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Financial frictions, the Phillips curve and monetary policy

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Non-technical summary

Research Question

In the aftermath of the Global Financial Crisis, the severe contraction of output was not associated with a pronounced drop in inflation. Against this backdrop, this paper analyzes whether frictions in financial markets affect the relationship between inflation and economic activity. This link – the so-called Phillips curve – is of crucial importance for monetary policy.

Contribution

This paper proposes a tractable structural New Keynesian model with financial frictions. The framework can be represented in three equations, nesting the standard model. This allows to characterize the effect of financial frictions on the Phillips curve.

Results

In the presence of financial frictions, the Phillips curve is flat, such that the link between inflation and economic activity is weak. This represents a challenge for central banks as the trade-off between inflation and economic activity is aggravated. In this environment, optimal monetary policy is strongly geared towards inflation stabilization. The central bank circumvents the weaker trade-off by being more forward-looking, sending signals to the public that it will stabilize inflation today and in the future.

Nichttechnische Zusammenfassung

Fragestellung

Im Zuge der globalen Finanzkrise kam es zu einem deutlichen Einbruch der Konjunktur, allerdings ohne einen damit verbundenen ausgeprägten Rückgang der Inflation. Vor diesem Hintergrund untersucht dieses Forschungspapier, ob und inwiefern Friktionen in Finanzmärkten den Zusammenhang zwischen Inflation und wirtschaftlicher Aktivität beeinflussen. Dieser Zusammenhang – die sogenannte Phillips-Kurve – ist für die Geldpolitik von zentraler Bedeutung.

Beitrag

Dieses Forschungspapier präsentiert ein strukturelles Neu-Keynesianisches Modell mit Finanzmarktfriktionen. Das Modell kann in drei Gleichungen repräsentiert werden, wobei das Standardmodell in dieser Formulierung inbegriffen ist. Auf Basis dieses Modells lassen sich daher die Effekte von Finanzmarktfriktionen auf die Phillips-Kurve charakterisieren.

Ergebnisse

In der Gegenwart von Finanzmarktfriktionen ist die Phillips-Kurve flach, so dass der Zusammenhang zwischen Inflation und ökonomischer Aktivität schwach ist. Dies stellt eine Herausforderung für Zentralbanken dar, da der Zielkonflikt zwischen Inflation und ökonomischer Aktivität verschärft ist. In dieser Situation ist die optimale Geldpolitik stark auf die Stabilisierung von Inflation ausgerichtet. Die Zentralbank umgeht den Zielkonflikt, indem sie sich stärker auf die Zukunft konzentriert: Sie signalisiert der Öffentlichkeit, dass sie sich heute und in der Zukunft zur Stabilisierung von Inflation verpflichtet.

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Financial Frictions, the Phillips Curve and Monetary Policy*

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Abstract

This paper proposes a tractable financial accelerator New Keynesian DSGE model that allows for closed-form solutions. In the presence of financial frictions, the New Keynesian Phillips curve features a flat slope with respect to the output gap and is strongly forward-looking. All shocks cause endogenous cost-push effects in the Phillips curve, leading to larger inflation responses and a breakdown of divine coincidence. The central bank's contemporaneous trade-off between output gap and inflation stabilization is aggravated. Optimal monetary policy is strongly forward-looking and geared towards inflation stabilization.

Keywords: Financial frictions, financial accelerator, Phillips curve, optimal monetary policy.

JEL classification: E42, E44, E52, E58.

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1 Introduction

The Phillips curve is a fundamental cornerstone of modern conceptions of monetary policy, prescribing a link between inflation and economic activity. However, the severe contraction of output in the aftermath of the Global Financial Crisis was not associated with a pronounced drop in inflation. This missing disinflation raises delicate questions for macroeconomists and policymakers: Is the Phillips curve alive and well after all in the presence of financial frictions? If not, what are the implications for the optimal conduct of monetary policy and the available policy space?

This paper aims to answer these questions through the lens of a tractable financial accelerator New Keynesian DSGE model that allows for closed-form solutions. I show that in the presence of financial frictions, the New Keynesian Phillips curve features a flat slope with respect to the output gap and is more forward-looking compared to the standard New Keynesian model. All shocks cause endogenous cost-push effects in the Phillips curve, leading to larger inflationary effects and a breakdown of divine coincidence (i.e. the possibility to jointly stabilize inflation and output gap). In this environment, the central bank's contemporaneous trade-off between output gap and inflation stabilization is aggravated. Optimal monetary policy is strongly forward-looking and geared towards inflation stabilization, whereas leaning-against-the-wind is suboptimal.

The model framework is a 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 (Ravenna and Walsh, 2006). Firms are operated by entrepreneurs, who finance their wage bill either by equity or debt financing. The loan contract is subject to a costly state verification problem à la Townsend (1979), which gives rise to a non-zero credit spread that depends on the entrepreneur's leverage. Entrepreneurial net worth stems from equity financing (Boehl, 2017). Equity is strongly procyclical, implying that entrepreneur leverage and the credit spread are countercyclical.

The framework allows for a tractable representation in three equations only, nesting the standard New Keynesian framework. This representation highlights in closed form how the presence of financial frictions alters the New Keynesian Phillips curve compared to the standard model. First, the slope with respect to the output gap flattens as the countercyclical credit spread makes overall marginal costs less procyclical. Second, the New Keynesian Phillips curve becomes more forward-looking. Firms take future expected nominal interest rates directly into account when making their pricing decisions, as these constitute important components of marginal costs in the presence of financial frictions. Third, shocks generally lead to inefficient fluctuations in entrepreneur leverage and thus cause endogenous cost-push effects. These three features of the New Keynesian Phillips curve imply a weaker contemporaneous interest rate channel of monetary policy and amplified inflation effects compared to the standard model.

To investigate optimal monetary policy in the context of financial frictions, I proceed in several steps. I first derive the central bank mandate in the presence of financial frictions as a second-order approximation of household welfare. The resulting loss function implies a traditional mandate to stabilize inflation volatility and output gap volatility, but no separate leaning-against-the-wind mandate. While financial frictions give rise to inefficient credit cycles, these ultimately only affect welfare via associated inefficient output fluctuations. With an appropriate redefinition of the output gap, the central bank mandate under financial frictions is thus identical to the one in the standard model.

In a second step, I analyze optimal monetary policy under commitment using the welfare-based central bank mandate. In the presence of financial frictions, a central bank operating under commitment fails to perfectly offset the inflationary effects of technology and preference shocks because of their endogenous cost-push effects. This is equivalent to a breakdown of divine coincidence. The targeting rule under commitment prescribes stronger policy inertia as a response to the larger degree of forward-lookingness in the Phillips curve. Optimal commitment policy is thus strongly geared towards inflation stabilization, allowing only minimal inflationary effects following contractionary shocks.

To reveal more insights why optimal monetary policy is geared towards inflation stabilization, I then turn to the case of discretion, which can be solved analytically. The targeting rule under discretion prescribes a more aggressive reaction of the output gap to inflation relative to the standard model. This reflects the weaker contemporaneous interest rate channel, such that the central bank's contemporaneous trade-off between output gap and inflation stabilization is aggravated. In particular, output gap stabilization is more costly in terms of inflation stabilization. Importantly, this also applies to leaning-against-the-wind, as the respective mandate is contained in the output gap stabilization mandate.

In a fourth step, I show that policy performance under discretion can be improved if the central bank operates according to an inflation-conservative mandate. In particular, the relative weight on inflation stabilization in the central bank's loss function needs to be larger than the welfare-based weight. The welfare-maximizing inflation weight increases in the degree of financial frictions. In the spirit of Rogoff (1985), this may be interpreted as society appointing an inflation-conservative central banker. Intuitively, a more severe contemporaneous trade-off and a more forward-looking economy implies that the expectations channel becomes more important and potent. If the central banker puts a high weight on inflation stabilization, this sends a strong signal to the public that future inflation will respond less to any shock.

The analytic results for optimal discretion thus suggest that optimal commitment policy employs stronger policy inertia to signal a commitment to stabilize inflation in the future. This policy operates through the more important expectations channel. Optimal monetary policy in the presence of financial frictions is thus strongly forward-looking and inherently geared towards inflation stabilization. In other words, forward guidance policies are advisable, whereas leaning-against the-wind is suboptimal.

This paper is related to three strands of the literature. In line with the paper at hand, Christiano et al. (2015), Del Negro et al. (2015) and Gilchrist et al. (2017) show that financial frictions alter the Phillips curve, using medium-scale New Keynesian DSGE models with financial frictions that require numerical solution methods. The focus of these contributions is to explain the missing disinflation puzzle, whereas they provide no formal analysis of optimal monetary policy. In comparison to these papers, I analyze a small-scale model that can be solved in closed form and investigate optimal monetary policy issues. This allows me to disentangle the role of financial frictions for firms' price setting (the New Keynesian Phillips curve) and the Phillips curve relationship in equilibrium. The analytic results of this paper provide further evidence for the monetary policy implications discussed in Del Negro et al. (2015) and Gilchrist et al. (2017), i.e. that inflation dynamics are strongly influenced by the central bank's commitment to stabilize inflation and that financial shocks lead to a breakdown of divine coincidence.

This paper is also part of the literature investigating optimal monetary policy in the presence of financial frictions.[1] Carlstrom et al. (2010), De Fiore and Tristani (2013) and Cúrdia and Woodford (2016) investigate optimal monetary policy under commitment in small-scale models with financial frictions. 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). In contrast to these papers, I provide a tractable variant of the financial accelerator framework that allows for closed-form solutions under discretion and simple Taylor rules. The analytic characterization enables me to go beyond the numerical analysis presented in these papers and to relate the optimal monetary policy results to specific characteristics of the New Keynesian Phillips curve in closed form.

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. Nakata and Schmidt (2019) 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. De 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. Section 3 discusses the features of the New Keynesian Phillips curve in the presence of financial frictions and the resulting general equilibrium implications under a simple Taylor rule. Section 4 investigates optimal monetary policy in the financial accelerator economy. First, the welfare-based central bank mandate is derived and used to evaluate optimal commitment numerically. Building on this, the closed-form solution for discretion is presented and used to interpret optimal monetary policy.

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 and the equations characterizing the general equilibrium.

[1] 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 Galí (2007) and many others.

2.1 The Economy

The model environment is populated by a representative household 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 spread 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 shocks occur. 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 idiosyncratic wholesale productivity shocks materialize. 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 as dividends to stockholders, who 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

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

specifying that utility is separable in consumption C_t and labor supply H_t. Consumption C_t is a composite of differentiated goods c_{jt}, with a Dixit-Stiglitz CES-aggregator such that

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

where ϵ is the (constant) elasticity of substitution. Consumption utility is subject to an exogenous preference shock ε^c_t following an AR(1) process. 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, while paying lump-sum taxes T_t. The household's budget constraint in nominal terms is thus given by:

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

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

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

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

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

Wholesale Firms: The wholesale sector is populated by a continuum of competitive firms, each being operated by a risk-neutral entrepreneur. Each wholesale firm i 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

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

with $A = 1$ and η_t^a 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 shocks). 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 perfectly 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

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

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), the source of the financial friction is a costly state verification problem à la Townsend (1979) between firms and banks. More specifically, the idiosyncratic productivity shock $\omega_{i,t}$ materializes after production and is 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. It can be shown (see Appendix A) that all entrepreneurs choose the same contract, which 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 Appendix A, I show that the contract implies that the credit spread (i.e. the external finance premium) evolves according to

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

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 compensation, the financial intermediary requires a loan rate above the safe central bank interest rate, with the spread increasing 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 participation constraint of the financial intermediary is binding such 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 assume that entrepreneurs issue equity claims on the stock market, following Boehl (2017). Stocks are priced by financial traders associated with the financial intermediary according to the expected dividend. Noting 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

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

where R^S_{t+1} 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 (expected) costs of equity financing equals the cost of external financing:

$$E_t[R^S_{t+1}] = R^L_t \tag{10}$$

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. Financial traders operate according to a rule-of-thumb and demand a share

$$\delta_t = f(\bar{\omega}) \frac{(Y_t/Y)^{\widetilde{\psi}-1}}{(R_t)^{\widetilde{\mu}-1}} e^{-\varepsilon^n_t} \tag{11}$$

of total output. The parameters $\widetilde{\psi} - 1$ and $\widetilde{\mu} - 1$ represent the elasticities with respect to aggregate variables. Following the notion from behavioral finance that investors systematically over-react to news (De Bondt and Thaler, 1985, 1987; Chopra et al., 1992), these elasticities are larger than one. ε^n_t is an exogenous financial shock originating in the banking sector. This shock may be interpreted analogous to the risk shock of Christiano et al. (2014), as it ultimately affects the credit spread via the entrepreneur balance sheet. It captures prevalent narratives of the Global Financial Crisis that financial frictions originating in the financial sector led to a deterioration of financing possibilities for the non-financial sector. In Appendix A, I show that internal funds of entrepreneurs then evolve according to

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

where $\boldsymbol{\varepsilon}_t$ is a vector containing the structural shocks, and $\frac{\partial N_t}{\partial Y_t} > 0$, $\frac{\partial N_t}{\partial R_t} < 0$, i.e. equity financing is procyclical and depends negatively on nominal interest rates. The internal funds are used by entrepreneurs to finance their wage bill, as described above.[2]

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 stem-

[2] It is important to note that worker are not paid via equity claims. Rather, the entrepreneur uses physical resources (loanable funds) obtained by equity financing. These physical resources ultimately stem from households via their bank deposits at financial intermediaries.

ming 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. These modeling choices allow keeping the model setup analytically tractable by avoiding that equity becomes an endogenous state variable. As shown further below, this setup gives rise to a countercyclical 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, 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:

$$\max_{P_{j,t}} \quad E_t \sum_{s=0}^{\infty} (\beta\theta)^s \frac{u'(C_{t+s})}{u'(C_t)} \left(\frac{P_{j,t}}{P_{t+s}} (Y_{j,t+s} - MC_{t+s}) \right)$$

$$s.t. \quad Y_{j,t+s} = \left(\frac{P_{j,s}}{P_{t+s}} \right)^{-\epsilon} Y_{t+s}$$

