The Financial Accelerator, Wages

and Optimal Simple Monetary Policy Rules

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The paper investigates welfare costs of monetary policy in form of implementable simple rules in a frictional financial intermediation framework with an endogenous financial accelerator. The results are twofold. First, inflation stabilization implies high welfare costs. This effect stems from a flat sloped price Phillips curve induced by financial frictions amplifying the rigidity of prices. Second, stabilizing nominal wage growth simultaneously closes the gap in output and reduces the volatility of the credit spread. The advantage of a nominal wage target is based on the absence of a trade-off between closing the output gap and stabilizing wage inflation. Central bank’s interest rate response is more pronounced due to a higher volatility of nominal wages. Combined with a relative rise in inflation the real risk free rate drops more, the credit spread is narrowed and henceforth the financial accelerating mechanism is mitigated.

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1. Introduction

The financial crisis in 2007 showed, that financial intermediation itself can be a source of endogenous risk and the cause of economic downturns. In the aftermath of the crisis a growing strand of literature on frictional financial intermediation was evolving. With the growing strand of literature focusing on financial frictions, the question arose how optimal monetary policy looks like in an environment of credit spreads.

Research conducted before the outbreak of the financial crisis neglected the importance of frictional financial intermediation for business cycle fluctuations. Consequently, early contributions that investigated the interaction of monetary policy and financial frictions abstracted from either endogenous financial amplification or from wedges between borrowing rate and the risk free rate. Under these early contributions is Carlstrom and Fuerst (2001), that studied monetary policy under agency costs and a borrowing in advance production sector. Ravenna and Walsh (2006) and Demirel (2009) analyzed optimal monetary policy in a model with agency costs giving rise to endogenous cost-push effects, causing a trade-off between stabilizing inflation, output gap and the risk premium. These endogenous cost-push behavior exists regardless of the type of shocks (Carlstrom et al. (2010)). Financial frictions introduce two channels relevant for monetary policy maker. One indirect cost channel by indirectly influencing the interest rate premium, that encourages inflation stabilization. The second channel given by the agency costs, makes output fluctuations more costly and increase the importance of stabilizing the output gap. Accordingly to Demirel (2009), which channel dominates depends on the model parameterization. In presence of agency costs, price stabilization remains nevertheless close to optimal even under severe financial frictions (Faia and Monacelli (2007), Carlstrom et al. (2010), Kolasa and Lombardo (2014)). Fiore and Tristani (2013) and Cúrdia and Woodford (2016) showed that even under financial frictions and shocks to financial aggregates price stability remains the main target for policy makers. Such a policy response would be in line with optimal monetary policy in a standard NK-DSGE
model and the target criterion would be not affected by credit frictions. However, as the authors admit, the optimal rule might change when allowing for more complex financial frictions e.g. a financial accelerator as in Bernanke et al. (1999). Most recent research that took endogenous capital and a financial accelerator into account found evidence that policy maker face a trade-off between financial stability and price stability (Collard et al. (2017), Hansen (2018)) and price stabilizing might be welfare costly.

The following questions remain open in the literature so far. First, whether in presence of credit spreads and the existence of a financial accelerator and sticky prices it is still close to optimal to completely stabilize price inflation. Second, how an imperfect labor market in that setting affects the transmission mechanism of monetary policy.

This paper will contribute to the existing literature by using an quantitative NK-DSGE model with financial frictions and an endogenous financial accelerator mechanism of the shelf and investigate the stabilizing effects monetary policy on the credit market and the real economy. I do so by computing the welfare implications of implementable simple monetary policy rules. The findings are twofold.

First, inflation stabilization imply high welfare costs. This is due to a flat slope of the price Phillips curve, that causes only small, sluggish movements in inflation compared to the drop in output after a negative shock. The price Phillips curve is affected by the countercyclical cost-push effects amplifying the rigidity of prices. A similar effect of financial frictions is also found in Christiano et al. (2015) and explains the small amount of disinflation after the Great Recession. An insight from the literature on nominal rigidities is that for a reasonable degree of real rigidities already small nominal frictions can induce large nominal rigidities (Ball and Romer (1990)). The existence of financial frictions and both nominal price rigidities amplify each other in a similar way. Furthermore, a trade-off between stabilizing inflation volatility and stabilizing credit spread volatility implies that a primarily focus on price stability comes with the cost of a stark financial amplifications of shocks and
thus high welfare costs.

Second, stabilizing nominal wage growth simultaneously closes the gap in output and reduces the volatility of the credit spread. The remarkable effect in this setting is the absence of a trade-off between closing the output gap and zero wage inflation. The advantage of stabilizing nominal wages stems from its higher volatility and henceforth from a stronger central bank’s interest rate response. Once nominal wages do not adjust firms’ nominal marginal costs relatively increase and inflation rises. A lower nominal policy rate together with relative higher inflation causes the real risk free rate to drop significantly, shrinking the spread in credit and mitigating the financial accelerator effect on output. By putting more emphasize on output gap stabilization, a similar beneficial effect can be obtained. However, the output gap is usually not observable for policy makers wherefore a focus on nominal wages is preferable. The positive correlation between output gap and credit spread in these kind of models is not surprising since the presence of a financial accelerator amplify the movements of output.

This paper is based on Gertler and Karadi (2011), a model with frictional financial intermediation. I extend the baseline model by introducing nominal wage rigidities into the model. The empirical evidence shows that nominal wages have some degree of stickiness (Rotemberg (1982)). Nominal wage rigidities will be included by staggered wage contracts based on a Calvo lottery as in Calvo (1983) following the modeling approach of Erceg et al. (2000).

The remainder of this paper is structured as follows. In section 2, I introduce the model structure, which is based on GK11 with changes to the labor market section. In section 3, I estimate the benchmark version of my model. In section 4, a measure for costs of welfare is introduced. I derive an optimal simple monetary policy rule and compare the welfare costs of a variety of policy rules. The transmission of a capital quality shock under optimal and non-optimal rules will be discussed. Last but not least I comment on the determinacy behavior of my model. In section 5, I will check the robustness of the coefficients of the derived optimal simple rule.
Finally, section 6 concludes.

2. Model

The model includes five different agents, a labor aggregator and a government sector. These are private households, intermediate goods-producing firms, final retailers, capital-producing firms and financial intermediaries. I shortly comment on the interaction between the different agents, before going into more detail in each subsection.

Monopolistic households supply differentiated labor to an aggregator, that combines the different labor types and sells the aggregate hours to perfectly competitive intermediate goods-producing firms. Workers receive an individual nominal wage as compensation. The intermediate firms combine labor and capital to produce intermediate goods. Capital input has to be bought from competitive capital producing firms. Intermediate goods-producing firms finance their capital demand by issuing claims to get loans from financial intermediaries. Households either buy private bonds from banks or government bonds. Financial frictions are introduced by an agency problem between households and banks. Bankers can divert a certain fraction of assets, transfer the revenue to their own households and shut down the bank. Borrowing is thus restricted and financial intermediaries face a balance sheet constraint. Intermediate goods are sold to monopolistic retailers, repacking the goods and sell them with a mark-up over competitive marginal costs to households. Prices of final goods are sticky. The government sector is modeled by a simple fiscal policy rule where government expenditures are financed by lump-sum taxes. The central bank provides conventional monetary policy following a Taylor rule. Later the interest rate rule will be modified to test welfare costs of a variety of policies.
2.1. Households

There exists a continuum of identical households of measure one. Each household is divided into two types of persons. A fraction \((1 - f)\) of each household are workers supplying differentiated labor hours of type \(l\) to non-financial firms under monopolistic competition. Workers receive a nominal wage which is then shared within their households. Another fraction \(f\) of each household are bankers, managing financial intermediaries. Financial intermediaries receive funds from households in the form of deposits and issue loans to finance non-financial firms’ capital demand. Financial firms are owned by households. Therefore, the profits bankers earn are transferred back to their own households in the end of each period. Consequently, all earnings of workers, revenues of bankers and returns on bonds are pooled within each household. The representative household can save income for future consumption by buying one-period risk-free bonds. Each single household supply a different type of labor to intermediate goods-producing firms. Within each household the type of labor hours is assumed to be the same. Hence, workers within each households are identical. The different households are indexed on the interval \(l \in [0, 1]\). Each household then supplies an amount of hours \(L_t(l)\) and sets the nominal wage \(W_t(l)\) in favor of its affiliated members. \(L_t(l)\) is the sum of all labor hours supplied by identical workers within this specific household. Different labor hours are not perfectly substitutable and therefore households have a degree of market power when setting their wages. Labor supply is chosen by an aggregator, as in Erceg et al. (2000). She combines differentiated labor and determines how much of each type is supplied. Aggregate employment can be written by the following Dixit-Stiglitz expression

\[
L_t = \left( \int_0^1 L_t(l) \frac{1}{\epsilon_w} dl \right)^{-\frac{1}{\epsilon_w - 1}},
\]

where \(\epsilon_w\) represents the elasticity of substitution between different kinds of labor. \(L_t(l)\) denotes the supplied labor of each type \(l\). Aggregate labor \(L_t\) equals the
aggregated firms’ labor demand. Aggregator’s demand for each type of labour $l$ which is given by the following constraint:

$$L_t(l) = \left( \frac{W_t(l)}{W_t} \right)^{-\epsilon_w} L_t.$$  

(2)

Thus, the demanded labor of each type depends on the ratio of household’s individual nominal wage $W_t(l)$ to the average wage index $W_t$ weighted by the elasticity $\epsilon_w$. The wage index

$$W_t = \left( \int_0^1 W_t(l)^{1-\epsilon_w} dl \right)^{\frac{1}{1-\epsilon_w}},$$

(3)

is defined as the average over all individual wage levels $W_t(l)$.

