Financial Frictions and Optimal Monetary Policy.

by

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December, 2021

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Chapter 1

Financial Frictions and Optimal Monetary Policy.

Abstract.

I analyze optimal monetary policy in a New Keynesian model with a banking sector that faces balance sheet constraints. Additionally, I consider monetary rules that can implement the Ramsey optimal policy.

In the presence of financial frictions, inflation stabilization remains as the main objective of policy, but, the presence of the financial accelerator introduces new policy concerns. In particular, when shocks hit, the policy maker cannot simultaneously stabilize inflation and the financial sector with the same policy instrument. In this setup, there is a policy trade off between stabilizing the cost of credit, which contributes to keep a healthy financial sector, and stabilizing inflation.

The simple rule that implements the optimal policy shows a strong reaction to changes in the cost of credit, in addition to the feedback coefficient on inflation.

1.1 Introduction.

The Great Recession (2007-09) renewed interest in analyzing the role of financial events on the propagation and amplification of shocks. The disruption observed in the financial markets during the crisis showed that the credit markets play a crucial role in macroeconomic stability.

The conventional New Keynesian model assumes that financial markets work perfectly. For example, Christiano et al. (2005) and Smets and Wouters (2007) develop quantitative models with several nominal and real rigidities, but assume frictionless financial markets[1].

Since the Great Recession, economic modeling has advanced in the introduction of imperfect financial markets into the conventional framework for analyzing monetary policy. For example, a

[1]Some exceptions to this are BGG(1999) and Kiyotaki and Moore (1997). However, the two previous studies focus on the qualitative aspects of the financial frictions rather than analyzing the quantitative effects of such distortions, or their optimal policy implications.

moral hazard problem in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) impedes the banks issuing an efficient amount of loans to non-financial firms. Their models are an attempt to capture the disrupting events after the Lehman bankruptcy and the posterior policy decisions. They analyze the set of unconventional policies implemented by the Federal Reserve during the subprime crisis. However, they abstract from optimal policy considerations. I fill in this gap.

Following the work of Gertler and Karadi (2011), in the current model, prices are sticky, there is monopolistic competition, and a banking sector facing balance sheet constraints. There is a moral hazard problem between savers and bankers. In particular, in every period the banks can divert a share of the funds available for lending. In order to prevent this, households impose an incentive constraint on the banks. This has the effect of tying the supply of credit to the value of the capital in the bank. In this context, a shock reducing the value of the banks' assets, increases the cost of credit, which leads to a fall in investment and asset prices. By directly affecting banks equity, swings in asset prices affect the cost of credit and tend to amplify movements in investment. This creates and endogenous feedback loop between asset prices and real activity. I analyze optimal monetary policy in such circumstances.

Does there exist a trade-off for optimal monetary policy in the presence of financial frictions?

The financial frictions create inefficient activity and they place an additional constraint on optimal policy. The central bank has to engineer an optimal response that stabilizes the financial sector, and inflation. However, there is only one policy instrument available. Within this framework, a productivity shock, a cost-push shock, or a financial shock are inflationary and recessionary. When negative shocks hit, the balance sheet constraints of the banks tighten. As a consequence of this, the banks reduce the supply of credit. This starts a cycle in which the initial shock amplifies the reduction in investment and the increase in the cost of credit, multiplying the effect on real activity. An optimizing central bank would seek to prevent this situation.

The main result of this chapter is that the introduction of financial frictions creates a trade-off between inflation and financial stabilization [2]. If the central bank pursues inflation stabilization, it comes at the cost of increased financial disruption and large deviations from the efficient allocation. Along this line, the central bank cannot simultaneously achieve inflation and financial stability with only one policy instrument. If the only policy instrument available is the nominal interest rate, the optimal policy trade-offs financial and inflation fluctuation. In particular, it reacts to increases in the cost of credit. If the premium on capital deviates from its long-run average, the central bank aims to reduce inefficient fluctuations in output by making the credit cheaper by contributing to the appreciation of the assets held by the financial institutions.