Each retail firm maximizes the expected discounted stream of profits, subject to 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 P_t^*:

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

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

$$Y_t = C_t = \frac{A_t H_t}{D_t} \tag{15}$$

where D_t is a measure of price dispersion given by:

$$D_t = \int_0^1 \frac{P_{j,t}}{P_t}^{-\epsilon} dj = (1-\theta)\left(\frac{1-\theta\Pi_t^{\epsilon-1}}{1-\theta}\right)^{\frac{\epsilon}{\epsilon-1}} + \theta\Pi_t^{\epsilon} D_{t-1} \tag{16}$$

The central bank sets the nominal interest rate R_t. For the reference case of following a Taylor-type policy rule, the rule is specified as:

$$\frac{R_t}{R} = \left(\frac{\Pi_t}{\Pi}\right)^{\phi} \tag{17}$$

The output gap compared to a counterfactual economy without financial frictions and with flexible prices is defined as

$$X_t = \frac{Y_t}{Y_t^e} \tag{18}$$

where output in the efficient economy is given by:

$$Y_t^e = \left(\frac{\epsilon}{\epsilon-1}\chi\right)^{-\frac{1}{\sigma+\eta}} A_t^{\frac{1+\eta}{\sigma+\eta}} (e^{\varepsilon_t^c})^{\frac{1}{\sigma+\eta}} \tag{19}$$

2.2 The Log-Linearized Model

In the following, I log-linearize the model around the deterministic steady state, denoting log-linearized variables with lower-case letters. For the household sector, the linearized Euler equation is given by:

$$y_t = -\sigma^{-1}\left(r_t - E_t[\pi_{t+1}] + E_t[\varepsilon_{t+1}^c] - \varepsilon_t^c\right) + E_t[y_{t+1}] \tag{20}$$

The Euler equation can also be written in terms of the output gap as

$$x_t = -\sigma^{-1}\left(r_t - E_t[\pi_{t+1}]\right) + E_t[x_{t+1}] + u_t \tag{21}$$

where the composite demand shock u_t in the Euler equation is a combination of technology and preference shocks:

$$u_t = -\frac{1+\eta}{\sigma+\eta}(1-\rho_a)a_t + \frac{\eta}{\sigma(\sigma+\eta)}(1-\rho_c)\varepsilon_t^c \tag{22}$$

The intratemporal trade-off between labor supply and consumption is given by:

$$w_t = \eta h_t + \sigma y_t - \varepsilon_t^c \tag{23}$$

Both the Euler equation (20) and the intratemporal trade-off between labor supply and consumption (23) are identical to the standard model without financial frictions. Moving to the firm sector, the aggregate production function is:

$$y_t = a_t + h_t \tag{24}$$

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

$$\pi_t = \kappa\, mc_t + \beta E_t[\pi_{t+1}] \tag{25}$$

where the slope with respect to marginal costs is $\kappa = \frac{(1-\theta\beta)(1-\theta)}{\theta}$. Marginal costs are given by

$$mc_t = w_t + \vartheta r_t^L - a_t \tag{26}$$

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 analysis below.

The credit spread specified by the financial contract can be written as[3]:

$$r_t^L - r_t = \nu(w_t + h_t - n_t) \tag{27}$$

The sensitivity of the credit spread with respect to leverage in Equation (27) is captured by $\nu > 0$: An increase in leverage by one percent triggers an increase in the spread by ν percentage points. The linear approximation of the credit spread thus allows to eliminate the dependence on the threshold productivity value (see Appendix A for more details). Intuitively, as all entrepreneurs choose the same contract, there exists a mapping between the threshold value and the credit spread. As a result, the above equation can be derived, where ν is a function of steady state values of the contract and the entrepreneur balance sheet:

$$\nu = \left[\frac{\bar{\omega}}{g - g'\bar{\omega}}\left(g' - g\left(\frac{f'}{f} - \frac{f''}{f'} + \frac{g''}{g'}\right)\right)\right]^{-1}\frac{WH}{L} > 0 \tag{28}$$

Finally, as shown in Appendix A, equity is given by:

$$n_t = \psi y_t - \mu r_t + \frac{1}{1-\nu}\left(\varepsilon_t^n + \nu(1+\eta)a_t + \nu\varepsilon_t^c\right) \tag{29}$$

The elasticities of equity financing with respect to output and the nominal interest rate are governed by $\psi > 0$ and $\mu > 0$, respectively. Lastly, for the reference case where the central bank follows a Taylor rule, the policy rule is:

$$r_t = \phi\pi_t \tag{30}$$

This concludes the description of the model framework.

[3]A risk shock along the lines of Christiano et al. (2014) would show up in this equation. In the present framework, however, such a shock is observationally equivalent (up to scale) to the financial shock to equity financing. The analysis thus abstracts from such shocks.

3 Inflation Dynamics in the Presence of Financial Frictions

3.1 The New Keynesian Financial Accelerator Phillips Curve

One distinct advantage of the framework at hand is that it allows a tractable representation in three equations only: A financial-frictions-augmented New Keynesian Phillips curve, an Euler equation and a specification of the nominal interest rate as set by the central bank. These can be written as

$$\pi_t = \mathcal{K}_x \, x_t + \mathcal{K}_r \, r_t + \beta E_t[\pi_{t+1}] + e_t \tag{31}$$
$$x_t = -\sigma^{-1} \left(r_t - E_t[\pi_{t+1}]\right) + E_t[x_{t+1}] + u_t \tag{32}$$
$$r_t = \phi \pi_t \tag{33}$$

where $\mathcal{K}_x$ and $\mathcal{K}_r$ are composite parameters and e_t is a composite cost-push shock, defined below. This representation highlights that financial frictions influence the economy entirely via the New Keynesian Phillips curve. The behaviors of households and the central bank are not directly affected by the presence of financial frictions, such that the Euler equation (32) and the Taylor rule (33) are identical to the standard model.

As I show in the following, the presence of financial frictions alters the New Keynesian Phillips curve in three distinct ways compared to the standard model: First, the slope with respect to the output gap $\mathcal{K}_x$ is different. Second, the nominal central bank interest rate appears directly in the New Keynesian Phillips curve, with coefficient $\mathcal{K}_r$. Third, a composite cost-push shock e_t appears, which is not present in the standard model.

Before proceeding, it should be noted that these three channels generally depend on all structural parameters, in particular those pertaining to the financial frictions: $\vartheta, \nu, \psi,$ and μ. In an economy characterized by financial frictions, all of these parameters are larger than zero and $\vartheta = 1$. Throughout the paper, I focus on the case of a financial accelerator economy. As shown by Bernanke et al. (1999), the key mechanism of the financial accelerator is countercyclical entrepreneur leverage, which translates into a countercyclical credit spread.[4] In the model at hand, leverage is given by

$$lev_t = w_t + h_t - n_t \tag{34}$$

which can be rewritten as:

$$lev_t = (1 + \sigma + \eta - \psi) y_t + \mu r_t + shocks \tag{35}$$

[4] Rannenberg (2016) shows that a financial accelerator model successfully replicates the negative correlation between GDP and firm leverage observed in the data, using the ratio between total liabilities and total net worth of the non-farm non-financial business sector from the Flow of Funds Account (FFA) of the Federal Reserve Board. Estimated financial accelerator models also imply countercyclical firm leverage, see for example Christiano et al. (2014) and Del Negro et al. (2015). The property of countercyclical entrepreneur leverage is thus not specific to the proposed labor variant, but shared with financial accelerator models where net worth is accumulated over time via retained earnings. Halling et al. (2016) provide empirical evidence that firm leverage is countercyclical for both constrained and unconstrained firms.

In order to obtain the financial accelerator, one needs to restrict the calibration of the model such that the above equation implies countercyclical entrepreneur leverage. To make sure that the countercyclicality occurs under sticky prices as well as flexible prices, one should condition the assumption on constant central bank interest rates. In other words, the countercyclicality should not merely reflect the endogenous response of monetary policy in general equilibrium. The necessary condition for entrepreneur leverage to be countercyclical, holding central bank interest rates constant, is thus that the term in front of output is negative (see Appendix C for more details). The key assumption such that the framework at hand is a financial accelerator economy can hence be formulated as:

Assumption 1. ***(A1)*** *The elasticity of equity financing with respect to output satisfies:*

$$\psi > 1 + \sigma + \eta$$

This condition is assumed to hold throughout the paper.

The Slope of the New Keynesian Financial Accelerator Phillips Curve: In the New Keynesian Phillips curve as shown in Equation (31), the slope with respect to the output gap is given by:

$$\mathcal{K}_x = \kappa(\sigma + \eta + \vartheta\nu(1 + \sigma + \eta - \psi)) \tag{36}$$

Lemma 1. *Assume $\vartheta = 1, \nu > 0$ and A1 (financial accelerator economy). Then, the slope of the New Keynesian Phillips curve with respect to the output gap flattens relative to the standard framework.*

To gain some intuition for this result, consider the standard model ($\vartheta = \nu = 0$) first. This implies that the slope of the Phillips curve is given by $\mathcal{K}_x = \kappa(\sigma+\eta)$, reflecting a *labor supply channel*. Suppose that for some reason, wholesale firms want to expand production. This requires them to hire more labor and to pay households a higher wage (given some level of technology), as seen in Equation (23). The degree to which workers want to be compensated by higher wages depends on the elasticities of labor supply and the degree of inter-temporal consumption smoothing which determine the household's intratemporal consumption-labor trade-off. As a result, marginal costs increase by a factor of $(\sigma + \eta)$.[5]

This contrasts to the case where financial frictions are present, in which case any change in production generally affects both sides of the entrepreneur's balance sheet. If wholesale firms want to expand production, the increased labor demand and wages require the entrepreneur to acquire a larger loan to pay workers in advance. Ceteris paribus, this *debt channel* translates into an increase of leverage and a higher loan rate. As a consequence, marginal costs increase by more than in the standard model (this is the term $1 + \sigma + \eta$). However, the higher output also raises expected dividends and thus allows entrepreneurs to raise more equity (governed by ψ), thus decreasing leverage, which counteracts the first effect. Under Assumption 1, equity financing is sufficiently procyclical

[5]In the standard model, marginal costs are simply given by a function of wages and aggregate productivity (see Equation 26). The relationship between marginal costs and the output gap is then given by $mc_t = (\sigma + \eta)x_t$.

such that the *equity channel* dominates and leverage is countercyclical. Accordingly, the slope of the New Keynesian Financial Accelerator Phillips curve with respect to the output gap is flatter compared to its counterpart in the standard model.

Forward-Lookingness of the New Keynesian Financial Accelerator Phillips Curve: In the presence of financial frictions, the nominal central bank interest rates appears directly in the New Keynesian Phillips curve. The corresponding coefficient is given by:

$$\mathcal{K}_r = \vartheta\kappa(1 + \nu\mu) \tag{37}$$

With the financial accelerator, nominal interest rates affect marginal costs via the loan rate that entrepreneurs have to repay. First, there is a *cost channel*, as nominal interest rate are equivalent to the funding costs of financial intermediaries via deposits. Second, nominal interest rates also affect marginal costs via the *equity channel*, as they influence the available equity financing and thus entrepreneur leverage.

As a consequence, financial frictions increase the degree of forward-lookingness in the New Keynesian Phillips curve. This can be seen by iterating the Phillips curve given in Equation (31) forward to obtain:

$$\pi_t = E_t \sum_{s=0}^{\infty} \beta^s (\mathcal{K}_x x_{t+s} + \mathcal{K}_r r_{t+s} + e_{t+s}) \tag{38}$$

Lemma 2. *Assume $\vartheta = 1, \nu > 0$ and A1 (financial accelerator economy). Then, expectations of future nominal interest rates matter directly for current inflation dynamics.*

Compared to the standard model, inflation today does not only depend on future expected discounted output gaps. Intuitively, retail firms also take both 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.

Cost-Push Shocks in the New Keynesian Financial Accelerator Phillips Curve: The composite cost-push shock e_t in the New Keynesian Phillips curve is given by:

$$e_t = -\vartheta\nu\frac{\kappa}{1-\nu}\varepsilon_t^n - \vartheta\nu\kappa\frac{\psi - 1 + \frac{\nu}{1-\nu}(\sigma+\eta)}{\sigma+\eta}\Big((1+\eta)a_t + \varepsilon_t^c\Big) \tag{39}$$

Note that the composite cost-push shock would be zero in the standard model ($\vartheta = 0$). In the presence of financial frictions, financial shocks ε_t^n are equivalent to pure cost-push shocks. Intuitively, a financial shock reduces equity financing available to entrepreneurs, thus increasing their leverage. In turn, this raises the credit spread that entrepreneurs have to pay, which increases marginal costs. As a result, financial shocks unfold inflationary effects. Moreover, one can state the following with respect to technology and preference shocks:

Lemma 3. *Assume $\vartheta = 1, \nu > 0$ and A1 (financial accelerator economy). Then, positive technology and preference shocks induce negative cost-push effects in the New Keynesian Phillips curve.*

In the financial accelerator economy, all shocks generally affect both sides of the entrepreneur's balance sheet via the *debt channel* and the *equity channel*. The overall magnitude of these channels in terms of endogenous cost-push effects depends on the procyclicality of equity financing. Under Assumption 1, the term in the numerator in Equation (39) is larger than zero, meaning that the *equity channel* dominates and the corresponding cost-push effects are negative. The associated general equilibrium implications are analyzed in the next section.