Given the labor market structure from above, households will maximize their utility given by equation (4) such that their budget constraint is fulfilled

$$\max_{\{C_t(l), B_{t+1}(l), W_t(l)\}} E_t \sum_{i=0}^{\infty} \beta^i \left[ \ln(C_{t+i}(l) - hC_{t+i-1}(l)) - \frac{\chi}{1 + \varphi} L_{t+i}^{1+\varphi}(l) \right].$$

(4)

The parameter $\beta \in (0, 1)$ is the household’s discount rate, $\chi > 0$ denotes disutility from working and the parameter $\varphi > 0$ is the inverse Frisch elasticity of labor supply, measuring the elasticity of working hours to wages given a certain level of wealth. The households’ budget constraint can be expressed in nominal terms, which becomes relevant when optimizing nominal wage setting.\(^1\)

$$P_t C_t(l) = W_t(l) L_t(l) + P_t \Pi_t^{Rev}(l) + P_t T_t(l) + R_t \Pi_t B_t(l)^n - B_{t+1}^n(l).$$

(5)

$W_t(l)$ is the nominal wage paid for labor hours of type $l$. The average price level in the economy is given by $P_t$. $\Pi_t^{Rev}(l)$ is the share of real profits households earn by owning financial intermediaries and non-financial firms net the start-up transfer households pay to newly founded banks. $T_t$ are lump-sum taxes in real terms paid.

\(^1\)The budget constrains in real terms as used in GK11 can easily be obtained by dividing equation (5) by the price level $P_t$. Note that real bonds are defined as $B_t(l) = B^n_t(l)P_{t-1}$ due to the timing notation.
to the government. Every period, households can buy one-period, risk-less nominal bonds $B^n_{t+1}(l)$ which will pay out the gross nominal interest rate $R_{t+1} \Pi_{t+1}$ in the next period where $\Pi_t = \frac{P_t}{P_{t-1}}$ being the gross inflation rate. The timing notation denotes the period in which purchased bonds are paying off.

### 2.1.1. Consumption and Bond-Holding Decision

By maximizing consumption I obtain the marginal utility

$$ \varrho_t = \frac{1}{C_t - hC_{t-1}} - h \beta E_t \left( \frac{1}{C_{t+1} - hC_t} \right). \quad (6) $$

Combining this equation (6) with the optimal bond-holding condition, yields the household’s Euler equation for consumption:

$$ \beta E_t \Lambda_{t,t+1} R_{t+1} = 1, \quad (7) $$

where $\Lambda_{t,t+1} = \frac{\varrho_{t+1}}{\varrho_t}$ is the marginal rate of substitution between current consumption and consumption in the next period. It is assumed that in each period some bankers quit with a constant probability $1 - \theta$ to ensure that bankers are not able to accumulate as many assets as it would require to make the balance sheet constraint not binding any more. Thus $\theta$ is the survival rate of a bankers.

### 2.1.2. Nominal Wage Setting

The second part of the households’ maximization problem is defined by their nominal wage decision. Staggered wage setting is introduced following Erceg et al. (2000) using a Calvo lottery. Each period, only a fraction $1 - \gamma_w$ can readjust their nominal wages. Households set nominal wages such that household’s utility (4) is maximized subject to household’s budget constraint (5) and labor demand (2). The optimal
wage fulfills the following first order condition

\[
E_t \sum_{i=0}^{\infty} \beta^i \gamma_w L_{t+i}(l) \varrho_{t+i} \left[ \frac{W_t^*}{P_{t+i}} - \frac{\epsilon_w}{\epsilon_w - 1} MRS_{t+i} \right] = 0, \tag{8}
\]

where \( \varrho_{t+i} \) is the marginal utility of consumption and \( MRS_{t+i} \) is the household’s marginal substitution between consumption and labor. The wage setter’s first order condition has to be expressed recursively. Following Schmitt-Grohé and Uribe (2005), I receive the following relationship between both terms:

\[
x_w^{1,t} = \varrho_w w_t \tilde{w}_t^{1-\epsilon_w} L_t + \beta \gamma_w E_t \left[ \left( \frac{1}{\Pi_W^{t+1}} \frac{\tilde{w}_t}{w_{t+1}} \right)^{1-\epsilon_w} x_w^{1,t+1} \right], \tag{10}
\]

with \( \tilde{w}_t = \frac{W_t^*}{W_t} \) denoting the newly set nominal wage \( W_t^* \) relative to the current wage index \( W_t \). \( w_t \) is the real wage. The wage inflation \( \Pi_W^{t} \) describes the change between last period nominal wage level \( W_{t-1} \) and the current wage index \( W_t \). The solution to the second element of (9) can be written as:

\[
x_w^{2,t} = \chi L_t^{1+\varphi} \tilde{w}_t^{-\epsilon_w(1+\varphi)} + \beta \gamma_w E_t \left[ \left( \frac{W_t^{t+1}}{w_{t+1}} \frac{\tilde{w}_t}{w_t} \right)^{\epsilon_w(1+\varphi)} x_w^{2,t+1} \right]. \tag{11}
\]

Finally wage inflation can be derived by using equation (3) and the law of large numbers:

\[
(\Pi_W^{t})^{1-\epsilon_w} = (1 - \gamma_w)(\Pi_W^{t+1})^{1-\epsilon_w} + \gamma_w \tag{12}
\]

where \( \Pi_W^{t} \) is the gross wage inflation level in the economy and \( \Pi_W^{t+1} \) is the wage inflation induced by newly set nominal wage contracts. This yields after some rear-
rangements the definition of real wages:

\[ w_t^{1-\epsilon_w} = (1 - \gamma_w) \left( w_t^* \right)^{1-\epsilon_w} + \gamma_w \left( w_{t-1} \Pi_t^{-1} \right)^{1-\epsilon_w}. \]  

(13)

The level of last period real wages in my model is affected by the gross price inflation rate \( \Pi_t \). The propagation of shocks and more specific the behaviour of real wages depend directly on the responses of both price inflation and nominal wage inflation. Finally, it remains to mention that the level of real wages ultimately depends on both price inflation and wage inflation in the following way

\[ w_t = \frac{\Pi^W_t}{\Pi_t} w_{t-1}. \]  

(14)

This is an identity which always has to hold.

2.2. Financial Intermediaries

Banks act as financial intermediaries, providing loans to firms for an interest and cover the loan supply by receiving deposits on which banks pay a deposit rate to the lender. The profit of banks is based on the expected difference between interest rates on loans they issue and the interest rate on deposits they receive. In an efficient market without frictions in the intermediation process, this interest rate spread should theoretically be close to zero. However, in times of financial distress, the spread on interest rates is expected to rise. This rise is triggered by an increase of expected future return on loans.