Price stability is suboptimal because policymakers stabilize the financial markets in order to

[2]In the benchmark New Keynesian model it is necessary to introduce a cost-push shock to generate a non-trivial policy trade-off (Woodford (2003)). Leith et al. (2015, 2012) show how in the New Keynesian model, the presence of deep habits in consumption serves to create interesting policy trade-offs. Ravenna and Walsh (2006) show that productivity shocks can create policy trade-offs if there is cost channel in which the firms' marginal costs depend directly on the nominal interest rate.

reduce inefficient fluctuation in output. For example, if inflation rises, the typical policy of increasing the nominal interest rate to reduce the inflation pressures, elevates the banks' cost of funding. In this case, the banks would require a larger premium on their loans, which will in turn exacerbate the collapse in investment spending and real activity, increasing the deviation from the efficient allocation. Hence, the optimal policy consists in allowing a temporary deviation from price stability in exchange for a partial stabilization of the financial markets.

How should optimal policy be conducted in this economy? Monetary policy can affect all the parts of the financial sector. By changing the cost of credit, the central bank can affect the incentives for leveraging in the financial sector. When negative shocks arise and financial frictions are present, it is optimal to aggressively reduce interest rates in order to stabilize the financial sector. This policy reduces the cost of funding, revalues the financial assets, and protects the profitability of the banking sector. In contrast, in the absence of financial frictions, the monetary stance is not required to be as expansionary ; inflation stabilization is optimal in that economy.

How can the central bank implement this optimal policy?

The second result of this chapter is that a central bank can mimic the optimal policy if it reacts to changes in the financial conditions, such as the cost of credit for firms. Not reacting to financial events is welfare decreasing. The optimal implementation of policy delivers an inertial rule that has feedback coefficients on both inflation deviations and deviations of the premium on capital. In particular, if the cost of credit for firms increases, which normally happens in a bad times, the central bank should cut the interest rate to make the cost of funding cheaper. In this case, the feedback coefficient on inflation is smaller, while larger coefficients decrease welfare. It is optimal to set the coefficient on output fluctuations to zero. The inertial rule has advantages over the non-inertial. The introduction of the inertial component allows the central bank to commit itself to stabilize the financial markets in the short-run, while, if necessary, reversing its policy in the long-run in order to anchor inflation expectations and to achieve price-level control. This setting implements the optimal policy.

To answer the questions posed here, I use a New Keynesian model with a banking sector that faces balance sheet constraints, as in Gertler and Karadi (2011). In this economy, I analyze the optimal monetary commitment. In order to accurately compare the welfare across different policies, I follow the approach developed by Schmitt-Grohé and Uribe (2004).

The plan of the paper is as follows. In the next section I present the literature review. In the third section I present the model. The fourth section contains the benchmark calibration. Section five presents the problem faced by a benevolent social planner who seeks to maximize the social welfare. This efficient allocation serves to compare the results of optimal policy, which is contained in section six. The optimal implementation of policy is presented in the seventh section. The section after that presents robustness checks. And the ninth section concludes.

1.2 Related Literature.

The current paper can be related to the literature analyzing policy trade-offs in the presence of real frictions. For example, in models without financial frictions, the introduction of a cost-push shock can generate significant trade-offs for the policy maker (Woodford (2003)). Leith et al. (2012, 2015) show that the introduction of deep habits in the utility function of the representative consumer can generate a non-trivial optimal policy exercise. Ravenna and Walsh (2006) show that if firms' marginal costs depend directly on the nominal interest rate, the optimal policy is to allow inflation fluctuations.

However, the particular emphasis of the current paper is on the trade-offs faced by the policy maker in the presence financial frictions. There is a group of works analyzing the optimal monetary commitment in the presence of financial frictions. For example, using the cost-channel mechanism and a costly state verification, De Fiore and Tristani (2012) show that productivity shocks can generate a trade-off for monetary policy. In their framework, the optimal policy is to mitigate output fluctuations and to allow deviations of inflation from its long run level. The central banks trades off stability of inflation for stability of real activity.

In Carlstrom et al. (2010), borrowers are restricted to borrow at efficient rates because there is a constraint that ties the amount of loans to their collateral. They show that the central bank's loss function is partly a function of the tightness of the credit constraint, which they interpret as a risk premium. However, their model abstracts from capital accumulation, which in the current paper is relevant to introduce the financial friction.