3.2 General Equilibrium Inflation Dynamics

The three characteristics of the New Keynesian Financial Accelerator Phillips curve have important implications for the general equilibrium solutions of the model. The tractability of the framework allows deriving these solutions in closed form. For the sake of illustration, the closed-form solutions are generally shown in terms of the composite shocks u_t and e_t, and for white-noise shocks (with $\rho_i = 0, i = a, c, n$).[6]

Lemma 4. *Assume $\vartheta = 1, \nu > 0$, A1 (financial accelerator economy) and let all shocks be white-noise innovations. The dynamics of inflation and the output gap under a Taylor rule of the form $r_t = \phi\pi_t$ are given by*

$$\pi_t = \frac{\sigma}{\sigma + \phi\widetilde{\kappa}}\Big(\mathcal{K}_x u_t + e_t\Big) \tag{40}$$

$$x_t = -\frac{\phi}{\sigma + \phi\widetilde{\kappa}}\Big(\mathcal{K}_x u_t + e_t\Big) + u_t \tag{41}$$

where $\widetilde{\kappa}$ is the contemporaneous general equilibrum slope of monetary policy with respect to inflation:

$$\widetilde{\kappa} = \kappa[\underbrace{\sigma + \eta}_{\text{Labor supply channel}} - \underbrace{\vartheta\sigma}_{\text{cost channel}} + \underbrace{\vartheta\nu(1 + \sigma + \eta)}_{\text{debt channel}} - \underbrace{\vartheta\nu(\psi + \mu\sigma)}_{\text{equity channel}}] \tag{42}$$

This parameter captures the contemporaneous effect of a given change in the interest rate on inflation in the general equilibrium, holding expectations constant (called *interest rate channel* in the following). Note that this coefficient and the closed-form solutions nest the corresponding counterpart in the standard model for $\vartheta = 0$.

In the presence of financial frictions, a given increase in the nominal interest rate unfolds four effects on marginal costs (and hence inflation). First, it raises the real interest rate, such that households want to postpone consumption. This lowers wages via the intratemporal trade-off and hence decreases marginal costs (*labor supply channel*). Second, marginal costs increase directly via the higher nominal interest rate (*cost channel*). Third, the lower labor supply reduces the loan size and hence leverage of the entrepreneur (*debt channel*). Fourth, higher nominal interest rates decrease available equity financing and increase leverage (*equity channel*). The labor supply channel is present in the standard model, while the other three channels only appear in the financial accelerator economy. Labor supply and debt channel strengthen the interest rate channel of monetary policy on inflation, whereas the cost channel and the equity channel weaken it.

[6] The corresponding solutions for persistent shocks and the solutions in terms of the structural shocks are shown in Appendix C.

Lemma 5. *Assume $\vartheta = 1, \nu > 0$ and A1 (financial accelerator economy). Then, the cost channel and the equity channel of monetary policy dominate the debt channel. As a result, the interest rate channel of monetary policy with respect to inflation is weaker compared to the standard model.*

The dampened interest rate channel implies the following for the general equilibrium effect of exogenous shocks:

Proposition 1. *Assume $\vartheta = 1, \nu > 0$, A1 (financial accelerator economy) and let all shocks be white-noise innovations. Then, the inflationary effect of supply shocks is amplified compared to the standard model.*

Proof 1. See Appendix.

This result can be seen from the closed-form solution of inflation in Equation (40). The case for financial shocks is straightforward. They only appear in the financial friction economy as supply shocks (contained in e_t), whereas their effect in the standard model is zero. Technology shocks enter both u_t and e_t with a negative sign, such that a positive shock unambiguously reduces inflation, amplified by the weaker interest rate channel of monetary policy. For preference shocks, the case is a bit more complicated. As seen in Equation (22), a positive realization of the shock raises the output gap via as households aim to consume more. This tends to raise inflation via the Phillips curve. At the same time, the negative cost-push effects counteract this inflationary pressure. The amplification result thus depends on the coefficient in the monetary policy rule, governing the denominator in Equation (40). It can be shown that the inflationary response following preference shocks is amplified for reasonable values of ϕ as long as ν and ψ are not excessively large (see Appendix C).

In the following, I show these results graphically for the case of persistent shocks. The impulse responses are obtained under an illustrative benchmark calibration that follows conventional values and satisfies Assumption 1. 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 inverse Frisch elasticity of labor supply with respect to the real wage $\eta = 2$.[7] 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%.

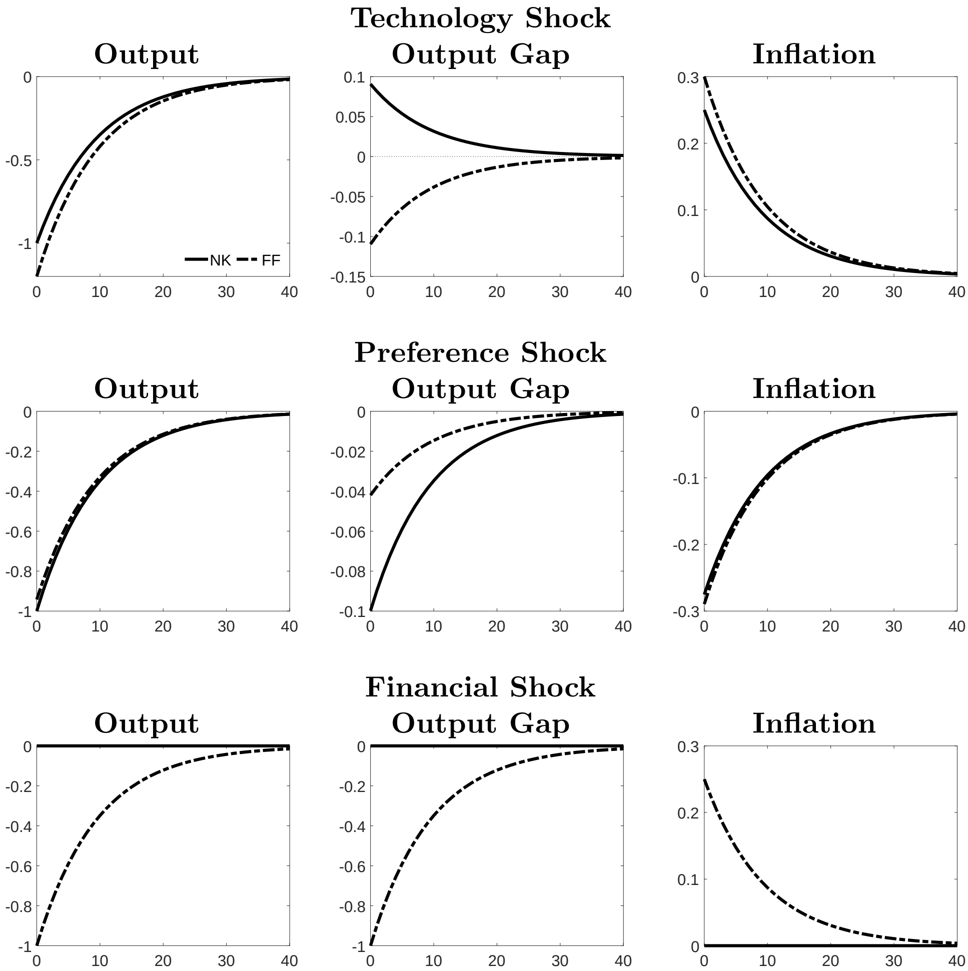
The cost channel requires $\vartheta = 1$.[8] For the elasticity of the loan rate to leverage, I follow Bernanke et al. (1999) by setting $\nu = 0.05$. The elasticities of equity to output

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

[8] 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 $\vartheta = 0$.

and interest rates are calibrated to $\psi = 6$ and $\mu = 1.05$.[9] This implies that the financial accelerator generates an amplification of technology shocks by 20% (see below), roughly in line with the original financial accelerator by Bernanke et al. (1999). With respect to monetary policy, I assume that the central bank follows the simplest version of the Taylor rule with coefficient $\phi = 1.5$. The autocorrelation coefficients of all shocks are set to 0.90.

Figure 1: Shock Transmission under Taylor Rule



Note: Impulse response functions for shocks with an autoregressive coefficient of 0.90. NK is the standard New Keynesian model (solid lines) and FF (dashed lines) is the financial accelerator economy. The shock size is calibrated to yield a one-percent decrease of output under the Taylor rule in the NK model (in the FF model for the financial shock). Output and output gap in percentage deviations from the non-stochastic steady state, for inflation in percentage-point deviations.

Figure 1 shows the transmission of contractionary shocks. The sizes of the technology and the preference shock are chosen such that output decreases by one percent in the

[9]As shown in Appendix A, the financial friction parameters ν, ψ and μ are non-linear functions of steady state contract and entrepreneur balance sheet values. In turn, these depend on aggregate (quarterly) default probabilities, the variance of the idiosyncratic productivity shock and monitoring costs ζ. Here, I prefer to calibrate the financial friction parameters directly to allow for straightforward comparative exercises later on. Importantly, the modeling of financial traders' behavior allows to calibrate ψ and μ independently of ν.

standard New Keynesian model. For the financial shock, the size is such that output decreases by one percent in the financial accelerator economy. The inflationary effect of all three shocks is amplified in the financial accelerator model compared to the standard model. Importantly, this does not hold for the effects on output. Whereas the output response following technology and financial shocks is also amplified, it is dampened for preference shocks. This reflects the negative endogenous cost-push effects that preference shocks unfold under financial frictions.

It is also worthwhile to note that the output gap response following technology shocks switches sign in the presence of financial frictions. In the standard model, output gap and inflation move in the same direction after a technology shock, reflecting the dampening effect of nominal rigidities on output responses. In the financial accelerator economy, however, the negative cost-push effects move inflation and output gap in opposite directions. This result is similar to "pure" cost-push shocks and also applies to the financial shock. It is well-known that the presence of such shocks represents a serious challenge for monetary policy. In the light of this finding, the optimal conduct of monetary policy is the subject of the next section.

4 Optimal Monetary Policy in the Financial Accelerator Economy

This section analyzes optimal monetary policy in the financial accelerator economy. As a starting point, I derive the central bank loss function as an approximation of household welfare. Using this mandate, I investigate optimal monetary policy under commitment. It turns out that this first-best policy regime needs to be solved numerically. To learn more about the properties of optimal monetary policy, I thus proceed by solving the case of discretion analytically. This reveals the key policy limitations in the presence of financial frictions and provides insights how optimal monetary policy under commitment overcomes these challenges.

4.1 Central Bank Mandate

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 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 derive a second-order Taylor approximation of household utility around the deterministic steady state. As shown in Appendix C, the steady-state output level of the financial accelerator economy is generally below the efficient level of output. This reflects inefficiently high marginal costs, both due to monopolistic competition and the presence of financial frictions. Following the literature, I assume that there are some subsidies 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. Under this standard assumption, one can show the following result:

Proposition 2. *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy) and assume that the steady-state is efficient. Then, one can approximate household welfare $\mathcal{W}_t$ to a second order as*

$$\mathcal{W}_t = E_t \sum_{s=0}^{\infty} \beta^s \left(\frac{U_{t+s} - U}{U_c C} \right) \approx -\frac{1}{2} E_t \sum_{s=0}^{\infty} \beta^s \mathcal{L}_{t+s} \tag{43}$$

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

$$\mathcal{L}_t = \pi_t^2 + \lambda \left(x_t^f - \frac{\vartheta}{\sigma + \eta} r_t^f - \frac{\vartheta \nu}{\sigma + \eta} lev_t^f \right)^2 \tag{44}$$

where

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

$$x_t^f = y_t - y_t^f \tag{46}$$

$$lev_t^f = w_t^f + h_t^f - n_t^f \tag{47}$$

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

Proof 2. See Appendix.

As in the standard model, household welfare can be approximated by a purely quadratic loss function that looks like a traditional central bank mandate and prescribes inflation and output stabilization.[11] 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

[10] This result also supported the "Jackson Hole consensus" (Bernanke and Gertler, 1995; Bean et al., 2010). 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.

[11] This also holds for the case of an inefficiently low steady state output level. Following Benigno and Woodford (2005), one could rewrite the resulting first-order terms as a function of purely quadratic terms, using a second-order approximation of the price dispersion term in Equation (16).

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.[12]

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:*

$$y_t^f - y_t^e = -\frac{\vartheta}{\sigma+\eta} r_t^f - \frac{\vartheta\nu}{\sigma+\eta} lev_t^f = -\frac{\vartheta}{\sigma+\eta} r_t^{L,f} \tag{48}$$

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 borrow 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 countercyclical under Assumption 1, Lemma 6 shows that the wedge is procyclical, 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 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.[13] One 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*

$$\mathcal{L}_t = \pi_t^2 + \lambda\, x_t^2 \tag{49}$$

where again

$$\lambda = \frac{\kappa(\sigma+\eta)}{\epsilon} \tag{50}$$

$$x_t = y_t - y_t^e = y_t - \frac{1+\eta}{\sigma+\eta} a_t \tag{51}$$

[12] By assumption, the 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 (Correia et al., 2008). This conveys an interesting notion of dynamic macroprudential policy in the context of the financial accelerator economy, in particular if allowing for a distorted steady state. Investigating this issue is left to future research.

[13] 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.

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 sole 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, implying inefficient labor supply and inter-temporal consumption allocations. 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 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.

It is worthwhile to discuss the similarities and differences of these results to the previous literature. Proposition 2 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 De 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 to stabilize some measure of the credit cycle.[14] This is in contrast to the paper at hand.[15] The 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

[14]Loosely speaking, one might categorize these objectives as financial stability mandates. 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.

[15]This result does not depend on the assumption of an efficient steady state, see Footnote 11.

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 credit cycle 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, the policy mandate can be written in canonical form. Lastly, the key differentiating assumption in Carlstrom et al. (2010) and De 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 separate mandate to minimize credit cycles.

To summarize, I abstract from entrepreneur consumption and consumer heterogeneity, while at the same time assuming standard household preferences. Under these assumptions, 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. A separate mandate to stabilize credit cycles does not arise.

4.2 Optimal Monetary Policy under Commitment

While the mandate of central banks is not substantially altered in the presence of financial frictions, Section 3 shows that the financial accelerator economy implies fundamentally different macroeconomic dynamics compared to the standard model. In light of these findings, one should expect that this requires a substantially different monetary policy stance.