Bank \( j \) can buy assets \( S_{j,t} \), representing bankers’ claims on non-financial firms, financed by the net worth \( N_{j,t} \) a banker possesses and the deposits received from households \( B_{j,t} \). The balance sheet of financial intermediaries can be written as

\[ Q_t S_{j,t} = N_{j,t} + B_{j,t+1}. \]  

(15)
$Q_t$ denotes the relative price of the loans or assets. Deposits will pay the return $R_{t+1}$ in the next period, where $R_{kt+1}$ is the return banks obtain in the next period from claims on non-financial firms. Therefore, banker’s net worth follows a law of motion

$$N_{j,t+1} = (R_{k,t+1} - R_{t+1})Q_tS_{j,t} + R_{t+1}N_{j,t}$$  \hspace{1cm} (16)$$

Future net worth is given by current wealth times the risk-free interest and the risk premium $R_{kt+1} - R_{t+1}$. The premium can be regarded as the bank’s net return on assets. No financial intermediary would finance assets yielding negative earnings. Hence the following inequality for discounted return on assets has to hold

$$E_t^{\beta_i\Lambda_{t,t+1+i}}(R_{k,t+1+i} - R_{t+1+i}) \geq 0, \hspace{0.5cm} i \geq 0.$$  \hspace{1cm} (17)$$

Without financial frictions, equation (17) would hold with equality and expected discounted premium would be zero. With financial frictions, one obtains a positive premium, which means the return on capital is higher than the risk-free rate. Financial intermediaries maximize terminal expected wealth that a banker would receive after exiting

$$V_{jt} = \max E_t \sum_{i=1}^{\infty} (1 - \theta)^{\beta_i^i\Lambda_{t,t+1+i}}N_{j,t+1+i}$$

$$= \max E_t \sum_{i=1}^{\infty} (1 - \theta)^{\beta_i^i\Lambda_{t,t+1+i}}[(R_{k,t+1+i} - R_{t+1+i})Q_{t+i}S_{j,t+i} + R_{t+1+i}N_{j,t+i}],$$  \hspace{1cm} (18)$$

where $(1 - \theta)$ is the probability that a banker leaves the financial sector and $\theta$ is the probability that a banker can continue her work. In order to prevent, that bankers increase their amount of assets without limit, GK11 formulated an agency problem between households and bankers. Each period, a banker can divert a constant fraction $\lambda$ of assets $Q_tS_{j,t}$ and transfers them back to her own household. The corresponding financial intermediary managed by this banker goes bankrupt and
Households recover the fraction $1 - \lambda$ of the bank’s funds. Because of this reason, households will limit their lending to financial intermediaries in times of a crisis. They will lend as long as a bank’s expected terminal wealth is larger or equal the amount the banker would gain by diverting assets. Therefore this incentive constraint has to hold:

$$V_{j,t} \geq \lambda Q_t S_{j,t}. \quad (19)$$

Households would stop borrowing if this constraint is violated. Hence, banks are restricted in their capability to obtain deposits. Further I follow GK11 in assuming a linear value function:

$$V_{j,t} = \nu Q_t S_{j,t} + \eta N_{j,t}. \quad (20)$$

By maximizing the expression (18) with the binding incentive constraint (19) and summing up over all individual agents, one obtains the aggregate demand for assets

$$Q_t S_t = \phi_t N_t, \quad (21)$$

with $\phi_t = \frac{m}{\lambda - \nu_t}$ denoting the leverage ratio of banks. The recursive solution for the value function is given by the following terms

$$\nu_t = E_t[(1 - \theta)\beta \Lambda_{t,t+1}(R_{k,t+1} - R_{t+1}) + \beta \Lambda_{t,t+1}\theta x_{t,t+1}\nu_{t+1}] \quad (22)$$

$$\eta_t = E_t[(1 - \theta) + \beta \Lambda_{t,t+1}\theta z_{t,t+1}\eta_{t+1}] \quad (23)$$

where $z_{t,t+1}$ is the growth rate in wealth and $x_{t,t+1}$ is the growth rate in assets. Both are given by these two expression

$$z_{t,t+1} = \frac{N_{j,t+1}}{N_{j,t}} = (R_{k,t+1} - R_{t+1})\phi_t + R_{t+1} \quad (24)$$

$$x_{t,t+1} = \frac{Q_{t+1}S_{j,t+2}}{Q_t S_{j,t+1}} = \frac{\phi_{t+1} N_{j,t+1}}{\phi_t N_{j,t}} = \frac{\phi_{t+1}}{\phi_t} z_{t,t+1}. \quad (25)$$
Therefore, neither growth rate of assets $x_{t,t+1}$ nor growth rate of net worth $z_{t,t+1}$ depends on firm-specific factors. Aggregated net wealth is the sum of wealth of existing financial intermediaries and newly founded banks.

$$N_t = N_{et} + N_{nt}.$$  (26)

The aggregate net worth of existing banks follows the law of motion from equation (16). Dividing by $N_{t-1}$ and rewriting the expression, I obtain:

$$N_{et} = \theta[(R_{k,t} - R_t)\phi_{t-1} + R_t]N_{t-1}.$$  (27)

Each period, households obtain in total $(1 - \theta)Q_tS_{t-1}$ from dissolved financial intermediaries. A fraction $\omega/(1 - \theta)$ will be used to finance new bankers with some start-up payments. Net worth of new banks is thus given by

$$N_{nt} = \omega Q_tS_{t-1}.$$  (28)

The equations (21)-(28) describe the aggregate financial sector.

### 2.3. Intermediate Goods-Producing Firms

Perfectly competitive firms produces intermediate goods by using labor hours $L_t$, homogeneous capital $K_t$ and capital utilization $U_t$ as input factors. Production is specified by a Cobb-Douglas function

$$Y_t = A_t(U_t\xi_t K_t)^{\alpha}L_t^{1-\alpha}.$$  (29)

The level of technology is denoted as $A_t$ and follows an autoregressive process of order one. $\xi_t$ is the quality of capital and also follows an AR(1) process. A shock to capital quality occurs as an exogenous, economic depreciation of the capital stock. The produced intermediate goods are sold to final retailers for the relative price
Intermediate firms are paying the real wage $w_t$ for labor hours and acquire capital from capital producers. It takes one period until new capital becomes active. After production, at the end of each period intermediate firms can decide both either to sell depreciated capital to price $Q_t$ or acquire new capital $K_{t+1}$. New capital is financed by funds from financial intermediaries. Non financial firms issue claims $S_t$ with price $Q_t$ such that the value of capital $Q_tK_{t+1}$ equals the value of claims $Q_tS_t$.

$$Q_tK_{t+1} = Q_tS_t. \quad (30)$$

Here the timing notation of capital denotes the period in which capital is installed and becomes active. Firms optimize profits such that the production function is satisfied. The resulting first order conditions are defined in the following.

$$\left(1 - \alpha\right)\frac{Y_t}{L_t} = \frac{w_t}{P_{m,t}}. \quad (31)$$

Equation (31) describes the labor demand in the economy. Firms pay the aggregate nominal wage index and receive a nominal price $P_tP_{m,t}$, both are taken as given by firms. Therefore, firms will react to real wage stickiness by adjusting labor input and output due to equation (31).

The second equation is derived by the optimal choice of capital, given as

$$R_{kt+1} = \frac{\xi_{t+1}(P_{m,t+1}\alpha Y_{t+1}\xi_{t+1}K_{t+1} + Q_{t+1} - \delta_t)}{Q_t}. \quad (32)$$

This equation defines the return financial intermediaries earn by financing capital acquirement. The return depends on the future quality of capital $\xi_{t+1}$ and is uncertain.

Firms choose the level of utilization accordant to the following first order condition:

$$P_{m,t} = \xi_tK_{t-1}b_KU_{tK}U_t\frac{U_t}{\alpha Y_t}. \quad (33)$$
The depreciation rate in the economy is defined by a core depreciation rate $\delta_c$ plus the level of utilization of capital:

$$
\delta_t = \delta_c + \frac{b_K}{1 + c_K} (U_t^{1+c_K}).
$$

(34)

$c_K$ defines the elasticity of marginal depreciation with respect to capital utilization. The parameters $\delta_c$ and $b_K$ are specified such that in steady state the depreciation rate is equal to 0.025.

