion and commitment given the welfare-based relative weight on the output gap λ. The diamond is the solution under Rogoff-discretion with weight $\tilde{\lambda}$.

Figure A6: Policy Frontiers Financial Shock



Note: Efficient policy frontiers under discretion following a one-standard-deviation financial shock in σ_π^2, σ_x^2 space. Points to the right of the frontiers are inefficient, points to the left infeasible. The circles show the optimal solutions under discretion and commitment given the welfare-based relative weight on the output gap λ. The diamond is the solution under Rogoff-discretion with weight $\tilde{\lambda}$.