Cúrdia and Woodford (2010) analyze optimal policy in an extended version of the New Keynesian model which incorporates household heterogeneity and financial frictions. Borrowers and savers discount future consumption at different rates, creating a positive wedge between borrowing and lending rates; the loans are costly to produce and this constrains the supply of credit. They conduct the optimal policy exercise using a linear-quadratic approach. In contrast, I conduct optimal policy in a medium size DSGE model with a banking sector facing balance sheet constraints. Similarly to the current paper, Cúrdia and Woodford (2010) consider the implementation of the optimal policy using Taylor rules. They also find that financial variables should be introduced into such rule.

Leduc and Natal (2015) also consider the optimal commitment in a model with financial frictions. The optimal monetary policy should lean against movements in asset prices and risk-premia. Their result is similar to one of the main conclusions in this paper. The optimal policy can be approximated by including a speed-limit rule that places a substantial weight on the growth of financial variables. In their model, the financial friction is on the borrowers side. In particular, they rely on the financial accelerator model by Bernanke, Gertler and Gilchrist (1999). In their framework, the demand for credit is constrained by entrepreneurs' net wealth. In contrast, in the current paper, financial frictions are on the supply side and the constrained agents are the banks, not the borrowers.

After the analysis of optimal policy in the presence of financial frictions, I deal with the issue of its optimal implementation. There is large literature researching the ability of simple rules to lean against the financial markets. For example, in Andres et al. (2010), borrowing is subject to collateral constraints and banks are monopolistically competitive. The optimal monetary commitment implies a short-run trade-off between output and inflation. A Taylor rule augmented with a feedback coefficient on the real-state prices implements the optimal policy.

Similarly, Gambacorta and Signoretti (2013) develop a DSGE with both a firm's balance sheet channel and a bank-lending channel. They assess whether Taylor rules augmented with asset prices and credit can improve upon a standard rule in terms of macroeconomic stabilization. If the central bank reacts to the financial variables, welfare is maximized. Inflation targeting and a standard Taylor rule are less effective in stabilizing fluctuations.

In a model with search and matching frictions in the credit market, Fujimoto et al. (2014) conclude that the optimal rule must maintain a balance between financial and real economic activity. By taking financial variables into account, monetary policy may contribute to financial stability. Notarprieto et al. (2015) analyze the implementation of optimal policy in a model with a housing sector. The social welfare-maximizing monetary policy rule features a reaction to house price variations. Similarly to the previous studies, I find that augmenting the conventional monetary rule to include financial elements is desirable. In particular, stabilizing the cost of credit increases welfare in the economy.

Kamber and Thoenissen (2012) show that the amplification of monetary shocks introduced by the feedback loop between financial and real events can be overturned by assuming a more canonical Taylor-type interest rate rule where the policy rate reacts to both inflation and the output gap. Output stabilization matters in this context and they find a case to reduce the inflation stabilization motive. The model they use for their analysis is similar to financial accelerator model by Bernanke, Gertler and Gilchrist (1999).

Finally, a group of authors find that there is no case to extend the conventional Taylor rules to include financial variables. For example, Gilchrist (2002) concludes that, although asset prices, and the economy as a whole, can exhibit large fluctuations in response to financial shocks, there is not a strong case for including asset prices in monetary policy rules. The reason, he argues, is that as asset channels are similar to aggregate demand channels, they tend to increase both output and inflation. Inflation targeting, therefore, yields most of the benefits of asset prices targeting. Faia and Monacelli (2007) study optimal Taylor-type rules in an economy with credit market imperfections. They conclude that for low values of the feedback coefficient in the policy rule, responding to a measure of assets is welfare improving. However, when monetary policy responds strongly to inflation, the marginal welfare gain of responding to asset prices vanishes. A strong anti-inflationary stance always attains the highest level of welfare.

In contrast to most of the literature presented above, I conduct an optimal policy exercise in a medium-size DSGE model in which the financial frictions affect the supply of credit, rather than demand. Similarly to most of them, I present the ability of simple rules to implement the optimal policy, which leans strongly against financial events. In the next section, I present my benchmark model for conducting this optimal policy analysis.

1.3 The Model.

The model I use for the analysis is a New Keynesian DSGE, similar to Christiano et al. (2005) and Smets and Wouters (2007), but modified by Gertler and Karadi (2011) to include financial intermediaries that face balance sheet constraints. Within this framework, an agency problem between borrowers and lenders limits the supply of credit. The number of loans that can be intermediated by the banking sector depends on the value of net wealth in this sector. A reduction in the value of this wealth has the effect of increasing the cost of credit. The increase in the cost of credit negatively affects investment. As a consequence, the economic activity decreases. The effects of the shock are amplified with respect to the case in which the financial friction is absent.