### 2.4. Capital Producing Firms

Competitive capital producers, owned by households, create new capital and repair depreciated capital bought from the intermediate goods-producers. Net investment $I_{nt}$ is defined as the difference between gross investment $I_t$ and depreciated capital $\delta t K_t$,

$$
I_{nt} = I_t - \delta t K_t.
$$

(35)

Firms maximize profits by choosing net investment $I_{nt}$,

$$
\max_{I_{nt}} \sum_{t=0}^{\infty} \beta^t \Lambda_{t,\tau} \left\{ (Q_{\tau} - 1)I_{nt} - f \left( \frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}} \right)(I_{nt} + I_{ss}) \right\}.
$$

(36)

The steady state value of gross investment is given by $I_{ss}$. $f(\cdot)$ denotes the functional form of investment adjustment costs. As described in GK11 the function shall fulfill $f(1) = f'(1) = 0$ and $f''(1) \geq 0$. Following CEE05 the specific function takes the form

$$
\frac{\eta_i}{2} \left( \frac{I_t - \delta t K_t + I_{ss}}{I_{nt-1} + I_{ss}} - 1 \right)^2,
$$

(37)

which fulfills all necessary properties. $\eta_i$ measures the inverse elasticity of net investments to changes in the price of capital $Q_t$. The first order condition defines the
price of capital as follows:

\[ Q_t = 1 + f_t(\cdot) + f'_t(\cdot) \frac{I_{nt} + I_{SS}}{I_{nt-1} + I_{SS}} - \beta E_t \left\{ \Lambda_{t,t+1} f'_{t+1}(\cdot) \left( \frac{I_{nt+1} + I_{SS}}{I_{nt} + I_{SS}} \right)^2 \right\}. \]  

(38)

2.5. Retail Firms

Retail firms combine the intermediate goods \( Y_{ft} \) and sell the final goods to consumers. Price setting for final goods is similar to the wage setting framework described before. Final output is given by the Dixit-Stiglitz aggregator:

\[ Y_t = \left( \int_0^1 Y_{ft}^{\frac{\epsilon-1}{\epsilon}} df \right)^{\frac{1}{\epsilon-1}}. \]  

(39)

The elasticity of substitution between two differentiated goods is expressed by the parameter \( \epsilon \). By consumers’ cost minimization of purchasing a certain consumption bundle \( C_t \) the aggregate price level is defined as:

\[ P_t = \left( \int_0^1 P_{ft}^{\frac{1}{1-\epsilon}} df \right)^{\frac{1}{1-\epsilon}}. \]  

(40)

The demand for goods of firm \( f \) can be written as the following demand constraint

\[ Y_{ft} = \left( \frac{P_{ft}}{P_t} \right)^{-\epsilon} Y_t. \]  

(41)

Again nominal price stickiness is introduced by a Calvo lottery. Every period a fraction \( \gamma \) of firms have to keep their prices constant. The other fraction of firms \( 1 - \gamma \) can adjust their prices. Firms that do not change prices will index their prices to lagged inflation. Retail firms are maximizing life time discounted expected profit according to the following optimization problem

\[ \max_{P_t^*} E_t \sum_{i=0}^\infty \gamma_i \beta^i \Lambda_{t,t+i} \left[ \frac{P_{t+i}}{P_t} \prod_{k=1}^i (1 + \pi_{t+k-1})^{\gamma_{t+k-1}} - P_{mt+i} \right] Y_{ft+i} \]  

(42)
such that the demand constraint \( Y_{ft} = \left( \frac{P^*}{P_f} \right)^{-\epsilon} Y_t \) is fulfilled. \( P^*_t \) is the newly set optimal price. Again the first order condition can be solved recursively.

Inflation occurs because a fraction \( 1 - \gamma \) of firms readjust their prices inducing \( \Pi^*_t \) inflation and the other fraction of firms \( \gamma \) keep their prices indexed to inflation.

### 2.6. Economy-wide Resource Constraint and Government Policy

The economy is modeled as a closed economy including capital and adjustment costs in investments. Gross domestic product \( Y_t \) consists of aggregate consumption \( C_t \), investments for new capital \( I_t \), the adjustment costs of investments and government expenditures \( G_t \).

\[
Y_t = C_t + I_t + f \left( \frac{I_{n,t} + I_{SS}}{I_{n,t-1} + I_{SS}} \right) (I_{n,t} - I_{SS}) + G_t
\]  

Government expenditures \( G_t \) are described by an AR(1) process. In equilibrium the Fisher equation for nominal interest rate \( i_t \) has to hold:

\[
i_t = E_t[R_{t+1} \Pi_{t+1}].
\]  

The central bank’s nominal interest rate rule is given by the following Taylor rule stabilizing price inflation, wage inflation and output gap.

\[
i_t = \left[ \bar{i} \Pi_t^{\kappa_{\pi}} (\Pi_t^W)^{\kappa_{\pi w}} (\ln(Y_t) - \ln(Y_t^*))^{\kappa_y} \left( \frac{x_{t}}{x_{ss}} \right)^{\kappa_x} \right] ^{1-\rho} i_{t-1}^{\rho} \epsilon_{m,t}
\]

\( \bar{i} \) is the steady state level of the nominal interest rate. The price inflation coefficient of the Taylor rule is defined as \( \kappa_{\pi} \) and the coefficient on wage inflation is given by \( \kappa_{\pi w} \). \( \kappa_y \) is the coefficient of stabilizing output gap. Interest rate smoothing is governed by parameter \( \rho \) and the response to credit growth is set by \( \kappa_x \).

Output gap is defined as the difference to level of output in absence of nominal frictions.
### Table 1: Targeted first moments

<table>
<thead>
<tr>
<th>Description</th>
<th>Moment</th>
<th>Model</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption to GDP ratio</td>
<td>$C$</td>
<td>0.5843</td>
<td>0.5745</td>
</tr>
<tr>
<td>Business investment to GDP ratio</td>
<td>$I$</td>
<td>0.2152</td>
<td>0.2250</td>
</tr>
<tr>
<td>Real wage to GDP ratio</td>
<td>$w$</td>
<td>0.5870</td>
<td>0.5490</td>
</tr>
<tr>
<td>Government Expenditure to GDP ratio</td>
<td>$G$</td>
<td>0.2005</td>
<td>0.2005</td>
</tr>
<tr>
<td>Steady state credit spread (annualized percentage points)</td>
<td>$400 \times (R_k - R)$</td>
<td>1.4107</td>
<td>1.4197</td>
</tr>
<tr>
<td>Real risk free rate (annualized percentage points)</td>
<td>$(R - 1) \times 400$</td>
<td>1.5460</td>
<td>1.5460</td>
</tr>
</tbody>
</table>

### Table 2: Preset and calibrated parameters by moments matching that affect the steady state of the model. The reported values of the calibrated non-financial parameters are used as prior means for the estimation procedure.

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preset Parameters (GK11 values)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital share</td>
<td>$\alpha$</td>
<td>0.33</td>
</tr>
<tr>
<td>Steady State depreciation rate</td>
<td>$\delta(U)$</td>
<td>0.025</td>
</tr>
<tr>
<td>Steady state utilization of capital</td>
<td>$U$</td>
<td>1</td>
</tr>
<tr>
<td>Calibrated Parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Households’ discount factor</td>
<td>$\beta$</td>
<td>0.9961</td>
</tr>
<tr>
<td>Government Expenditure to GDP</td>
<td>$g_{ss}$</td>
<td>0.2005</td>
</tr>
<tr>
<td>Intratemporal elasticity of substitution</td>
<td>$\epsilon$</td>
<td>6.453</td>
</tr>
<tr>
<td>Habits</td>
<td>$h$</td>
<td>0.8993</td>
</tr>
<tr>
<td>Share of divertable assets</td>
<td>$\lambda$</td>
<td>0.4327</td>
</tr>
<tr>
<td>Share assets transferred to new banks</td>
<td>$\omega$</td>
<td>0.01004</td>
</tr>
<tr>
<td>Survival Rate of Banks</td>
<td>$\theta$</td>
<td>0.9556</td>
</tr>
<tr>
<td>Intratemporal labor elasticity</td>
<td>$\epsilon_w$</td>
<td>5.992</td>
</tr>
<tr>
<td>Inverse Frisch labor elasticity</td>
<td>$\varphi$</td>
<td>3.993</td>
</tr>
</tbody>
</table>

### 3. Estimation

In the model one period corresponds to one quarter of a year. The model is estimated using quarterly macroeconomic and financial time series for the Euro-Area between 1992Q1 and 2016Q4. A similar version of the GK11 model was already estimated by Villa (2016), however without financial data and with financial parameters match ad-hoc targets. Since my focus in this paper is to investigate the empirical relevance of financial frictions on the optimal simple rules during times of financial distress I chose

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2 As observables I chose the growth rates of real GDP per capita, real consumption per capita, real business investment per capita, real wage per capita, real bank’s net worth per capita and loans to non-financial firms. Further inflation and the 3-month Euribor as nominal time series. All the series are linear detrended. The non-financial series and the data on inflation and short term interest rate are taken from the Area Wide Model Database (Fagan et al. (2001)). The financial series are taken from the ECB Statistical Data Warehouse (SDW).
to estimate the model with financial series and calibrate the financial parameters.\(^3\)

The estimation of the model parameters is done in two steps. First, I split the set of parameters into two groups, the parameters that affect the deterministic steady state \(\Theta_{SS}\) and the parameters that does not affect the deterministic steady state \(\Theta_{NSS}\).