As a starting point, I consider optimal monetary policy under commitment, which serves as the welfare-optimal benchmark. Under this regime, the central bank is able to credibly commit to an entire path for current and future inflation and the output gap. The central bank's optimization problem is to maximize household welfare, which is equivalent to minimizing the loss function derived in the previous section. One can write the optimization problem as

$$\underset{\{\pi_{t+s},x_{t+s}\}_{s=0}^{\infty}}{min} E_t \sum_{s=0}^{\infty} \beta^s \left\{ \pi_{t+s}^2 + \lambda x_{t+s}^2 \right\} \tag{52}$$

$$\text{s.t.} \quad E_t[\pi_{t+s}] = E_t[\widetilde{\kappa} x_{t+s} + \mathcal{K}_r \sigma x_{t+1+s} + \overline{\beta} \pi_{t+1+s} + e_{t+s} + \mathcal{K}_r \sigma u_{t+s}] \tag{53}$$

where Equation (53) combines both Euler equation and Phillips curve. The coefficient $\overline{\beta}$

is given by:

$$\overline{\beta} = \beta + \vartheta\kappa(1+\nu\mu) = \beta + \mathcal{K}_r \tag{54}$$

Lemma 8. *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). The optimal targeting rule under commitment from a timeless perspective is given by*

$$\pi_t + \vartheta\upsilon\pi_{t-1} = -\frac{\lambda}{\widetilde{\kappa}}\left(x_t - \frac{\overline{\beta}}{\beta}x_{t-1}\right) \tag{55}$$

with

$$\upsilon = \frac{\kappa\sigma(1+\nu\mu)}{\beta\widetilde{\kappa}} \tag{56}$$

For comparison, the (nested) targeting rule in the standard New Keynesian model is:

$$\pi_t = -\frac{\lambda}{\kappa(\sigma+\eta)}\left(x_t - x_{t-1}\right) \tag{57}$$

As discussed in Section 3.1, financial frictions make private expectations of the future more important for current dynamics. As a response, the optimal commitment policy follows a targeting rule with more inertia by additionally considering lagged inflation.

Lemma 9. *Assume $\vartheta = 1, \nu > 0$ and A1 (financial accelerator economy). Then, it holds that*

$$\frac{\partial\upsilon}{\partial\nu} > 0 \tag{58}$$

$$\frac{\partial\upsilon}{\partial\psi} > 0 \tag{59}$$

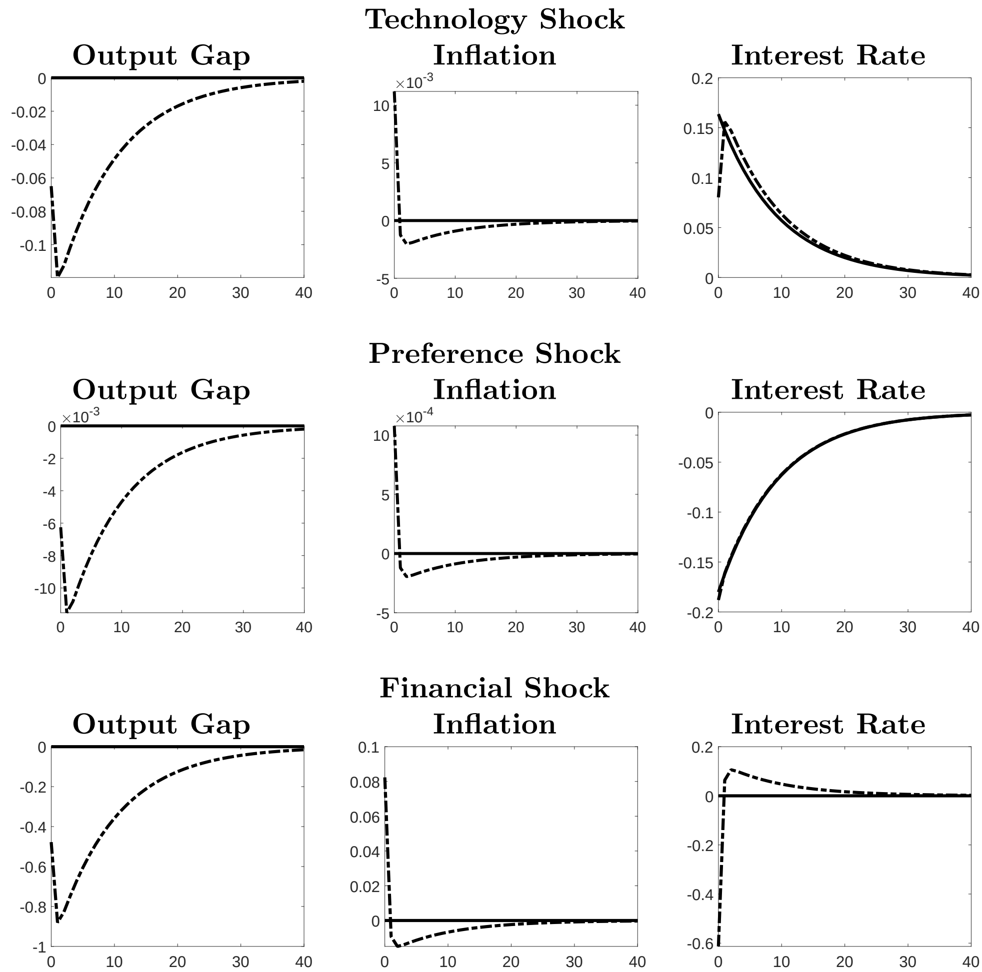
such that the degree to which optimal commitment policy responds to lagged inflation increases in the degree of financial frictions as captured by ν and ψ.

This highlights 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 public expectations, improving the overall trade-off between output gap and inflation stabilization.

Figure 2 illustrates the general equilibrium implications of this targeting rule under optimal commitment policy using the benchmark calibration.[16] The sizes of the shocks are the same as in Section 3.2. As seen in Figure 2, optimal commitment policy is able to perfectly stabilize inflation and output gap following technology and preference shocks in the absence of financial frictions. Financial shocks have no effect in the standard model by construction. As a result, divine coincidence holds. However, this is not the case in the financial accelerator economy.

[16]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 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 2: Shock Transmission under Optimal Commitment



Note: Impulse response functions for shocks with an autoregressive coefficient of 0.90. NK is the standard New Keynesian model (solid lines) and FF (dashed lines) is the financial accelerator economy. The shock size is calibrated to yield a one-percent decrease of output under the Taylor rule in the NK model (in the FF model for the financial shock). Output and output gap in percentage deviations from the non-stochastic steady state, for inflation in percentage-point deviations.

Lemma 10. *Assume $\vartheta = 1, \nu > 0$ and A1 (financial accelerator economy). Then, divine coincidence does not hold and optimal monetary policy fails to perfectly offset technology, preference and financial shocks.*

The breakdown of divine coincidence is a result of the shock amplification implied by the financial accelerator. As outlined in Lemma 3 and Proposition 1, technology and preference shocks induce endogenous negative cost-push effects that amplify the inflationary responses. 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 the 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 commitment is suboptimal relative to the standard model. Shocks then lead to non-zero inflation in the presence of financial frictions.

Despite this suboptimal stabilization performance in the financial accelerator economy, it is remarkable that the inflationary responses are very small. Recall that the shock sizes are chosen such that output declines by one percent in the standard model (in the FF model for the financial shock) under a simple Taylor rule. The responses of output under optimal commitment are similar in magnitude (not shown in Figure 2), with the peak responses ranging from -0.88 for the financial shock to 1.15 for the technology shock. In comparison, the inflationary responses are substantially smaller for all shocks. This shows that optimal monetary policy under commitment is strongly geared towards inflation stabilization.

Unfortunately, the case of commitment cannot be solved analytically. Such a closed-form solution would reveal more insights why optimal policy is geared towards inflation stabilization. However, the model can be solved analytically under discretion. It is furthermore well-known that discretionary policy can mimic commitment to a simple rule (Woodford, 2003; Galí, 2015). In the following, I therefore derive and analyze the analytic solutions of the model under discretion and under commitment to a simple rule.

4.3 Optimal Monetary Policy under Discretion

Under discretion, the monetary policymaker cannot pre-commit to future actions and is hence unable to manipulate private sector expectations. 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. One can hence write the optimization problem as:

$$\min_{\pi_t, x_t, r_t} \mathcal{L}_t = \pi_t^2 + \lambda\, x_t^2 \tag{60}$$

$$s.t.\ \ x_t = -\sigma^{-1}\left(r_t - E_t[\pi_{t+1}]\right) + E_t[x_{t+1}] + u_t \tag{61}$$

$$\pi_t = \mathcal{K}_x x_t + \mathcal{K}_r r_t + \beta E_t[\pi_{t+1}] + e_t \tag{62}$$

The first-order condition for the nominal interest rate yields

$$-\sigma^{-1}\Theta_t = \mathcal{K}_r \Lambda_t \tag{63}$$

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.[17] This leads to the following result for the optimal targeting rule under discretion:

Lemma 11. *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). The optimal targeting rule*

[17] 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. However, as shown in the previous section, the welfare approximation implies $\lambda > 0$.

for monetary policy under discretion is given by:

$$\pi_t = -\frac{\lambda}{\widetilde{\kappa}} x_t \tag{64}$$

To interpret this targeting rule, recall that $\widetilde{\kappa}$ is the general equilibrium slope of monetary policy with respect to inflation, holding expectations constant. As such, the targeting rule reflects the various channels that govern the overall interest rate channel of monetary policy:

$$-\lambda x_t = \kappa[\underbrace{\sigma + \eta}_{\text{Euler channel}} - \underbrace{\vartheta\sigma}_{\text{cost channel}} + \underbrace{\vartheta\nu(1 + \sigma + \eta)}_{\text{factor-supply channel}} - \underbrace{\vartheta\nu(\psi + \mu\sigma)}_{\text{equity channel}}]\pi_t \tag{65}$$

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

$$\pi_t = -\frac{\lambda}{\kappa(\sigma + \eta)} x_t \tag{66}$$

Lemma 12. *Assume $\vartheta = 1, \nu > 0$ and A1 (financial accelerator economy). Then, 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 mirror the weaker interest rate channel of monetary policy, outlined in Lemma 5. In the presence of financial frictions, stabilizing inflation is more costly in terms of the output gap because the debt 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 a given inflation. This is equivalent to a more aggressive targeting rule under discretion. Note that the targeting rule under discretion is also contained in the targeting rule under commitment, indicating that these considerations also hold for optimal commitment.

What does the more aggressive targeting rule under discretion imply for macroeconomic dynamics? The tractability of the framework allows using the optimal targeting rule to obtain a closed-form solution in terms of shocks only:

Lemma 13. *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). The dynamics of inflation and the output gap under optimal discretionary policy are given by*

$$\pi_t = \frac{\lambda}{\widetilde{\kappa}^2 + \lambda(1 - \rho_e \widetilde{\beta})} e_t + \frac{\lambda\sigma\mathcal{K}_r}{\widetilde{\kappa}^2 + \lambda(1 - \rho_u \widetilde{\beta})} u_t \tag{67}$$

$$x_t = -\frac{\widetilde{\kappa}}{\widetilde{\kappa}^2 + \lambda(1 - \rho_e \widetilde{\beta})} e_t - \frac{\sigma\mathcal{K}_r\widetilde{\kappa}}{\widetilde{\kappa}^2 + \lambda(1 - \rho_u \widetilde{\beta})} u_t \tag{68}$$

where

$$\widetilde{\beta} = \beta + \mathcal{K}_r \left(1 - \frac{\widetilde{\kappa}\sigma}{\lambda}\right) \tag{69}$$

As before, the analytic solution nests the case of the standard model for $\vartheta = 0$. In that case, $e_t = 0$ and $\mathcal{K}_r = 0$ such that:

$$\pi_t = x_t = 0 \tag{70}$$

In the absence of financial frictions, optimal discretionary monetary policy is able to perfectly stabilize both inflation and the output gap, just like under optimal commitment. This can be achieved by appropriately varying the interest rate in response to the pure demand shock component of shocks. In the financial accelerator economy, however, it is straightforward to see that shocks have a non-zero effect on inflation and the output gap. This is the breakdown of divine coincidence, as already shown for optimal commitment policy in the previous section. More specifically, the dynamics of inflation and the output gap depend on a common coefficient α:

$$\alpha = \frac{1}{\widetilde{\kappa}^2 + \lambda(1 - \rho\widetilde{\beta})} \tag{71}$$

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, one can postulate the following:

Proposition 3. *Assume $\vartheta = 1, \nu > 0$, A1 (financial accelerator economy) and $\rho = 0$. Then, it holds that*

$$\frac{\partial \alpha}{\partial \nu} > 0 \tag{72}$$

$$\frac{\partial \alpha}{\partial \psi} > 0 \tag{73}$$

such that the inflationary response to shocks increases in the degree of financial frictions as captured by ν and ψ via the flatter New Keynesian Phillips curve.

Proof 3. See Appendix.

The intuition for this result is straightforward. Under Assumption 1, the financial accelerator leads to a flatter New Keynesian 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 effects of shocks increase in the degree of financial frictions under optimal discretion.

In Proposition 3, the assumption $\rho = 0$ serves to isolate the effect of the New Keynesian Phillips curve for the conduct of discretionary policy. Another driving factor of inflation under discretion is the degree of forward-looking behavior. To show the corresponding effect, the following assumption is helpful:

Assumption 2. ***(A2)***

$$\eta < \frac{\sigma\mu\kappa + \epsilon(\sigma(1 + \nu\mu) + \nu\mu\sigma\kappa)(\psi + \mu\sigma - 1 - \sigma)}{\mu\kappa(\sigma\epsilon(1 + \nu) - 1) + \epsilon\sigma(1 + \nu\mu)} \tag{74}$$

This is a (mild) constraint on the Frisch labor supply elasticity $1/\eta$. Under the benchmark calibration, it is equivalent to $\eta < 4.71$, which is far below conventional calibrated and estimated values.[18] Intuitively, the stronger forward-looking behavior in the presence of financial frictions occurs because household expectations matter directly for current inflation dynamics (or alternatively, because retailers marginal costs depend directly on interest rates, which in turn depend on household expectations via the Phillips curve). As seen in Equation (69), households take the optimal targeting rule of monetary into account to translate output gap expectations into inflation expectations. The targeting rule implies that the extent to which (positive) output gap expectations translate into (negative) inflation expectations decreases in the Frisch elasticity of labor supply ($\partial \left|\frac{\widetilde{\kappa}}{\lambda}\right| / \partial \frac{1}{\eta} < 0$). This operates via the labor supply channel and the debt channel, counteracted by cost and equity channel (compare also Lemma (4)). As long as the Frisch elasticity of labor supply is sufficiently high (such that η is sufficiently low), the relative weight of inflation expectations from households that is relevant for current dynamics increases in the degree of financial frictions. This is captured in the following Proposition.