There are five groups of agents: households, financial intermediaries, non-financial producers, capital producers, and retailers.

1.3.1 Households.

Households choose consumption (C_t), labor (L_t), and debt (D^h_{t+1}) in order to maximize their utility. Each household has a continuum of members. Within the household there is perfect consumption insurance. There are two types of agents inside each household. At each period, the fraction $(1-f)$ represents workers and (f) bankers. A household owns the banks managed by its members. The deposits of this household are in intermediaries they do not own.

The survival horizon of banks is finite. Introducing this finite horizon has the effect of ensuring that over time the banks do not reach the point where they can fund all the investment from their own capital. (θ) is the probability that a bank operates until the next period. This probability is independent of how long the agent has been a banker. The average survival length of a bank is $((\frac{1}{1-\theta}))$.

The relative share of workers and bankers is constant. Each period, the number of bankers leaving the industry is $(1-\theta)f$. The same number of workers become bankers. Households provide their new bankers with startup funds. When a bank leaves the industry its retained profits are returned in a lump-sum transfer to its owner.

Preferences.

To capture consumption dynamics, the utility function includes habits in consumption. The utility function for the representative household is:

$$E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} [\frac{(C_\tau - hC_{\tau-1})^{1-\sigma}}{1-\sigma} - \chi \frac{L_\tau^{1+\varphi}}{1+\varphi}] \tag{1.1}$$

where (L_t) is labor. $0 < \beta < 1$, is the subjective discount factor. The parameter h measures the habit persistence in consumption. σ is the inverse of the intertemporal elasticity of substitution. χ is the weight of labor disutility. φ is the inverse of the Frisch elasticity of labor supply.

The budget constraint of the household is:

$$C_t = W_t L_t + \Pi_t + R_t[D_t + B_t^g] - [D_{t+1} + B_{t+1}^g] - T_t. \tag{1.2}$$

Deposits (D_{t+1}) and government bonds (B_{t+1}^g) are short-term assets paying the same return in equilibrium. Following Gertler and Karadi (2011), this condition is imposed from the beginning. $[B_{t+1}^g + D_{t+1}]$ is the quantity of short-term riskless debt that the household acquires at period (t). The gross real return on those assets is (R_t). This return is paid from $(t-1)$ to (t).

Profits (Π_t) from financial and non-financial firms are net of the amount the household gives to its starting bankers at period (t). (T_t) are lump sum transfers from the government. The real wage (W_t) complements the household's budget constraint.

Optimality Conditions.

It is assumed that the intertemporal elasticity of substitution is unitary. The intertemporal maximization of (1.1) subject to the set of constraints of the form (1.2) implies the optimality conditions[3]:

Optimal labor supply:

$$\frac{\chi L_t^\varphi}{U_{ct}} = W_t. \tag{1.3}$$

Euler equation:

$$1 = \beta E_t \Lambda_{t,t+1} R_{t+1}, \tag{1.4}$$

where marginal utility of consumption (U_{ct}) is:

$$U_{ct} = E_t[\frac{1}{(C_t - hC_{t-1})} - h\beta \frac{1}{(C_{t+1} - hC_t)}] \tag{1.5}$$

and

$$\Lambda_{t,t+1} = \frac{U_{ct+1}}{U_{ct}}. \tag{1.6}$$

[3]Appendix A.1 contains the detailed derivations of these conditions.

1.3.2 Banks.

Balance Sheet.

The financial intermediary (j) receives deposits from households (D_{jt+1}). These deposits pay the short-term real interest (R_{t+1}) from (t) to $(t+1)$. These funds complement the accumulated wealth of banks (N_{jt}). Banks make use of these two sources of funds to make loans to producers. Loans pay the rate (R^k_{t+1}) between (t) and $(t+1)$.

The quantity of assets that the bank holds is (S_{jt}). The relative price of the financial asset is (Q_t). In each period the total value of assets held by the representative bank is $(Q_t S_{jt})$. The value of the bank's liabilities plus capital is $(D_{jt+1} + N_{jt})$. The balance sheet of the representative bank is:

$$Q_t S_{jt} = D_{jt+1} + N_{jt}. \tag{1.7}$$

Evolution of Wealth.