The financial parameters \(\Theta_{SS,FF}\) and non-financial parameters \(\Theta_{SS,NFF}\) that affect the deterministic steady state are calibrated by minimizing a loss function with equal weights on the distance of first moments. Within the latter group, two parameters have a direct data equivalent. The share of government expenditure \(g_{ss}\) and the discount factor of households \(\beta\) are thus directly set to their corresponding empiric value. In the second step the remaining parameters \(\Theta_{NSS}\) together with the non-financial parameters \(\Theta_{SS,NFF}\) are estimated with Bayesian estimation methods. The calibrated values from step one serve as prior means. The set of financial parameters \(\Theta_{SS,FF}\) remain at their calibrated value and are not estimated.

The moments I try to match are summarized in table 1. The values of the calibrated parameters are reported in table 2. The credit spread can be matched by varying the three financial parameters. The probability that a banker will not exit the financial intermediary is given by \(\theta = 0.9556\). Thus each period with a probability of 4.44% a bank will shut down and transfer the fraction \((1 - \theta)Q_tS_{t-1}\) of intermediated assets back to the households. This revenue is then used by households to give a start-up fund, represented by the fraction \(\frac{\omega}{1 - \theta}\), to newly entering banks. With \(\omega = 0.01\) I obtain the result that 22.64% of assets of exiting bankers will be used to finance new financial intermediaries. Given the value of \(\lambda\), banks can divert up to 43% of their funds. For the Bayesian estimation

The elasticity of substitution between different kinds of goods and the elasticity of substitution between types of labor are around a value of 6. The inverse Frisch labor elasticity is relative high and so are habits. The values of the non-financial parameters are used in the next step as prior means for the Bayesian estimation.

\(^3\)Further, the coefficients of a capital quality shock are not estimated in Villa (2016).
The financial parameters are not estimated and remain at their calibrated values. I preset the capital share, the steady state depreciation rate and the steady state value of utilization to standard values from the literature that are also used in GK11.

**Shocks and Measurement Errors**

The model economy is driven by seven shocks. These are a transitory productivity shock $\epsilon_A$, a price markup shock $\epsilon_{mark_p}$, a wage markup shock $\epsilon_{mark_w}$, a capital quality shock $\epsilon_{ksi}$, a shock to bankers’ wealth $\epsilon_w$, a shock to the credit spread $\epsilon_{prem}$ and a monetary policy shock $\epsilon_m$. Furthermore, I introduce a measurement error on the equity series.

**Estimates**

Table 3 summarizes the resulting estimated parameters. I chose relative agnostic priors for most of the parameters. The wage Calvo parameters is in line with Euro-area estimates as in Christiano et al. (2014) and Villa (2016). The lifetime of nominal wage contracts are about 4 quarters. The probability of resetting price contracts $\gamma_p$ is relative low compared to similar estimates from the literature. Each two and a half quarters firms reset their prices. The relative high coefficient on price indexation with 0.54 might be an explanation why prices are not that sticky. The posterior mean of habit formation is way below its assumed prior mean. The inverse Frisch labor elasticity is in line with estimates from the literature (Negro et al. (2007)). The estimated coefficients of the Taylor rule provide a more than one-to-one response to both nominal wage growth and price inflation and high coefficient on interest rate smoothing. The data suggest a mild response to growth rate of assets.

4. Monetary Policy

In a classical new-Keynesian DSGE models with both sticky wages and sticky prices but without financial frictions, the monetary policy maker faces a trade-off between
### Table 3: Baseline Model, Estimated Parameters

<table>
<thead>
<tr>
<th>parameters</th>
<th>prior mean</th>
<th>post. mean</th>
<th>90% HPD interval</th>
<th>prior</th>
<th>prior std. dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\epsilon$</td>
<td>6.453</td>
<td>4.9708</td>
<td>3.5982</td>
<td>6.4118</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\eta_i$</td>
<td>1.3</td>
<td>1.3012</td>
<td>1.0894</td>
<td>1.5281</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\epsilon_w$</td>
<td>5.992</td>
<td>5.7329</td>
<td>4.2748</td>
<td>7.3948</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\varphi$</td>
<td>3.993</td>
<td>2.0531</td>
<td>1.2438</td>
<td>2.7912</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\kappa_x$</td>
<td>1.5</td>
<td>1.7654</td>
<td>1.5256</td>
<td>1.9878</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\kappa_{w}$</td>
<td>1.5</td>
<td>1.2019</td>
<td>1.0132</td>
<td>1.3828</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\kappa_y$</td>
<td>0.125</td>
<td>0.6367</td>
<td>0.5673</td>
<td>0.7056</td>
<td>Beta</td>
</tr>
<tr>
<td>$\kappa_z$</td>
<td>0.3</td>
<td>0.1088</td>
<td>0.0535</td>
<td>0.1634</td>
<td>Beta</td>
</tr>
<tr>
<td>$h$</td>
<td>0.899</td>
<td>0.4258</td>
<td>0.3942</td>
<td>0.4593</td>
<td>Beta</td>
</tr>
<tr>
<td>$\gamma_p$</td>
<td>0.5</td>
<td>0.5659</td>
<td>0.4889</td>
<td>0.6396</td>
<td>Beta</td>
</tr>
<tr>
<td>$\gamma_w$</td>
<td>0.5</td>
<td>0.7629</td>
<td>0.7108</td>
<td>0.8177</td>
<td>Beta</td>
</tr>
<tr>
<td>$\gamma_{Ind}$</td>
<td>0.5</td>
<td>0.5436</td>
<td>0.2734</td>
<td>0.8252</td>
<td>Beta</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.5</td>
<td>0.8189</td>
<td>0.7783</td>
<td>0.8604</td>
<td>Beta</td>
</tr>
<tr>
<td>$\rho_a$</td>
<td>0.5</td>
<td>0.7976</td>
<td>0.7239</td>
<td>0.8704</td>
<td>Beta</td>
</tr>
<tr>
<td>$\rho_{ksi}$</td>
<td>0.5</td>
<td>0.0601</td>
<td>0.0094</td>
<td>0.1097</td>
<td>Beta</td>
</tr>
<tr>
<td>$\rho_w$</td>
<td>0.5</td>
<td>0.5295</td>
<td>0.3937</td>
<td>0.705</td>
<td>Beta</td>
</tr>
<tr>
<td>$\rho_{mark_p}$</td>
<td>0.5</td>
<td>0.9261</td>
<td>0.8937</td>
<td>0.9585</td>
<td>Beta</td>
</tr>
<tr>
<td>$\rho_{mark_w}$</td>
<td>0.5</td>
<td>0.3917</td>
<td>0.1843</td>
<td>0.5521</td>
<td>Beta</td>
</tr>
<tr>
<td>$\rho_{prem}$</td>
<td>0.5</td>
<td>0.491</td>
<td>0.1823</td>
<td>0.7852</td>
<td>Beta</td>
</tr>
<tr>
<td>$\sigma_A$</td>
<td>0.001</td>
<td>0.0049</td>
<td>0.004</td>
<td>0.0058</td>
<td>Inv. Gamma</td>
</tr>
<tr>
<td>$\sigma_{ksi}$</td>
<td>0.001</td>
<td>0.0074</td>
<td>0.0065</td>
<td>0.0082</td>
<td>Inv. Gamma</td>
</tr>
<tr>
<td>$\sigma_{mark_p}$</td>
<td>0.001</td>
<td>0.0061</td>
<td>0.0048</td>
<td>0.0074</td>
<td>Inv. Gamma</td>
</tr>
<tr>
<td>$\sigma_{mark_w}$</td>
<td>0.001</td>
<td>0.1797</td>
<td>0.125</td>
<td>0.2388</td>
<td>Inv. Gamma</td>
</tr>
<tr>
<td>$\sigma_m$</td>
<td>0.001</td>
<td>0.0017</td>
<td>0.0014</td>
<td>0.002</td>
<td>Inv. Gamma</td>
</tr>
<tr>
<td>$\sigma_w$</td>
<td>0.001</td>
<td>0.028</td>
<td>0.0218</td>
<td>0.0333</td>
<td>Inv. Gamma</td>
</tr>
<tr>
<td>$\sigma_{Prem}$</td>
<td>0.001</td>
<td>0.0009</td>
<td>0.0002</td>
<td>0.0015</td>
<td>Inv. Gamma</td>
</tr>
<tr>
<td>$ME_{N,obs}$</td>
<td>0.001</td>
<td>0.1148</td>
<td>0.1021</td>
<td>0.1273</td>
<td>Inv. Gamma</td>
</tr>
</tbody>
</table>

stabilizing inflation, wage inflation and output gap. (Erceg et al. (2000)). This effect is caused by real wages that do not sufficiently adjust to their efficient level. What Blanchard and Galí (2007) called divine coincidence does not hold anymore. Neither does wage inflation stabilizing simultaneously closes the output gap nor does inflation targeting stabilize the output gap or wage inflation.