Proposition 4. *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). It holds that*

$$\frac{\partial \widetilde{\beta}}{\partial \psi} > 0 \tag{75}$$

Under Assumption 2, it furthermore holds that

$$\frac{\partial \widetilde{\beta}}{\partial \nu} > 0 \tag{76}$$

such that the inflationary effect of shocks increases in the degree of financial frictions as captured by ν and ψ via the higher relevance of future expectations for current inflation dynamics.

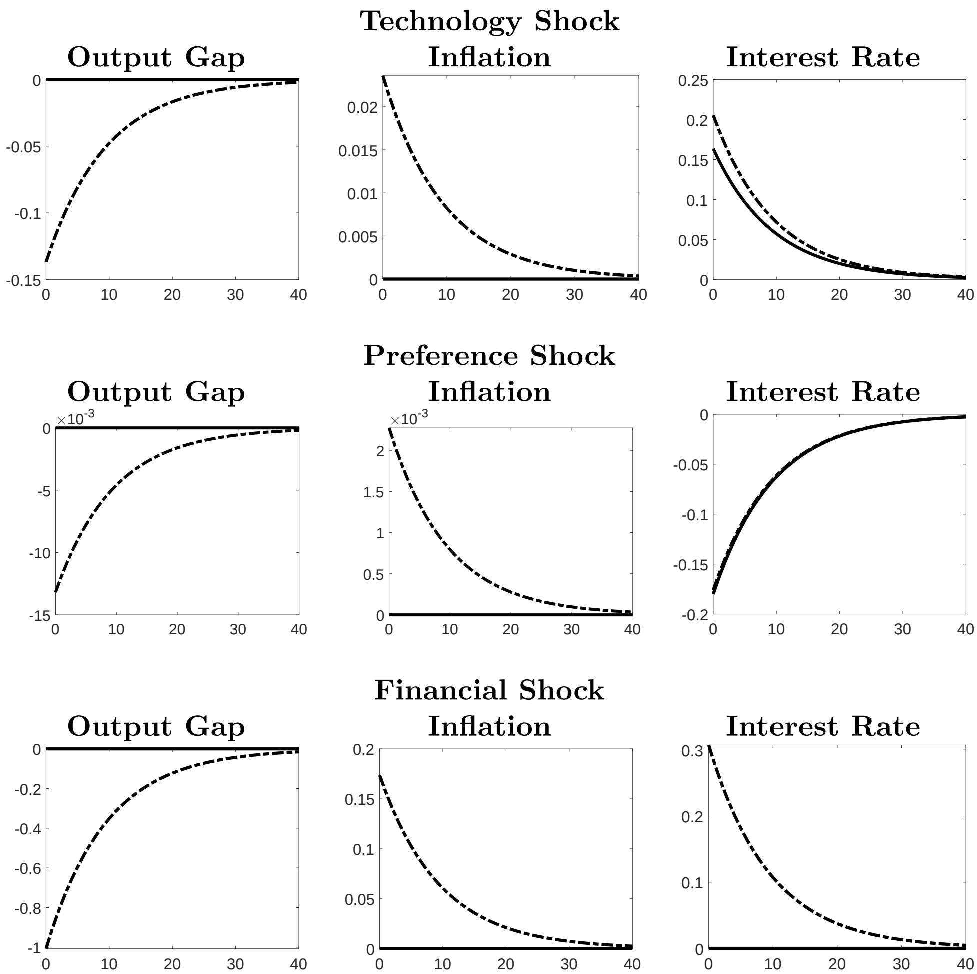
Proof 4. See Appendix.

As shown in Lemma 2, 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. A policymaker acting under discretion inherently cannot commit to setting future interest rates and hence fails to account for these more relevant forward-looking elements. This further amplifies the inflationary effects of shocks under optimal discretion.

Figure 3 shows these results graphically. Compared to optimal commitment, the responses of inflation and the output gap are larger under optimal discretion. This is equivalent to a stabilization bias relative to optimal commitment. Importantly, the stabilization bias only occurs in the financial accelerator economy. In the standard model, both optimal commitment and optimal discretion achieve divine coincidence. The stabilization bias in the financial accelerator economy results from both the flatter New Keynesian Phillips curve, implying a weaker interest rate channel of monetary policy, and the higher degree of forward-looking behavior being inherently ignored under discretion.

[18] For general calibrations, Assumption 2 is a slightly more restrictive assumption than Assumption 1. Under no disutility of labor ($\eta = 0$), one can show that Assumption 1 implies that Assumption 2 holds.

Figure 3: Shock Transmission under Optimal Discretion



Note: Impulse response functions for shocks with an autoregressive coefficient of 0.90. NK is the standard New Keynesian model (solid lines) and FF (dashed lines) is the financial accelerator economy. The shock size is calibrated to yield a one-percent decrease of output under the Taylor rule in the NK model (in the FF model for the financial shock). Output and output gap in percentage deviations from the non-stochastic steady state, for inflation in percentage-point deviations.

4.4 Optimal Monetary Policy under Commitment to a Simple Rule

Clearly, the stabilization bias of discretionary monetary policy is undesirable from a policymaker's perspective. This naturally raises the question whether policy performance can be improved in the presence of financial frictions. Two of the three factors governing the stabilization bias are largely beyond the control of monetary policy: The flatter New Keynesian Phillips curve and the cost-push shocks leading to the breakdown of divine coincidence in the first place.

However, the third source of the stabilization bias is that discretionary policy inherently fails to take private sector expectations into account. While optimal discretion thus cannot achieve the same stabilization performance as optimal commitment, discretionary policy can mimic commitment to a simple rule (Galí, 2015; Woodford, 2003). This constitutes a second-best policy regime that tries to mimic the first-best policy regime of optimal commitment as close as possible. One can learn more about optimal commitment by investigating commitment to a simple rule, which can be solved analytically in the framework at hand.

For the sake of illustration, the analysis of commitment to a simple rule is conducted for the financial shock (in terms of e_t). This has the advantage that one can neglect the demand shock u_t in the Euler equation, which substantially increases the clarity and comprehensibility of the analytic solutions. All of the following results also hold for technology and preference shocks.

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:

$$x_t = b_e e_t \tag{77}$$

Lemma 14. *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Under commitment to a simple rule of the form $x_t = b_e\, e_t$, inflation dynamics are given by*

$$\pi_t = \frac{1 + \widetilde{\widetilde{\kappa}} b_e}{1 - \rho_e \widetilde{\widetilde{\beta}}} e_t \tag{78}$$

where

$$\widetilde{\widetilde{\kappa}} = \widetilde{\kappa} + \sigma \rho \mathcal{K}_r \tag{79}$$

$$\widetilde{\widetilde{\beta}} = \beta + \mathcal{K}_r \tag{80}$$

This can be shown by inserting the targeting rule in the Phillips curve and iterating forward. The optimal value of b_e is chosen by the central bank to maximize household welfare. The central bank's optimization problem is given by

$$\min_{b_e} \quad E_t \sum_{s=0}^{\infty} \beta^s \left\{ \pi_{t+s}^2 + \lambda x_{t+s}^2 \right\} \tag{81}$$

$$s.t. \quad \pi_t = \frac{1 + \widetilde{\widetilde{\kappa}} b_e}{1 - \rho_e \widetilde{\widetilde{\beta}}} e_t \tag{82}$$

$$x_t = b_e\, e_t \tag{83}$$

where the two constraints Equation (82) and Equation (83) capture the economic dynamics and the functional form of the simple commitment, respectively. The solution to this optimization problem yields the following result:

Lemma 15. *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). The dynamics of inflation and the output gap under optimal commitment to a simple rule of the form $x_t = b_e\, e_t$ are* *given by:*

$$\pi_t = \frac{\lambda(1-\rho_e\widetilde{\widetilde{\beta}})}{\widetilde{\widetilde{\kappa}}^2 + \lambda(1-\rho_e\widetilde{\widetilde{\beta}})^2} e_t \tag{84}$$

$$x_t = -\frac{\widetilde{\widetilde{\kappa}}}{\widetilde{\widetilde{\kappa}}^2 + \lambda(1-\rho_e\widetilde{\widetilde{\beta}})^2} e_t \tag{85}$$

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 placing a relative weight on output gap stabilization different from the welfare-based weight:

Proposition 5. *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Optimal discretionary monetary policy mimics optimal commitment to a simple rule of the form $x_t = b_e\, e_t$ if it operates according to a loss function with relative weight $\widetilde{\lambda}$ on output gap stabilization*

$$\widetilde{\lambda} = (1-\rho_e\widetilde{\widetilde{\beta}})\frac{\widetilde{\kappa}}{\widetilde{\widetilde{\kappa}}}\lambda \tag{86}$$

Proof 5. See Appendix.

Lemma 16. *Assume $\vartheta = 1, \nu > 0$ and A1 (financial accelerator economy). Under $0 < \rho_e < 1$, it holds that:*

$$\widetilde{\lambda} < \lambda \tag{87}$$

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), one 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 3. *The persistence of cost-push shocks ρ_e satisfies:*

$$\rho_e\widetilde{\widetilde{\beta}} < 1 \tag{88}$$

Proposition 6. *Assume $\vartheta = 1, \nu > 0$, A1 (financial accelerator economy) and A3. Then, it holds that*

$$\frac{\partial\widetilde{\lambda}}{\partial\nu} < 0 \tag{89}$$

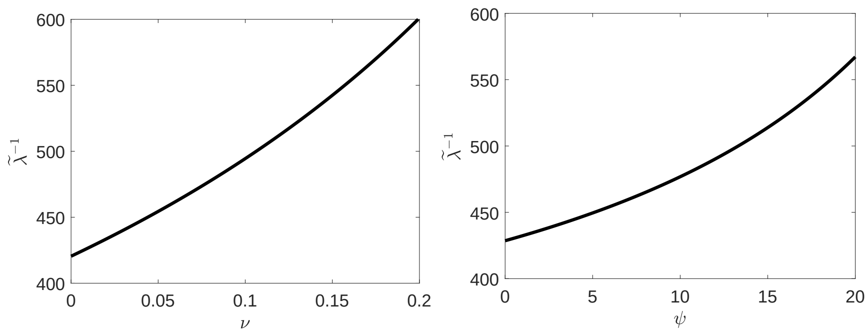
$$\frac{\partial\widetilde{\lambda}}{\partial\psi} < 0 \tag{90}$$

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

Proof 6. See Appendix.

Proposition 6 shows that the stronger the financial frictions, the more conservative the central banker must be. Prevailing financial frictions lead to a flattening of the New Keynesian Phillips curve, and a larger degree of forward-looking behavior being relevant for current macroeconomic outcomes. Accordingly, the stabilization bias of discretionary policy resulting from 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. As a consequence, current inflation can be stabilized, with a smaller fall in the output gap, such that welfare increases. Figure 4 shows the optimal inflation weight as a function of the degree of financial frictions:

Figure 4: Optimal Inflation Weight and Financial Frictions



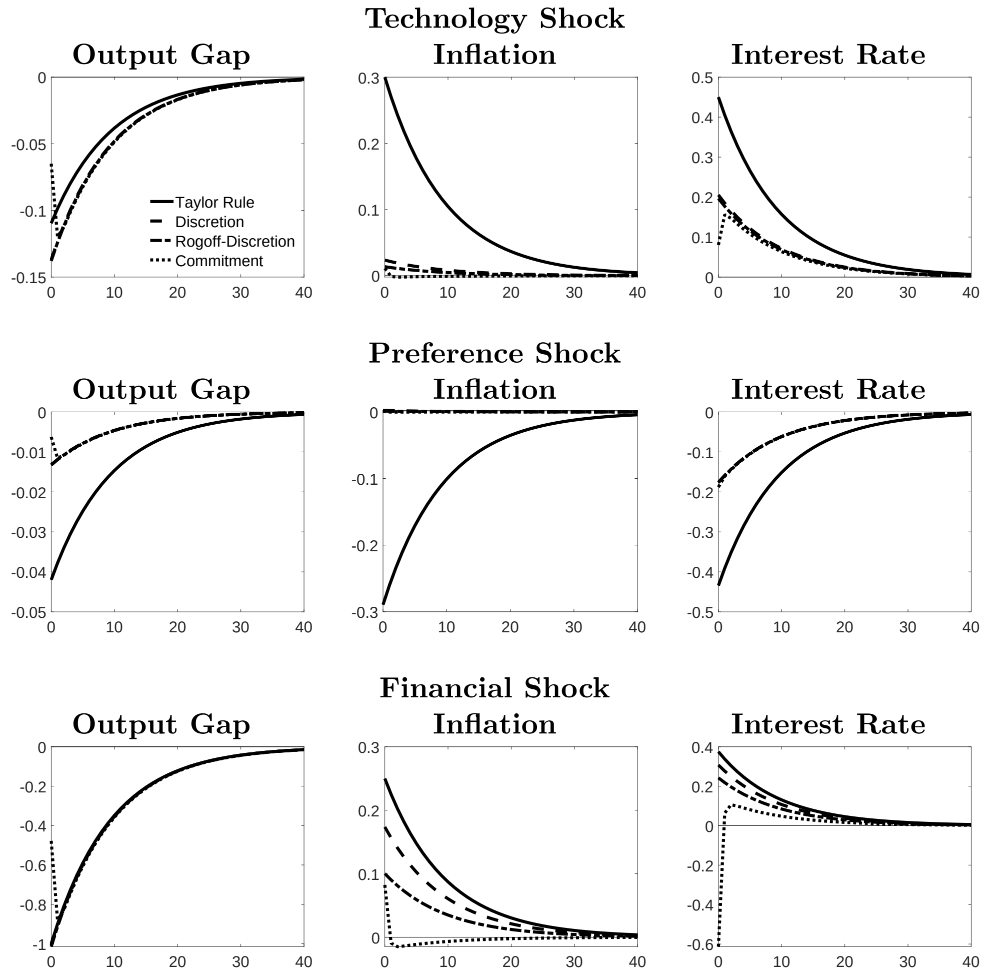
Note: The required inflation weight $\widetilde{\lambda}^{-1}$ relative to the weight on output gap such that discretionary policy mimics the solution under commitment to a simple rule, as a function of the degree of financial frictions.