A bank's net wealth evolves according to

$$N_{jt+1} = R^k_{t+1} Q_t S_{jt} - R_{t+1} D_{jt+1}, \tag{1.8}$$

which is the difference between the return on its assets $(R^k_{t+1} Q_t S_{jt})$ and the cost of its liabilities $(R_{t+1} D_{jt+1})$. After solving (1.7) for deposits and inserting the result in (1.8), the evolution of wealth can be expressed as:

$$N_{jt+1} = [R^k_{t+1} - R_{t+1}] Q_t S_{jt} + R_{t+1} N_{jt}, \tag{1.9}$$

the term $[R^k_{t+1} - R_{t+1}]$ is the asset's premium over the riskless rate.

The banker will not fund a project with a return less than the cost of deposits. If the discount factor applied by the bank to assets between period (t) and $(t+i)$ is $[\beta^i \Lambda_{t,t+i}]$, then the next condition should apply for the bank to operate:

$$E_t \beta^{1+i} \Lambda_{t,t+1+i} [R^k_{t+1+i} - R_{t+1+i}] \geq 0 \tag{1.10}$$

in any period $(i \geq 0)$. In frictionless capital markets this relationship holds with equality. By contrast, when the financial frictions are present, this risk adjusted premium may be positive. The presence of a positive spread in equilibrium will translate into inefficiently low levels of capital and overall economic activity.

Bank Maximization Problem.

The problem of the bank is to maximize the expected value of its terminal wealth (V_{jt})

$$V_{jt} = \max E_t \sum_{i=0}^{\infty} (1 - \theta_{t+1+i})[\Pi_{k=t+1}^{t+i} \theta_k] \beta^{i+1} \Lambda_{t,t+1+i}(N_{jt+1+i}) \tag{1.11}$$

where

$$N_{jt+1+i} = [R_{t+1+i}^k - R_{t+1+i}] Q_{t+i} S_{jt+i} + R_{t+1+i} N_{jt+i}$$

The probability of survival of banks (θ_t) is subject to a random shock, which evolves as

$$\ln(\theta_t) = \rho_\theta \ln(\theta_{t-1}) + \varepsilon_{\theta_t}.$$

where (ε_{θ_t}) has mean zero and variance ($\sigma_{\theta t}^2$).

There is a frictionless process of lending and borrowing between producers and banks. The possibility of making profits encourages the banker to remain in the industry as long as possible. In order to issue new loans, the bank borrows from households. Then, the bank uses its accumulated wealth and the deposits to issue loans to producers. It is assumed that banks face frictions in this process of borrowing from households. This friction reduces the ability of the bank to issue new loans.

In particular, every period, the bankers can divert a fraction (λ) of available funds. To avoid that the bank absconds with the funds, the household imposes an incentive constraint on the bank. The cost to the banker of diverting funds is that the households can force the bank to shut down and households can recover the fraction $(1 - \lambda)$ of assets. For the lender to be willing to supply funds to the banker, the following incentive constraint must be satisfied:

$$V_{jt} \geq \lambda Q_t S_{jt}. \tag{1.12}$$

The left-hand part (V_{jt}) is the expected present value of the bank's financial activity if it remains in the industry. This is what the bank would lose if it is forced to leave the industry. The term ($\lambda Q_t S_{jt}$) is what the bank would gain if it absconds with the funds. The bank assesses this trade-off and acts optimally. The bank would remain in the industry as long as the benefits from doing so covers the benefits from absconding with a share of assets.

The household would deposit in the bank only if the benefit for the bank of lending and borrowing is at least as large as the benefit for the bank from diverting funds. This contract limits the ability of the banking sector to raise funds from households. As a consequence, the banks have limits on the loans they can issue. This will impact the level of capital that firms can accumulate and the overall economic activity would be inefficiently low.

In the appendix A.1 it is shown that the conjectured solution to the banks maximization problem can be expressed as

$$V_{jt} = \upsilon_t Q_t S_{jt} + \eta_t N_{jt} \tag{1.13}$$

where

$$v_t = \begin{aligned} & E_t(1-\theta_{t+1})\beta\Lambda_{t,t+1}(R^k_{t+1} - R_{t+1}) \\ & +E_t\theta_{t+1}\beta\Lambda_{t,t+1}x_{t,t+1}v_{t+1} \end{aligned} \tag{1.14}$$

and

$$\eta_t = \begin{aligned} & E(1-\theta_{t+1})\beta\Lambda_{t,t+1}R_{t+1} \\ & +E_t\theta_{t+1}\beta\Lambda_{t,t+1}z_{t,t+1}\eta_{t+1}. \end{aligned} \tag{1.15}$$

The term (v_t) is the marginal expect return to the bank of increasing assets. (η_t) is the marginal expected return to the bank of increasing its accumulated wealth.