Erceg et al. (2000) were able to show that in case of additional nominal wage rigidities, strict price inflation targeting is costly in welfare terms and is far off from being an optimal policy instrument. Instead a hybrid rule stabilizing either wage inflation

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4The simultaneous stabilization of both price inflation and output gap by just targeting of one of them.
and price inflation or output gap and price inflation were close to optimal.

In the following I introduce a welfare measure for the model economy and compare a variety of policy rules with the derived optimal simple rule. I answer the questions whether it remains optimal for policy makers to stabilize price inflation in presence of a financial accelerator. I demonstrate that output gap and nominal wage inflation can simultaneously be stabilized without a trade-off caused by its effect on decreasing the credit spread and thus by mitigating the financial accelerator effects. The shrinkage of the credit spread relies on the degree of inflation volatility. It will be shown that inflation stabilization implies significant welfare costs. Hybrid rules of wage inflation and output gap targeting are proven to be the least welfare costly policy that come closest to the optimal simple rule.

**Optimal Simple Rule**

The objective function for the policy maker is given by the lifetime utility of households

$$W_t = E_t \sum_{i=0}^{\infty} \beta^i \left[ \ln(C_{t+i} - hC_{t+i-1}) - \frac{\chi}{1 + \varphi} L_{t+i}^{1+\varphi} \right].$$

All monetary policies I consider yield the same first-order welfare effects for lifetime utility $V_t$. This is due to identical steady states under the considered policies.

For the welfare measurement of monetary policy I thus take second-order welfare effects into account. I measure the relative welfare costs of implementing a certain policy by evaluating the conditional expected lifetime utility at period zero, following Schmitt-Grohé and Uribe (2007). For all policies my economy starts at the same deterministic steady state. The welfare comparison accounts for the transition from the identical deterministic steady state to the policy specific stochastic steady state.

Let us define the conditional expected lifetime utility of policy $a$ which will be our
Table 4: Coefficients of optimal simple rules under different model scenarios.

| Model Scenario                        | $\kappa_x$ | $\kappa_{yx}$ | $\kappa_y$ | $\kappa_x$ | $\rho$ | Welfare  
|---------------------------------------|------------|----------------|------------|------------|--------|----------
| Financial Frictions (FF-NK)           |            |                |            |            |        |          
| Sticky Prices                         | 2.1299     | 24.0418        | 10.6280    | 0.0387     | 0.0957 | -206.0295
| Sticky Prices + Sticky Wages          | 1.0983     | 49.8931        | 2.0071     | 0.0006     | 0.0012 | -206.0109
| No Financial Frictions (NK)           |            |                |            |            |        |          
| Sticky Prices                         | 13.8466    | 0.0043         | 0.0047     | -0.9858    | 203.8991|
| Sticky Prices + Sticky Wages          | 49.9985    | 0.0019         | 8.7883     | -0.0001    | 203.8674|

One can now measure the welfare costs of policy b’s implementation by the fraction of regime a’s consumption a household gives up to be equally good off. Regime b’s conditional welfare thus can be expressed in term of the contingent plans for consumption and labor hours under the reference policy

$$\mathcal{W}_0^b = E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^b, L_t^b)$$

and lifetime utility for a second policy b by

$$\mathcal{W}_0^a = E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^a, L_t^a)$$

where $\lambda_{wc}$ denotes the welfare costs of adopting policy b instead of policy a.

Using the definition of the utility function and rearranging the expression above provides us with a relative measure for welfare costs in percentage points:

$$\lambda_{wc} \times 100 = (1 - \exp((\mathcal{W}_0^b - \mathcal{W}_0^a) (1 - \beta))) \times 100 \quad (46)$$

The coefficients of the optimal simple rules were found by running a constraint optimization routine on the parameter space of policy parameters. The parameter vector that yields the highest conditional welfare is the one I denote as optimal simple rule. The search was constraint by a lower bound of zero for all parameters,
except for inflation with a lower bound of one.\textsuperscript{5} Values for the weights on price inflation, wage inflation, output gap and credit growth were constrained by an upper bound of 50.\textsuperscript{6} For the interest rate indexation parameter the search was bounded between zero and one. Besides the benchmark version of the FF-NK model with both sticky wages and sticky prices, I additionally computed also the optimal values for the cases of nominal price rigidities only. Further, the optimal policy rules for a NK-DSGE model with endogenous capital accumulation but without financial frictions are reported for comparison. The results are summarized in table 4. The optimal rule in the FF-NK benchmark case gives only high weight on wage inflation and no weight on output gaps stabilization or price inflation.\textsuperscript{7} The optimal rule under the presence of financial frictions does not put any weight on interest rate smoothing. This result is robust to the case of deactivating one of the nominal rigidities. Surprisingly the best policy under sticky prices is also achieved by neglecting inflation and by focusing on nominal wage inflation and output gap instead. This effect will be discussed in detail in the subsequent section. It is a result of the interaction of nominal price frictions and financial frictions. Financial frictions introduce a countercyclical endogenous mark-up reducing the slope of the inflation Phillips curve. A trade-off between credit spread stabilization and price inflation stabilization exists. The more stable inflation the higher is the credit spread in absolute terms. Due to the accelerating effect of the spread inflation stabilization is quite costly in output terms. In comparison, the simple rules for the NK-model without financial frictions regards smoothing of the policy rate as optimal together with a strong weight on price inflation targeting. My results on optimal monetary policy in a model with endogenous

\textsuperscript{5}For several policy parameters the lower bound is hit. I did not allow for negative responses to inflation, wage inflation and output gap since central banks would have problems to communicate the plausibility of such policies. To ensure determinacy the parameter on inflation can not become smaller than one.

\textsuperscript{6}The high values of the upper bound ensure that the found solution is an interior solution.

\textsuperscript{7}The coefficients for wage inflation hit the upper bound. The optimal response would be to put an arbitrarily large weight on nominal wage inflation.
\[ \gamma_p = 0.75, \quad \gamma_w = 0.75, \quad \gamma_p = 0.75. \]

Table 5: Welfare costs of an one standard deviation capital quality shock for a selection of Taylor rules. The costs of welfare are expressed in consumption equivalents relative to the outcome of the optimal simple rule. In the specification presented in the first column sticky prices are absent, in the second column sticky wages are not present. The third column’s results are based on the specification with both sticky wages and sticky prices.

The welfare costs for a variety of simple policy rules are reported in table 5. The costs of adopting a policy are denoted in consumption equivalents relative to the optimal simple rules. In the presence of financial frictions inflation targeting becomes costly in welfare terms. Under a conventional inflation targeting rule with \( \kappa_\pi = 1.5 \), households have to be compensated by slightly more than 0.42% to be as good off as under the optimal rule regime. By combining the inflation targeting rule with smoothing or with a response to credit growth, the costs can be reduced, but this rule is still relative welfare costly. A central bank targeting solely wage inflation comes remarkable close to the optimal rule. Increasing the weight on inflation can not compete in welfare terms with even the simplest wage inflation rule. As one can see under the strict stabilization regimes (last 3 rows) the output gap rule yield similar results for welfare as the wage inflation rule.
The beneficial effects of wage inflation targeting is not a special case caused by sticky wages. The results also hold without assuming sticky wages.

**Policy Frontier**

A monetary policy focusing solely on an inflation target yields high welfare costs, whereas simple rules putting more weight on nominal wage dynamics or output gap perform remarkable well. In this section I will elaborate the mechanism behind the results presented in the previous tables.

Monetary policy makers usually face trade-off between stabilizing the volatility of welfare relevant variables. Under conventional monetary policy, there is only one instrument available, the nominal interest rate, but more than one welfare relevant aggregates.

In order to visualize the underlying trade-offs figure 1 plots the policy frontiers for three different policy regimes in the benchmark model with the Taylor rule (45). For these three policies, I allow the central bank to minimize either a quadratic loss function of a weighted average of a) inflation and wage inflation (blue circles), b) inflation and output gap (red crosses) and c) output gap and wage inflation (yellow stars). The frontiers are obtained by varying the weight $W$ on variable one and the weight $1-W$ on variable two in these quadratic loss functions, with $W \in [0, 1]$.