Analyzing 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 call for a stronger focus on stabilizing economic activity. However, 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 because of the flattening of the Phillips curve. Intuitively, a more severe contemporaneous trade-off and a more forward-looking economy imply that the expectations channel of monetary policy becomes more important and potent. If the central banker puts a high weight on inflation stabilization, this sends a strong signal to the public that future inflation will respond less to any shock. Against this backdrop, optimal monetary policy is strongly forward-looking and geared towards inflation stabilization.

4.5 Comparing Policy Regimes

Figure 5 shows the transmission of shocks across the four policy regimes considered. Comparing full commitment and the discretion regime with the higher inflation weight shows that both regimes stabilize inflation almost completely. The inflation-conservative central banker stabilizes inflation even more than the first-best policy. This comes at the expense of a larger volatility of the output gap. 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 higher volatility of economic activity.

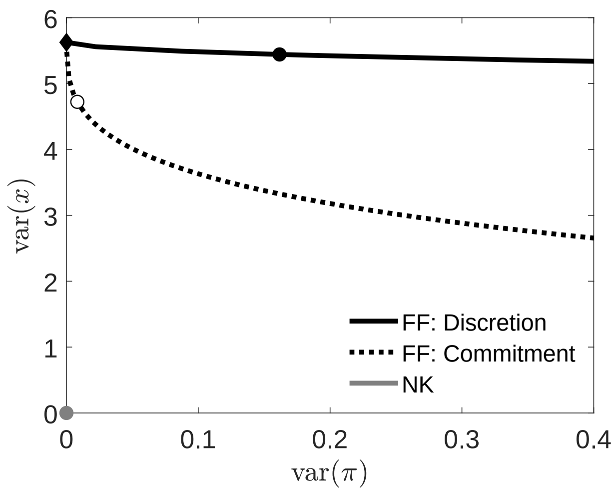
Figure 5: Shock Transmission across Policy Regimes



Note: Impulse response functions for shocks with an autoregressive coefficient of 0.90 in the financial accelerator economy. The shock size is calibrated to yield a one-percent decrease of output under the Taylor rule in the NK model (in the FF model for the financial shock). The shock transmission is shown for a Taylor rule (solid lines), optimal discretion (dashed lines), optimal commitment (dotted lines) and discretion using the inflation-conservative weight (dashed-dotted lines). Output and output gap in percentage deviations from the non-stochastic steady state, for inflation in percentage-point deviations.

An alternative way to see this result is to consider policy frontiers, shown in Figure 6 below. These are efficient combinations of inflation and output gap volatilities achievable under a given policy regime. The area below the policy frontier is not achievable, the area above is inefficient. The solution under discretion using the welfare-based mandate is denoted with a black circle. 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, which is the black diamond. The solution under inflation conservatism comes closer to the policy frontier under commitment and the corresponding solution (the white circle).

Figure 6: Policy Frontiers



Note: Efficient policy frontiers under discretion (solid line) and commitment (dotted line) for various output gap weights λ in σ_π^2, σ_x^2 space. The optimal combinations in the financial accelerator economy are shown for discretion (black circle) and commitment (white circle) using the welfare-based weight on the output gap λ, and for discretion using the inflation-conservative weight $\widetilde{\lambda}$ (black diamond). In the NK model, the optimal combinations are the same for all policy regime, denoted by a grey circle.

Summing up, these results suggest that optimal monetary policy in the financial accelerator economy is inflation-conservative. In the first place, shocks generate cost-push effects in the presence of financial frictions. This leads to a breakdown of divine coincidence and inefficient fluctuations of credit variables. Financial frictions also generate a flat and more forward-looking New Keynesian Phillips curve. In this context, the contemporaneous interest rate channel is substantially weaker, while the expectation channel is more important and potent. Policies that influence private sector expectations by sending credible inflation-conservative signals therefore yield the best stabilization performance.

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 and the optimal conduct of monetary policy.

The model framework is a tractable labor variant of the financial accelerator model à la Bernanke et al. (1999). The tractability of the framework allows investigating the implications of the presence of financial frictions on the New Keynesian Phillips curve in closed form. Compared to the standard model, the slope with respect to the output gap is flatter, the Phillips curve is more forward-looking and shocks unfold endogenous cost-push effects reflecting inefficient leverage fluctuations.

For monetary policy, the flatter slope of the Phillips curve implies that the contemporaneous interest rate channel is weaker, implying a more severe trade-off between inflation and output gap stabilization. At the same time, the larger degree of forward-lookingness implies that the expectation channel of monetary policy is more important and potent. Optimal monetary policy is thus strongly forward-looking and geared towards inflation stabilization, sending credible inflation-conservative signals to stabilize the economy via the expectation channel. Whereas such forward guidance policies are advisable, leaning-against-the-wind policies are suboptimal: Fluctuations in the credit cycle are subsumed in the mandate to stabilize the output gap, and this mandate receives a small weight based on approximation of household welfare.

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. As shown in this paper, 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 firms and banks. This gives rise to entrepreneur leverage being relevant for marginal costs, in turn leading to the canonical financial accelerator mechanism.

Let us first consider the financial contract. Entrepreneurs operating the intermediate goods-producing are indexed by i and have available equity financing of $N_{i,t}$, which is described in more detail below. In order to hire $H_{i,t}$ workers and pay them the market-determined wage W_t before production, entrepreneurs need to borrow

$$L_{i,t} = W_t H_{i,t} - N_{i,t} \tag{A1}$$

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 $\omega_{i,t}$. Production is thus given by

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

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 $L_{i,t}$, a loan rate $R^L_{i,t}$ and a threshold value for the idiosyncratic shock $\bar{\omega}_{i,t}$ defined by:

$$\bar{\omega}_{i,t} A_t H_{i,t} = R^L_{i,t} L_{i,t} \tag{A2}$$

If the realization of $\omega_{i,t} \geq \bar{\omega}_{i,t}$, the firm repays $R^L_{i,t} L_{i,t}$ and the bank does not monitor the firm. If $\omega_{i,t} < \bar{\omega}_{i,t}$, the firm defaults, the bank decides to monitor the firm, pays the monitoring cost and seizes the remaining fraction of output $(1-\zeta)\omega_{i,t} A_t H_{i,t}$.

The contract can be written as:

$$\max_{L_{i,t},R^L_{i,t},\bar{\omega}_{i,t},H_{i,t}} \quad f(\bar{\omega}_{i,t})A_tH_{i,t} \tag{A3}$$

$$s.t. \quad W_tH_{i,t} \leq L_{i,t} + N_{i,t} \tag{A4}$$

$$f(\bar{\omega}_{i,t})A_tH_{i,t} \geq R_tN_{i,t} \tag{A5}$$

$$g(\bar{\omega}_{i,t},\zeta)A_tH_{i,t} \geq R_tL_{i,t} \tag{A6}$$

$$\bar{\omega}_{i,t}A_tH_{i,t} = R^L_{i,t}L_{i,t} \tag{A7}$$

$$f(\bar{\omega}_{i,t}) = \int_{\bar{\omega}_{i,t}}^{\infty}(\omega_{i,t} - \bar{\omega}_{i,t})\phi(\omega)d\omega \tag{A8}$$

$$g(\bar{\omega}_{i,t},\zeta) = \int_0^{\infty}(1-\zeta)\omega_{i,t}\phi(\omega)d\omega + \int_{\bar{\omega}_{i,t}}^{\infty}\bar{\omega}_{i,t}\phi(\omega)d\omega \tag{A9}$$

$$f(\bar{\omega}_{i,t}) + g(\bar{\omega}_{i,t},\zeta) + \zeta\int_0^{\bar{\omega}_{i,t}}\omega_{i,t}\phi(\omega)d\omega = 1 \tag{A10}$$

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). 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 aggregate terms that are exogenous to the contract, one can rewrite the maximization problem as

$$\max_{L_{i,t},R^L_{i,t},\bar{\omega}_{i,t}} \quad f(\bar{\omega}_{i,t})v_t(L_{i,t} + N_{i,t}) \tag{A12}$$

$$s.t. \quad g(\bar{\omega}_{i,t},\zeta)v_t(L_{i,t} + N_{i,t}) = R_tL_{i,t} \tag{A13}$$

where the threshold and the shares are given by Equations (A7)-(A10). Denoting the Lagrange multiplier on (A13) by $\xi_{i,t}$, the FOCs with respect to $L_{i,t}$ and $\bar{\omega}_{i,t}$ are given by

$$f(\bar{\omega}_{i,t})v_t - \xi_{i,t}(g(\bar{\omega}_{i,t},\zeta)v_t - R_t) = 0 \tag{A14}$$

$$f'(\bar{\omega}_{i,t}) - \xi_{i,t}g'(\bar{\omega}_{i,t},\zeta) = 0 \tag{A15}$$

where $f'(.)$ and $g'(.)$ denote the derivatives of f and g with respect to $\bar{\omega}_{i,t}$. Combining these equations yields:

$$\frac{f(\bar{\omega}_{i,t})v_t}{g(\bar{\omega}_{i,t},\zeta)v_t - R_t} = \frac{f'(\bar{\omega}_{i,t})}{g'(\bar{\omega}_{i,t},\zeta)} \tag{A16}$$

This equation, together with (A13) and (A7), defines the optimal contract $\{L_{i,t}, R^L_{i,t}, \bar{\omega}_{i,t}\}$. Equation (A16) implies that the contract terms are solely a function of aggregate variables. Hence, all firms choose the same contract. As equity financing is also identical across entrepreneurs (see below), the project size is also the same. Accordingly, the entrepreneur subscripts are dropped in the following. One can rearrange the equations characterizing the contract to:

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

This equation can be rewritten as

$$\frac{R_t^L}{R_t} = s\left(\frac{W_tH_t}{N_t}, \bar{\omega}_t\right) \tag{A18}$$

with $s'(.) > 0$. To obtain the linear approximation of this relationship, note that combining Equation (A7) with (A11) and (A13) implies that:

$$\frac{R_t^L}{R_t} = \frac{\bar{\omega}_t}{g(\bar{\omega}_t,\zeta)} \tag{A19}$$

The log-linearized version is

$$r_t^L - r_t = \widehat{\bar{\omega}}_t - \widehat{g}_t \tag{A20}$$

using small-case letters to denote log-linearized variables as in the main text, or "hats" whenever using small-case letters is not feasible. The function arguments of $f(\bar{\omega}_t)$ and $g(\bar{\omega}_t, \zeta)$ are dropped in the following to ease notation. Variables without a time subscript denote steady state values. Log-linearizing Equation (A14) and substituting for $\widehat{g}_t$ in Equation (A20) yields:

$$r_t^L - r_t = \widehat{\bar{\omega}}_t - \frac{gv - R}{gv}\left(\widehat{f}_t - \widehat{\xi}_t\right) - \frac{R}{gv}\left(r_t - \widehat{v}_t\right) \tag{A21}$$

Inserting the log-linearized versions of Equations (A4), (A13) and (A15) gives

$$r_t^L - r_t = \widehat{\bar{\omega}}_t + \frac{N}{L}\left(\widehat{f}_t - \widehat{f}'_t + \widehat{g}'_t\right) - \frac{WH}{L}\widehat{g}_t + \frac{WH}{L}\frac{N}{L}(w_t + h_t - n_t) \tag{A22}$$

where Equation (A13) was used to rewrite the steady state values. Noting that $\widehat{f(x_t)} = \frac{f'(x)}{f(x)} x \widehat{x}_t$ yields:

$$r_t^L - r_t = \left[1 + \bar{\omega}\frac{N}{L}\left(\frac{f'}{f} - \frac{f''}{f'} + \frac{g''}{g'}\right) - \bar{\omega}\frac{WH}{L}\frac{g'}{g}\right]\widehat{\bar{\omega}}_t + \frac{WH}{L}\frac{N}{L}(w_t + h_t - n_t) \tag{A23}$$

Using the same reasoning in Equation (A20) shows that

$$\widehat{\bar{\omega}}_t = \frac{g}{g - g'\bar{\omega}}(r_t^L - r_t) \tag{A24}$$

which one can use to replace $\widehat{\omega}_t$ in Equation (A23). This yields:

$$r_t^L - r_t = \left[1 + \bar{\omega}\frac{N}{L}\left(\frac{f'}{f} - \frac{f''}{f'} + \frac{g''}{g'}\right) - \bar{\omega}\frac{WH}{L}\frac{g'}{g}\right]\frac{g}{g - g'\bar{\omega}}(r_t^L - r_t) + \frac{WH}{L}\frac{N}{L}(w_t + h_t - n_t) \tag{A25}$$

After rearranging terms, one arrives at the linear relationship between the credit spread and entrepreneur leverage shown in Equation (27) in the main part

$$r_t^L - r_t = \nu(w_t + h_t - n_t) \tag{A26}$$

where

$$\nu = \left[\frac{\bar{\omega}}{g - g'\bar{\omega}}\left(g' - g\left(\frac{f'}{f} - \frac{f''}{f'} + \frac{g''}{g'}\right)\right)\right]^{-1}\frac{WH}{L} > 0 \tag{A27}$$

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. 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

$$S_t = N_t\frac{E_t[R_{t+1}^S]}{R_t} \tag{A28}$$

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:

$$E_t[R_{t+1}^S] = R_t^L \tag{A29}$$

Stocks are priced by risk-neutral financial traders associated with a continuum of financial intermediaries according to the expected dividend on the stocks.[19] Financial intermediaries collect deposits B_t from households and use them to provide funding to entrepreneurs in the form of loans and equity financing. Indexing financial intermediaries by k, their balance sheet is given by

$$S_tJ_{k,t} + L_{k,t} = B_{k,t} \tag{A30}$$

where $J_{k,t}$ is the proportion of stocks held by financial intermediary k. Financial traders operate according to a rule-of-thumb and demand a share

$$\delta_t = f(\bar{\omega})\frac{(Y_t/Y)^{\widetilde{\psi}-1}}{(R_t)^{\widetilde{\mu}-1}}e^{-\varepsilon_t^n} \tag{A31}$$

of total output. The parameters $\widetilde{\psi} - 1$ and $\widetilde{\mu} - 1$ represent the elasticities with respect

[19] Alternatively, one could also think of the financial intermediary as consisting of a wholesale and a trading branch.

to aggregate variables. Following the notion from behavioral finance that investors systematically over-react to news (De Bondt and Thaler, 1985, 1987; Chopra et al., 1992), these elasticities are larger than one. ε_t^n is an exogenous financial shock originating in the banking sector. Similar to De Fiore and Tristani (2013), I assume that entrepreneur consumption is fully taxed. As a result, entrepreneurs are indifferent between paying out the return as dividends or as taxes to the government and thus accommodate the financial traders' dividend demand. Accordingly, financial traders attach a price of

$$S_t = \frac{\delta_t Y_t}{R_t} \tag{A32}$$

to stocks. Combining Equations (A28)-(A32) and using (A18) yields

$$N_t = \frac{\delta_t Y_t}{R_t} s^{-1}\left(\frac{W_t H_t}{N_t}, \bar{\omega}_t\right) \tag{A33}$$

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

$$n_t = \psi y_t - \mu r_t + \frac{1}{1-\nu}\left(\varepsilon_t^n + \nu(1+\eta)a_t + \nu\varepsilon_t^c\right) \tag{A34}$$

where

$$\psi = \frac{\widetilde{\psi} - \nu(1+\sigma+\eta)}{1-\nu} > 0 \tag{A35}$$

$$\mu = \frac{\widetilde{\mu}}{1-\nu} > 0 \tag{A36}$$

This is what Equation (12) in the main text captures. 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 procyclical, while at the same time depending directly on central bank interest rates.