As shown in the very first graph in the first panel, the standard result (Erceg et al. (2000)) of a trade-off between inflation and wage inflation holds in the model. The lower the volatility of inflation the more volatile are nominal wages. This relation holds under all tested quadratic loss functions. The graph below, in the second panel of the first column, provides an explanation why inflation targeting involves high welfare costs. It depicts a trade-off central banks face between inflation volatility and the credit spread volatility. The more stable prices are, the more pronounced is the financial accelerator mechanism. All policies that allow for a certain volatility
inflation can shrink the credit spread. For nominal wages this relation reverses
as shown in the second graph in the second panel. Both nominal wages and the
spread in credit can be stabilized without a trade-off. Hence, stable nominal wages
cushion the effects of the financial accelerator and stabilizes henceforth output. This
explains finally the results depicted in the last graph in column two, panel one: the
missing trade-off between closing the output gap and zero wage inflation.

Two results are key from this subsection. First, policies allowing for some degree of
inflation volatility stabilize the financial sector more than a fully inflation targeting
regime. Second, given inflation is not stabilized, the volatility of credit spread,
nominal wages and the output gap can all simultaneously be significantly reduced
by focusing on one of the three aggregates. Out of these the focus on nominal wages
might be the easiest target for a central bank. The following subsection explains
in more detail the transmission of the shock and the reasoning behind the result
depicted in the policy frontiers.

**Transmission Mechanism**

Figure 2 compares the simulations of the economy to a one percent capital quality
shock under four different policy scenarios. First, the optimal simple rule with high
weight on wage inflation. Second, a simple rule with inflation, output gap stabiliza-
tion and smoothing as defined in Gertler and Karadi (2011) (labeled benchmark).
Third the outcome of a simple price inflation targeting rule with $\kappa_\pi = 1.5$ and
smoothing and fourth a Taylor rule with wage inflation targeting, $\kappa_{\pi_w} = 1.5$.
A drop in capital quality of one percent is comparable to an initial exogenous de-
struction of the economy-wide effective capital stock by the same magnitude. I will
shortly comment on the mechanism of the endogenous financial accelerator effect in
this kind of models.
Assuming a e.g. non-financial shock negative shock, output will fall and so does

8Easiest in terms of an observable target.
the demand for capital. The price of assets is reduced by the decline in investment following the contraction, depressing the asset side of bankers’ balance sheet. The effect is a reduction in net worth of banks and the existence of financial frictions thus imply a rise in the credit spread, the need of deleveraging and a significant drop in credit. A rise in the spread, puts even more downward pressure on the demand for capital and hence on the price of assets.

[Figure 2 about here]

The interaction of both nominal rigidities causes real wages to be extremely sluggish, putting more downward pressure on output, labor demand and capital demand. The deeper recession under sticky wages in terms of output will additionally decrease the demand for capital resulting in a lower price for capital and a more constrained financial sector. Therefore sluggish real wages amplify the effects of the financial accelerator via the demand for capital.

The performance of the economy can significantly be improved under the optimal rule compared to the calibrated benchmark scenario. The initial response of output falls about 50 % less. Wage inflation is close to zero under the optimal policy and the policy maker nearly closes the output gap by solely stabilizing wage inflation. When nominal wages do not fall, real wages adjust by a rise in price inflation. Instead of deflation, now prices rise in response to the negative shock. In case of lowering the policy rate households save less and consume more. Households’ labor supply increases. Whereas firms’ marginal costs are relative high due to relatively high lending rates. The wedge between capital lending rate and risk free rate prevents a one-to-one transmission of monetary policy to firm’s price setting. A high lending rate will depress capital demand and output and by the effects of general equilibrium also the demand for labor hours. To clear the labor market real wages have to fall as a consequence. Hence nominal wages would have to fall or inflation has to
rise. However as a response to nominal wage deflation fully wage stabilizing central banks would lower their policy rate even further. The equilibrium outcome of wage stabilization therefore would be, that after a capital quality shock firms increase their prices\(^9\), inflation rises and does not fall to clear the labor market.

By stabilizing wages two main frictions of the model are eased. First, the sticky wages which do not cause any welfare losses when nominal wages are constant. Second, the adjustment of prices is not disturbed by the effects of financial frictions. An efficient level of prices is only prevented by the degree of nominal price rigidities.

For the second effect the frictional transmission between policy rate and lending rate is crucial for understanding. Both the financial frictions and the sticky prices prevent efficient levels of inflation. They amplify each other in a similar fashion as in Ball and Romer (1990) real rigidities can amplify small nominal frictions causing large nominal rigidities.

The lower real interest rate also has a second effect, it relaxes the banks’ balance sheet constraints. The expected return on capital \(E_t[R_{k,t+1}]\) declines and so does the credit spread. This dampening effect on the financial accelerator will help to stabilize output.

The financial accelerator causes an enormous amplification of the shock to capital quality compared to standard DSGE models without financial frictions. Thus every monetary policy rule that is able to reduce the rise in the spread of interest rates (and thus the financial accelerator) is desirable and brings the economy very close to its efficient level. The justification for this statement is similar to the case Gertler and Karadi (2013) made for the QE1 program.

**Determinacy**

In this section I comment shortly on the set of policy parameters under which the model is determinant. The price level in new-Keynesian DSGE models is determined by the Taylor rule giving rise to a unique equilibrium. As long as the central bank

\(^9\)Real marginal costs of firms are high in case nominal wages do not adjust. Firms account for the resulting higher real wage by increasing prices.
reacts more than one-to-one to rises in inflation the model equilibrium is determined (Cochrane (2011)). The effectiveness of monetary policy and thus determinacy crucially depends on the transmission channel of policy rate to price setting behavior of firms. As long as the borrowing rate of firms is equal to the risk free rate set by policy makers, this transmission is undisturbed.

[Figure 3 about here]

As shown in figure 3 the introduction of financial frictions affects the effectiveness of monetary policy. Lowering/Rising the policy rate does not one-to-one transmit to a lowering/rise of the borrowing rate. As a consequence firms will increase/decrease their prices less than under a frictionless financial market. Thus the inflation rate will be less affected by monetary policy. By increasing the degree of financial frictions policy makers are required to put a higher weight on price inflation stabilization to ensure a unique equilibrium as shown graph (a) of figure 3.

Figure 3 shows that under the the benchmark value from the calibration of $\lambda = 0.381$, prices are undetermined for $\kappa_{\pi} = 1.25$ and below, given all other policy parameters are set to zero. In case of further increasing the degree of financial frictions the region of indeterminacy covers also values up to 1.75. In times of high financial distress it might be not completely unlikely that up to 50% of banks in a country default. The plots suggest that Taylor rules stabilizing price inflation with conventional parametrization in times of severe financial crisis might switch from being an active rule to being passive.

Nevertheless the determinacy behavior of the model does not change for wage inflation coefficients under different degrees of financial frictions as shown in sub-figure (b). The reason for this is that nominal wages are set by households. A change in the policy rate transmit one-to-one to households’ expected return of bonds. As pointed out previously lowering the policy rate to fully stabilize falling nominal wages in case of a negative shock has two effects. First, aggregate demand goes up and so does total output. Second, inflation increases to account for the drop in real wages and
to clear the labor market.

The frictionless transmission of policy rate to bond return rate explains why the determinacy properties of stabilizing wage inflation is not affected by the degree of financial frictions. The optimality of wage stabilization might change in case of some different type of financial frictions imposing a spread between household’s deposit rate and risk free rate.

5. Robustness Checks

In this section I check how robust the results from table 4 are to changes in the value of the Taylor rule coefficients. For this scenario I vary the value of one single parameter of the policy equation and keep the remaining parameters set to their corresponding optimal values. For each parameter of the Taylor rule the welfare costs of deviating from the optimal coefficients of the simple rule are reported in figure 4, figure 5 and figure 6. The robustness checks are conducted for the NK-FF model with both nominal wage and nominal price rigidities and for the scenario of only sticky prices.

[Figure 4 about here]

Figure confirms the previous result that high weight on wage inflation goes hand in hand with small losses in welfare. In the model version with both sticky prices and sticky wages the optimal outcome is reached at the upper bound of $\kappa_{\pi_{\text{w}}}$ of five. Welfare is quite sensitive to changes in the weight on price inflation. Deviating from the optimal weight on price inflation by increasing the weight, steadily increases the costs of welfare. Minimizing the volatility of nominal wages does also close the output gap. Thus there is no welfare gain by imposing a non-zero weight on output gap when the central bank already fully stabilize wage inflation.

In case nominal wages are flexible but nominal prices are inflexible a similar picture
emerges. Deviating from the optimal weight on wage inflation targeting towards smaller values increases the welfare costs to a large proportion. Higher values for $\kappa_{\pi_w}$ than the optimal one around 1.5 increase the costs of welfare only slightly. A measure for output gap should not be targeted under the optimal rule. Deviations from the optimal output gap weight are more costly than deviations from the optimal coefficient on inflation.

Overall the welfare costs of deviating from the optimal values of the simple rules are way smaller in case nominal wages are flexible.

[Figure 5 about here]

Figure 5 confirms that no weight should be put on interest rate smoothing for an optimal simple rule. The costs of deviating from the optimal coefficient however are relative small. The lower the sensitivity to deviations from their optimal value the less the importance of the coefficient for welfare gains/losses. The insignificance of interest rate indexation is the opposite of the case for optimal monetary policy in the NK model without financial frictions. The insignificance of indexation to lagged policy rate values stems from the effect that an initial sharp drop in the risk free rate in period one cushion significantly the increase of the risk premium. The policy maker can relax the bankers’ constraint by effecting the balance sheet via the deposit rate and mitigate the rise of the expected return on capital.

[Figure 6 about here]

Last but not least figure 6 suggests that a slightly positive coefficient on loan growth can yield reasonable gains in welfare. Stabilizing the growth rate of loans by more than one-to-one however increases the welfare costs nearly up to one percent even when all other policy parameters are set to their respective optimal values.
6. Conclusion

This paper demonstrates that a monetary policy stabilizing inflation in a setting with financial frictions can imply severe welfare costs. This effect is primarily driven by the existence of a trade-off between stabilizing inflation and stabilizing the spread between rental rate and risk free rate. A widening of the credit spread has a large amplification effect on output fluctuations and the opening of the output gap. The flatly sloped price Phillips curve on the other hand side, that occur by the interaction of financial frictions and nominal frictions, make price stability more difficult to obtain in general. Periods of deflation in recession, and periods of inflation in boom periods are long and persistent, causing a inefficiently high/low real risk free rate and a wide credit spread. As an alternative this paper suggests central banks might want to focus more on nominal wage growth. The absence of a trade-off between closing the output gap and stabilizing nominal wages on the one hand side, and on the other hand side also being able to shrink the wedge between rental rate and risk free rate, makes such a policy extremely desirable. Nominal wage growth in contrast to output gap has the advantage that it is (easier) observable. I demonstrated that during a recession the policy rate is cut more harsher under such a policy due to the higher volatility of the target variable and inflation rises relatively. Both effects combined yield a significant drop in the real risk free rate, finally reducing the credit spread and mitigating the financial accelerator mechanism.

This model does not account for frictions between banks and households. It remains to show whether the reported findings also hold when a spread between risk free policy rate and households’ deposit rate emerges.
References


Carlstrom, Charles T., Timothy S. Fuerst, and Matthias Paustian (2010). “Optimal Monetary Policy in a Model with Agency Costs”. In: Journal of Money, Credit and Banking 42.s1, pp. 37–70.


A. Appendix
Figure 1: Policy frontiers for optimal simple rules minimizing a quadratic loss functions. Under the policy 1 (blue circles) the central bank’s objective is to stabilize a weighted average of inflation and wage inflation. The weight on both targets, inflation $\varsigma$ and wage inflation $1 - \varsigma$, lies in the interval $[0, 1]$. Policy 2 (red crosses) stabilizes a weighted average of inflation and output gap and policy 3 (yellow stars) stabilizes a weighted average of wage inflation and output gap.
Figure 2: Impulse responses to an one percent capital quality shock. The coefficients of the optimal rule are given by $\kappa_{\pi} = 0.0047$, $\kappa_{\pi w} = 0.906$, $\kappa_y = 0.0075$ and $\rho = 0.0116$. 

\[ \kappa_{\pi y} = 4.906, \quad \kappa_y = 0.0075 \quad \text{and} \quad \rho = 0.0116. \]
Figure 3: Determinacy region of price inflation and wage inflation coefficients for different degrees of financial frictions. The $\lambda$ parameter denotes the fraction of bankers diverting assets. Dark colored regions define the parameter sets for which the Blanchard Kahn condition is violated.
Figure 4: Welfare costs of deviating from optimal parameter values for weight on wage inflation, weight on price inflation and weight on output gap relative to the optimal simple rule.
Figure 5: Welfare costs of deviating from optimal parameter value for interest rate smoothing relative to the optimal simple rule.

(a) prices and sticky wages
(b) sticky prices only
Figure 6: Welfare costs of deviating from optimal parameter value for weight on asset growth relative to the optimal simple rule.
\[ \begin{array}{ccccc}
\hline
\text{Financial Frictions (FF-NK)} & \kappa_\pi & \kappa_{\pi W} & \kappa_y & \rho & \text{Welfare} \\
\hline
\text{Sticky Prices} & 2.3668 & 4.1145 & 2.4734 & 0.0004 & -0.1997 \\
\text{Sticky Wages} & 0.0000 & 0.0000 & 4.9742 & 0.0111 & -0.2017 \\
\text{Sticky Prices + Sticky Wages} & 0.0037 & 1.3952 & 4.9480 & 0.0471 & -0.1996 \\
\hline
\end{array} \]

Table 6: Coefficients of optimal simple rules after a positive shock to credit spreads under different model scenarios.

<table>
<thead>
<tr>
<th>Financial Frictions (FF-NK)</th>
<th>( \gamma_w = 0.75 )</th>
<th>( \gamma_p = 0.75 )</th>
<th>( \gamma_w = 0.75 )</th>
<th>( \gamma_p = 0.75 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \kappa_\pi = 1.5, \kappa_y = 0.125, \rho = 0.8 ) (Bench)</td>
<td>0.0389</td>
<td>0.0122</td>
<td>0.0388</td>
<td></td>
</tr>
<tr>
<td>( \kappa_\pi = 1.5, \rho = 0 )</td>
<td>0.2166</td>
<td>0.0234</td>
<td>0.3410</td>
<td></td>
</tr>
<tr>
<td>( \kappa_\pi = 1.5, \rho = 0.8 )</td>
<td>0.0676</td>
<td>0.0126</td>
<td>0.0799</td>
<td></td>
</tr>
<tr>
<td>( \kappa_{\pi W} = 1.5, \rho = 0 )</td>
<td>0.0626</td>
<td>0.0012</td>
<td>0.0939</td>
<td></td>
</tr>
<tr>
<td>( \kappa_{\pi W} = 1.5, \rho = 0.8 )</td>
<td>0.0321</td>
<td>0.0090</td>
<td>0.0415</td>
<td></td>
</tr>
<tr>
<td>( \kappa_{\pi W} = 1.5, \kappa_y = 0.125, \rho = 0.8 )</td>
<td>0.0244</td>
<td>0.0084</td>
<td>0.0262</td>
<td></td>
</tr>
<tr>
<td>( \kappa_\pi = 1.5, \kappa_{\pi W} = 1.5, \rho = 0.8 )</td>
<td>0.0296</td>
<td>0.0075</td>
<td>0.0315</td>
<td></td>
</tr>
<tr>
<td>Optimal Simple Rule</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td></td>
</tr>
</tbody>
</table>

Table 7: Welfare costs of a 25 basic point increase in the credit spread for a selection of Taylor rules. The costs of welfare are expressed in consumption equivalents relative to the outcome of the optimal simple rule. In the specification presented in the first column sticky prices are absent, in the second column sticky wages are not present. The third column’s results are based on the specification with both sticky wages and sticky prices.
<table>
<thead>
<tr>
<th>Financial Frictions (FF-NK)</th>
<th>$\kappa_\pi$</th>
<th>$\kappa_{\pi W}$</th>
<th>$\kappa_y$</th>
<th>$\kappa_x$</th>
<th>$\rho$</th>
<th>Welfare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sticky Prices</td>
<td>4.9999</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.8851</td>
<td>-0.0603</td>
<td></td>
</tr>
<tr>
<td>Sticky Wages</td>
<td>0.0103</td>
<td>4.8322</td>
<td>0.0042</td>
<td>0.7328</td>
<td>0.0008</td>
<td>-0.0568</td>
</tr>
<tr>
<td>Sticky Prices + Sticky Wages</td>
<td>0.0011</td>
<td>4.9960</td>
<td>0.0003</td>
<td>0.7137</td>
<td>0.0000</td>
<td>-0.0551</td>
</tr>
</tbody>
</table>

Table 8: Coefficients of optimal simple rules after a one percent wealth shock under different model scenarios.
Table 9: Welfare costs of a one percent wealth shock for a selection of Taylor rules. The costs of welfare are expressed in consumption equivalents relative to the outcome of the optimal simple rule. In the specification presented in the first column sticky prices are absent, in the second column sticky wages are not present. The third column’s results are based on the specification with both sticky wages and sticky prices.