B Log-Linearized Equilibrium Equations

The log-linear version of the model can be obtained by log-linearizing Equations (1)-(19) around the non-stochastic steady state. Lower-case letters denote variables in percentage deviations from the steady state, with the exception of inflation and interest rates which are in percentage point deviations.

B.1 Sticky-Price Economy

Euler equation:

$$y_t = -\sigma^{-1}\left(r_t - E_t[\pi_{t+1}] + E_t[\varepsilon^c_{t+1}] - \varepsilon^c_t\right) + E_t[y_{t+1}] \tag{A37}$$

Intratemporal consumption-labor trade-off:

$$w_t = \eta h_t + \sigma y_t - \varepsilon^c_t \tag{A38}$$

Production function:

$$y_t = a_t + h_t \tag{A39}$$

Marginal costs:

$$mc_t = w_t + \vartheta r^L_t - a_t \tag{A40}$$

Phillips curve:

$$\pi_t = \kappa mc_t + \beta E_t[\pi_{t+1}] \tag{A41}$$

Credit spread:

$$r^L_t = r_t + \nu(w_t + h_t - n_t) \tag{A42}$$

Equity:

$$n_t = \psi y_t - \mu r_t + \frac{1}{1-\nu}\left(\varepsilon^n_t + \nu(1+\eta)a_t + \nu\varepsilon^c_t\right) \tag{A43}$$

Taylor rule:

$$r_t = \phi\pi_t \tag{A44}$$

B.2 Auxiliary Variables and Shocks

Efficient output:

$$y^e_t = \frac{1+\eta}{\sigma+\eta}a_t + \frac{1}{\sigma+\eta}\varepsilon^c_t \tag{A45}$$

Output gap:

$$x_t = y_t - y^e_t \tag{A46}$$

Technology shock:

$$a_t = \rho_a\, a_{t-1} + \eta^a_t \tag{A47}$$

Consumption preference shock:

$$\varepsilon^c_t = \rho_c\, \varepsilon^c_{t-1} + \eta^c_t \tag{A48}$$

Financial Shock:

$$\varepsilon_t^n = \rho_n \, \varepsilon_{t-1}^n + \eta_t^n \tag{A49}$$

B.3 Flexible-Price Economy

Euler equation:

$$y_t^f = -\sigma^{-1} \left(r_t^f + E_t[\varepsilon_{t+1}^c] - \varepsilon_t^c \right) + E_t[y_{t+1}^f] \tag{A50}$$

Intratemporal consumption-labor trade-off:

$$w_t^f = \eta h_t^f + \sigma y_t^f - \varepsilon_t^c \tag{A51}$$

Production function:

$$y_t^f = a_t + h_t^f \tag{A52}$$

Marginal costs:

$$0 = w_t^f + \vartheta r_t^{L,f} - a_t \tag{A53}$$

Credit spread:

$$r_t^{L,f} = r_t^f + \nu(w_t^f + h_t^f - n_t^f) \tag{A54}$$

Equity:

$$n_t^f = \psi y_t^f - \mu r_t^f + \frac{1}{1-\nu}\left(\varepsilon_t^n + \nu(1+\eta)a_t + \nu \varepsilon_t^c \right) \tag{A55}$$

C Proofs

This section shows details about Assumption 1 and the proofs of Propositions 1-6.

C.1 Assumption 1

Leverage is given by

$$lev_t = w_t + h_t - n_t \tag{A56}$$

which can be rewritten as:

$$lev_t = (1 + \sigma + \eta - \psi)y_t + \mu r_t - \frac{1}{1-\nu}\Big(\varepsilon_t^n + (1+\eta)a_t - \varepsilon_t^c\Big) \tag{A57}$$

In general equilibrium under a simple Taylor rule and white-noise shocks, using the results from Lemma 4, the solution for leverage is:

$$\begin{aligned} lev_t = {} & (\psi - 1 - \sigma - \eta)\frac{\phi \mathcal{K}_x}{\sigma + \phi\widetilde{\kappa}}u_t + (1 + \sigma + \eta - \psi)u_t \\ & + (\psi - 1 - \sigma - \eta)\frac{\phi}{\sigma + \phi\widetilde{\kappa}}e_t + \mu r_t \\ & + \frac{1+\eta}{\sigma+\eta}\Big(1 + \sigma + \eta - \psi - \frac{\sigma+\eta}{1-\nu}\Big)a_t \\ & + \frac{1}{\sigma+\eta}\Big(1 + \sigma + \eta - \psi - \frac{\sigma+\eta}{1-\nu}\Big)\varepsilon_t^c - \frac{1}{1-\nu}\varepsilon_t^n \end{aligned} \tag{A58}$$

For technology shocks, this implies that

$$lev_t = -(\psi - 1 - \sigma - \eta)\frac{\phi\kappa(1+\eta)}{\sigma + \phi\widetilde{\kappa}}\Big[1 + \vartheta\nu\Big(1 + \frac{\nu}{1-\nu} + \frac{\sigma + \phi\widetilde{\kappa}}{\phi(1-\nu)(\kappa\eta - \widetilde{\kappa})}\Big)\Big]a_t + \mu r_t \tag{A59}$$

The first term is the response of leverage in terms of structural shocks, reflecting the dependence of leverage on aggregate output. The second term captures the direct effect of monetary policy on leverage. To obtain a financial accelerator model, one needs to restrict the calibration such that leverage is countercyclical, abstracting from the latter monetary policy effect via nominal interest rates. This implies that the coefficient in front of a_t should be positive. The term in square brackets is positive under plausible calibrations of the financial contract, which imply that $\nu > 0$ is small. For leverage to be countercyclical in general equilibrium following technology shocks, holding central bank interest rates constant, the term in the first brackets thus needs to be positive. This yields the key assumption stated in the main part, which is:

$$\psi > 1 + \sigma + \eta \tag{A60}$$

Similar reasoning can be applied for financial shocks and preference shocks.

C.2 Proposition 1

Proposition 1. *Assume $\vartheta = 1, \nu > 0$, A1 (financial accelerator economy) and let all shocks be white-noise innovations. Then, the inflationary effect of supply shocks is amplified compared to the standard model.*

Proof 7. The dynamics of inflation in terms of composite shocks is given by:

$$\pi_t = \quad \frac{\sigma}{\sigma + \phi\widetilde{\kappa}}\Big(\mathcal{K}_x u_t + e_t\Big) \tag{A61}$$

This can be rewritten in terms of the structural shocks as

$$\begin{aligned}\pi_t = &-\vartheta\frac{\nu}{1-\nu}\frac{\kappa\sigma}{\sigma+\phi\widetilde{\kappa}}\varepsilon_t^n - \frac{\kappa\sigma}{\sigma+\phi\widetilde{\kappa}}(1+\eta)\Big(1+\vartheta\nu+\vartheta\frac{\nu^2}{1-\nu}\Big)a_t \\ &+\frac{\kappa}{\sigma+\phi\widetilde{\kappa}}\Big(\eta+\vartheta\nu\Big(1+\eta-\psi-\sigma\frac{\nu}{1-\nu}\Big)\Big)\varepsilon_t^c\end{aligned} \tag{A62}$$

For the financial shocks, the acceleration result is trivial. Setting $\vartheta = 0$ shows that they unfold no inflationary response in the standard model, whereas the term is positive in the presence of financial frictions. For technology shocks, the coefficient $\widetilde{\kappa}$ in the denominator is smaller compared to the standard model under Assumption 1 and the term $(1 + \vartheta\nu + \vartheta\frac{\nu^2}{1-\nu})$ is larger. It follows directly that the inflationary response to technology shocks is larger in the financial accelerator economy.

Concerning the preference shocks, the term in brackets decreases in the degree of financial frictions. Therefore, the amplification result depends on the Taylor rule coefficient ϕ, which scales the denominator derivative. As a comparison the (nested) response of inflation to preference shocks in the standard model is:

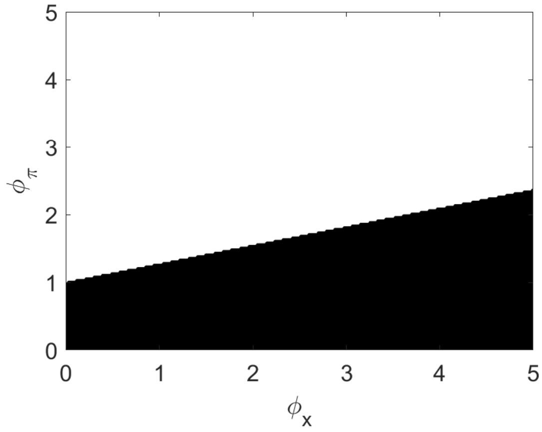
$$\pi_t = \frac{\kappa\eta}{\sigma + \phi\kappa(\sigma+\eta)}\varepsilon_t^c \tag{A63}$$

Comparing the two solutions, one can show that the inflationary response in the financial accelerator economy is larger if

$$\phi > \frac{\nu\Big(\psi + \sigma\frac{\nu}{1-\nu} - \eta - 1\Big)}{\kappa\Big(\eta\Big(1+\nu\mu-\frac{\nu}{1-\nu}\Big)+\nu\Big(1-\psi-\sigma\frac{\nu}{1-\nu}\Big)} \tag{A64}$$

For the benchmark calibration used to compute the impulse responses, this condition implies that the inflationary effect of preference shocks is amplified as long as $\phi > 1.03$. This is below standard values and close to the threshold for determinacy in the financial accelerator model, as shown below. The proposition therefore holds for reasonable calibrations, as long as ν and ψ are not excessively large.

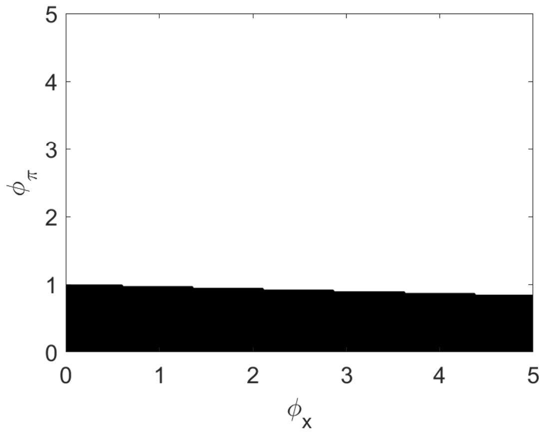
Figure A1: Determinacy Region Financial Accelerator Model



Note: The determinacy (white) and indeterminacy (black) regions of the financial frictions model ($\vartheta = 1, \nu = 0.05, \psi = 6, \mu = 1.05$) 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.

For comparison, the determinacy region of the standard model is:

Figure A2: Determinacy Region NK Model



Note: The determinacy (white) and indeterminacy (black) 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.

As a side remark, the general solution for persistent shocks is given by:

$$\pi_t = \frac{\mathcal{K}_x\sigma}{\sigma(1-\rho_u)(1-\mathcal{K}_r\phi-\beta\rho_u)+\mathcal{K}_x(\phi-\rho_u)}u_t + \frac{\sigma(1-\rho_e)}{\sigma(1-\rho_e)(1-\mathcal{K}_r\phi-\beta\rho_e)+\mathcal{K}_x\phi(1-\rho_e)-\mathcal{K}_x(1-\phi)\rho_e\sigma}e_t \quad \text{(A65)}$$

C.3 Proposition 2

Proposition 2. *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy) and assume that the steady state is efficient. Then, one can approximate household welfare $\mathcal{W}_t$ to a second order as*

$$\mathcal{W}_t = E_t \sum_{s=0}^{\infty} \beta^s \left(\frac{U_{t+s} - U}{U_c C} \right) \approx -\frac{1}{2} E_t \sum_{s=0}^{\infty} \beta^s \mathcal{L}_{t+s} \tag{A66}$$

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

$$\mathcal{L}_t = \pi_t^2 + \lambda \left(x_t^f - \frac{\vartheta}{\sigma + \eta} r_t^f - \frac{\vartheta \nu}{\sigma + \eta} lev_t^f \right)^2 \tag{A67}$$

where

$$\lambda = \frac{\kappa(\sigma + \eta)}{\epsilon} \tag{A68}$$

$$x_t^f = y_t - y_t^f \tag{A69}$$

$$lev_t^f = w_t^f + h_t^f - n_t^f \tag{A70}$$

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

Proof 8. Start from the per-period household utility function, which is given by

$$U_t = U(C_t, H_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \chi \frac{H_t^{1+\eta}}{1+\eta} \tag{A71}$$

and is thus separable in consumption and hours worked.[20] A second-order Taylor expansion of U_t around a steady state (C, H) yields

$$U_t - U \simeq U_c C \left(\frac{C_t - C}{C} \right) + U_h H \left(\frac{H_t - H}{H} \right) + \frac{1}{2} U_{cc} C^2 \left(\frac{C_t - C}{C} \right)^2 + \frac{1}{2} U_{hh} H^2 \left(\frac{H_t - H}{H} \right)^2 + tip \tag{A72}$$

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

$$U_t - U \simeq U_c C \left(c_t + \left(\frac{1}{2} + \frac{U_{cc} C}{2U_c} \right) c_t^2 \right) + U_h H \left(h_t + \left(\frac{1}{2} + \frac{U_{hh} H}{2U_h} \right) h_t^2 \right) + tip \tag{A73}$$

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 $c_t = y_t$ one can rewrite this as

$$U_t - U \simeq U_c C \left(y_t + \frac{1-\sigma}{2} y_t^2 \right) + U_h H \left(h_t + \frac{1+\eta}{2} h_t^2 \right) + tip \tag{A74}$$

[20] This abstracts from the preference shocks present in the main part for the sake of illustration. It can easily be shown that the proposition also holds for preference shocks. These are efficient in the standard model and thus merely affect the definition of marginal utility and efficient output.

From the production function, it follows that

$$h_t = y_t - a_t + d_t \tag{A75}$$

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

$$d_t = \frac{\epsilon}{2} var_j \{p_{j,t}\} \tag{A76}$$

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. One can use this to rewrite utility as

$$U_t - U = U_c C \left(y_t + \frac{1-\sigma}{2} y_t^2\right) + U_h H \left(y_t + \frac{\epsilon}{2} var_j\{p_{j,t}\} + \frac{1+\eta}{2}(y_t - a_t)^2\right) + tip \tag{A77}$$

Dividing by $U_c C$ and rearranging terms yields

$$\frac{U_t - U}{U_c C} = \left(1 + \frac{U_h H}{U_c C}\right) y_t + \frac{1-\sigma}{2} \widehat{y}_t^2 + \frac{1}{2}\left[\frac{U_h H}{U_c C}\left(\epsilon \, var_j\{p_{j,t}\} + (1+\eta)(y_t - a_t)^2\right)\right] + tip \tag{A78}$$

The aim at this stage is to evaluate the term $\frac{U_h H}{U_c C}$, which is based on steady-state values. The steady-state output level of the financial accelerator economy Y^{FF} is given by:

$$Y^{FF} = \left[\chi^{-1}\left(\frac{\epsilon}{\epsilon - 1}\right)^{-1} \left(R^L\right)^{-1}\right]^{\frac{1}{\sigma+\eta}} \tag{A79}$$

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), one can label this wedge as the inefficiency gap.

Lemma 17. *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*

$$\frac{\chi H^\eta}{C^{-\sigma}} A^{-1} = \left(\frac{\epsilon}{\epsilon - 1}\right)^{-1} \left(R^L\right)^{-1} \tag{A80}$$

In the following, 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 4. *The government issues steady-state subsidies* $\tau = \frac{\epsilon}{\epsilon-1}(R^L)$ *to firm's marginal cost.*

Lemma 18. *Let* $\vartheta = 1, \nu > 0$ *(financial accelerator economy). Under Assumption 4, 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*

$$Y^{FF} = \left[\chi^{-1}\tau\left(\frac{\epsilon}{\epsilon-1}\right)^{-1}\left(R^L\right)^{-1}\right]^{\frac{1}{\sigma+\eta}} = \chi^{-\frac{1}{\sigma+\eta}} = Y^{NK} \tag{A81}$$

Imposing efficiency of the steady state through appropriate subsidies implies

$$-\frac{U_h}{U_c} = MPN = \frac{Y}{H} \tag{A82}$$

such that

$$\frac{U_h H}{U_c C} = -1 \tag{A83}$$

and the linear term involving y_t drops out. Equation (A78) then reduces to:

$$\frac{U_t - U}{U_c C} = -\frac{1}{2}\left[(\sigma-1)y_t^2 + \epsilon\, var_j\{p_{j,t}\} + (1+\eta)\left(y_t - a_t\right)^2\right] + tip \tag{A84}$$

The efficient allocation is given by

$$y_t^e = \frac{1+\eta}{\sigma+\eta}a_t \tag{A85}$$

which one can use to replace a_t and get

$$\frac{U_t - U}{U_c C} = -\frac{1}{2}\left[(\sigma-1)y_t^2 + \epsilon\, var_j\{p_{j,t}\} + (1+\eta)\left(y_t - \frac{\sigma+\eta}{1+\eta}y_t^e\right)^2\right] + tip \tag{A86}$$

which can be rearranged to

$$\frac{U_t - U}{U_c C} = -\frac{1}{2}\left[(\sigma+\eta)(y_t - y_t^e)^2 + \epsilon\, var_j\{p_{j,t}\}\right] + tip \tag{A87}$$

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

$$\begin{aligned}\mathcal{W}_t &= E_t\sum_{s=0}^{\infty}\beta^s\left(\frac{U_{t+s}-U}{U_c C}\right)\\ &= -\frac{1}{2}E_t\sum_{s=0}^{\infty}\beta^s\left(\epsilon\, var_j\{p_{j,t+s}\} + (\sigma+\eta)x_{t+s}^2\right)\end{aligned} \tag{A88}$$

Following Woodford (2003), one can rewrite

$$\sum_{s=0}^{\infty} \beta^s var_j\{p_{j,t+s}\} = \frac{\theta}{(1-\beta\theta)(1-\theta)} \sum_{s=0}^{\infty} \beta^s \pi_{t+s}^2 \tag{A89}$$

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

$$\mathcal{W}_t = -\frac{1}{2} E_t \sum_{s=0}^{\infty} \beta^s \left(\frac{\epsilon}{\kappa} \pi_{t+s}^2 + (\sigma + \eta) x_{t+s}^2 \right) \tag{A90}$$

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

$$\mathcal{L}_t = \pi_t^2 + \lambda x_t^2 \tag{A91}$$

where $\lambda = \frac{\kappa(\sigma+\eta)}{\epsilon}$.The wedge between flexible-price output and the efficient level of output is

$$y_t^f = y_t^e - \vartheta r_t^L \tag{A92}$$

such that one can write the loss function as

$$\mathcal{L}_t = \pi_t^2 + \lambda \left(y_t - y_t^f - \vartheta r_t^L \right)^2 \tag{A93}$$

or alternatively using

$$r_t^L = r_t^f + \nu(w_t^f + h_t^f - n_t^f) \tag{A94}$$

as

$$\mathcal{L}_t = \pi_t^2 + \lambda \left(x_t^f - \frac{\vartheta}{\sigma + \eta} r_t^f - \frac{\vartheta \nu}{\sigma + \eta} lev_t^f \right)^2 \tag{A95}$$

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 $lev_t^f = w_t^f + h_t^f - n_t^f$.

C.4 Proposition 3

Proposition 3. *Assume $\vartheta = 1, \nu > 0$, A1 (financial accelerator economy) and $\rho = 0$. Then, it holds that*

$$\frac{\partial \alpha}{\partial \nu} > 0 \tag{A96}$$

$$\frac{\partial \alpha}{\partial \psi} > 0 \tag{A97}$$

such that the inflationary response to shocks increases in the degree of financial frictions as captured by ν and ψ via the flatter New Keynesian Phillips curve.

Proof 9. Under $\rho = 0$:

$$\alpha = \frac{1}{\widetilde{\kappa}^2 + \lambda} \tag{A98}$$

The derivative of $\widetilde{\kappa}$ with respect to ν and ψ is negative under Assumption 1, such that the derivative of α is positive for both cases.

C.5 Proposition 4

Proposition 4. *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). It holds that*

$$\frac{\partial \widetilde{\beta}}{\partial \psi} > 0 \tag{A99}$$

Under Assumption 2, it furthermore holds that

$$\frac{\partial \widetilde{\beta}}{\partial \nu} > 0 \tag{A100}$$

such that the inflationary effect of shocks increases in the degree of financial frictions as captured by ν and ψ via the higher relevance of future expectations for current inflation dynamics.

Proof 10. Note that $\widetilde{\beta}$ is given by:

$$\widetilde{\beta} = \beta + \vartheta\kappa(1+\nu\mu)\left(1 - \frac{\widetilde{\kappa}\sigma}{\lambda}\right) \tag{A101}$$

The derivative with respect to ψ is:

$$\frac{\partial \widetilde{\beta}}{\partial \psi} = -\vartheta\kappa(1+\nu\mu)\frac{\sigma}{\lambda}\frac{\partial \widetilde{\kappa}}{\partial \psi} = \vartheta^2\nu\kappa(1+\nu\mu)\frac{\sigma}{\lambda} > 0 \tag{A102}$$

The derivative with respect to ν is:

$$\frac{\partial \widetilde{\beta}}{\partial \nu} = \vartheta\kappa\mu - \vartheta\kappa\frac{\sigma}{\lambda}\left[\mu\widetilde{\kappa} + (1+\nu\mu)\frac{\partial \widetilde{\kappa}}{\partial \nu}\right] \tag{A103}$$

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

$$\mu(\lambda - \sigma\widetilde{\kappa}) - \sigma(1+\nu\mu)(1+\sigma+\eta-\psi-\mu\sigma) \tag{A104}$$

This term is positive under Assumption 2.

C.6 Proposition 5

Proposition 5. *Let $\vartheta = 1, \nu > 0$ (financial accelerator economy). Optimal discretionary monetary policy mimics optimal commitment to a simple rule of the form $x_t = b_e\, e_t$ if it operates according to a loss function with relative weight $\widetilde{\lambda}$ on output gap stabilization*

$$\widetilde{\lambda} = (1 - \rho_e\widetilde{\widetilde{\beta}})\frac{\widetilde{\kappa}}{\widetilde{\widetilde{\kappa}}}\lambda \tag{A105}$$

Proof 11. Discretion with relative weight $\widetilde{\lambda}$ on output gap stabilization yields the following inflation dynamics:

$$\pi_t^{\text{Disc}} = \frac{\widetilde{\lambda}}{\widetilde{\kappa}^2 + \widetilde{\lambda}(1-\rho_e\widetilde{\beta})} e_t \tag{A106}$$

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

$$\pi_t^{\text{CSR}} = \frac{\lambda(1-\rho_e\widetilde{\widetilde{\beta}})}{\widetilde{\widetilde{\kappa}}^2 + \lambda(1-\rho_e\widetilde{\widetilde{\beta}})^2} e_t \tag{A107}$$

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

$$\frac{\widetilde{\lambda}}{\widetilde{\kappa}^2 + \lambda(1-\rho_e\widetilde{\beta}(\widetilde{\lambda}))} = \frac{\lambda(1-\rho_e\widetilde{\widetilde{\beta}})}{\widetilde{\widetilde{\kappa}}^2 + \lambda(1-\rho_e\widetilde{\widetilde{\beta}})^2} \tag{A108}$$

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

C.7 Proposition 6

Proposition 6. *Assume $\vartheta = 1, \nu > 0$, A1 (financial accelerator economy) and A3. Then, it holds that*

$$\frac{\partial\widetilde{\lambda}}{\partial\nu} < 0 \tag{A109}$$

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

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

Proof 12. The first derivative is given by:

$$\begin{aligned}\frac{\partial\widetilde{\lambda}}{\partial\nu} &= -\rho_e\frac{\widetilde{\kappa}}{\widetilde{\widetilde{\kappa}}}\frac{\partial\widetilde{\widetilde{\beta}}}{\partial\nu} + (1-\rho_e\widetilde{\widetilde{\beta}})\frac{\partial\frac{\widetilde{\kappa}}{\widetilde{\widetilde{\kappa}}}}{\partial\nu} \\ &= -\rho_e\frac{\widetilde{\kappa}}{\widetilde{\widetilde{\kappa}}}\vartheta\kappa\nu + (1-\rho_e\widetilde{\widetilde{\beta}})\vartheta\frac{\widetilde{\widetilde{\kappa}}-\widetilde{\kappa}}{\widetilde{\kappa}^2}\frac{\partial\widetilde{\kappa}}{\partial\nu}\end{aligned} \tag{A111}$$

For $0 < \rho_e < 1$, $\widetilde{\widetilde{\kappa}} > \widetilde{\kappa}$. Under Assumption 3, it follows that $(1-\rho_e\widetilde{\widetilde{\beta}}) > 0$ and $\frac{\partial\widetilde{\kappa}}{\partial\nu} < 0$ under Assumption 1. This implies that:

$$\frac{\partial\widetilde{\lambda}}{\partial\nu} < 0 \tag{A112}$$

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

$$
\begin{aligned}
\frac{\partial \widetilde{\lambda}}{\partial \psi} &= (1 - \rho_e \widetilde{\widetilde{\beta}}) \frac{\partial \frac{\widetilde{\kappa}}{\widetilde{\widetilde{\kappa}}}}{\partial \psi} \\
&= (1 - \rho_e \widetilde{\widetilde{\beta}}) \frac{\widetilde{\widetilde{\kappa}} - \widetilde{\kappa}}{\widetilde{\kappa}^2} \frac{\partial \widetilde{\kappa}}{\partial \psi}
\end{aligned}
\tag{A113}
$$

For $0 < \rho_e < 1$, $\widetilde{\widetilde{\kappa}} > \widetilde{\kappa}$. Under Assumption 3, it follows that $(1 - \rho_e \widetilde{\widetilde{\beta}}) > 0$ and $\frac{\partial \widetilde{\kappa}}{\partial \psi} = -\vartheta \nu < 0$ in the financial accelerator economy. This implies that:

$$
\frac{\partial \widetilde{\lambda}}{\partial \psi} < 0 \tag{A114}
$$