The term

$$x_{t,t+i} = \frac{Q_{t+i}S_{jt+i}}{Q_tS_{jt}} \tag{1.16}$$

is the gross growth of assets between period t and $t+i$. Over the same period, the net wealth of the banker has a gross growth of

$$z_{t,t+1} = \frac{N_{jt+i}}{N_{jt}}. \tag{1.17}$$

Leverage Ratio.

Substituting the conjectured solution (1.13) in the incentive constraint (1.12)

$$\nu_tQ_tS_{jt} + \eta_tN_{jt} \geq \lambda Q_tS_{jt}, \tag{1.18}$$

and solving for assets, the incentive constraints can be expressed as

$$\frac{Q_tS_{jt}}{N_{jt}} \geq \frac{\eta_t}{\lambda - \nu_t}. \tag{1.19}$$

Defining the leverage ratio in the banking sector (ϕ_t) as the maximum ratio of loans to net wealth $[\frac{Q_tS_{jt}}{N_{jt}} = \phi_t]$, then

$$\phi_t = \frac{\eta_t}{\lambda - \nu_t}. \tag{1.20}$$

Combining (1.19) and (1.20), it is possible to express the assets intermediated by the bank as

$$Q_tS_{jt} = \phi_tN_{jt}, \tag{1.21}$$

which is the leverage ratio times the bank's net wealth. The previous expression means that the maximum amount of loans issued by the representative bank is limited by the maximum leverage ratio tolerated by the household. This leverage ratio is a function of the diverting preference of the banks and the profitability of the banking industry. The maximum amount of loans is also restricted by the amount of accumulated wealth of the bank.

Substituting the leverage ratio in the evolution of wealth (eq. 1.9)

$$N_{jt+1} = \{[R^k_{t+1} - R_{t+1}]\phi_t + R_{t+1}\}N_{jt}, \tag{1.22}$$

and using this in (1.16) and (1.17)

$$z_{t,t+1} = [R^k_{t+1} - R_{t+1}]\phi_t + R_{t+1}, \tag{1.23}$$

and the gross rate of assets can be written as

$$x_{t,t+1} = \frac{\phi_{t+1}}{\phi_t} z_{t,t+1}. \tag{1.24}$$

Evolution of Aggregate Leverage Ratio.

The components of the leverage ratio are the same for each bank. After aggregating (1.21),

$$Q_t S_t = [\left[\frac{\eta_t}{\lambda - \nu_t}\right]] N_t. \tag{1.25}$$

the overall demand for assets in the economy ($Q_t S_t$) can be written as a function of the leverage ratio and the accumulated wealth (N_t) in the banking sector

Evolution of Aggregate Net Wealth.

The evolution of aggregate wealth (N_t) is the sum of two components: the net worth of the existing banks (N_{et}), and the net wealth of the new banks (N_{nt})

$$N_t = N_{et} + N_{nt}. \tag{1.26}$$

The fraction of bankers (θ_{t-1}) at $(t-1)$ survives until (t). Then, using the aggregation of (1.22),

$$N_{et} = \theta_{t-1}\{[R^k_t - R_t]\phi_{t-1} + R_t\}N_{t-1}. \tag{1.27}$$

As outlined by Gertler and Karadi (2011), I assume that the newly entering bankers receive start-up funds from their respective households. It is assumed that these start-up funds are equal to a small fraction of the value of assets that exiting bankers had intermediated in their final operating period. The total value of assets of exiting bankers is $(1 - \theta_{t-1})Q_t S_{t-1}$. It is assumed that each period the household transfers a fraction $[[\frac{w}{1-\theta_{t-1}}]]$ of those assets to its new bank. In aggregate $[N_{et} = wQ_tS_{t-1}]$. The evolution of aggregate wealth is

$$N_t = \theta_{t-1}\{[R_t^k - R_t]\phi_{t-1} + R_t\}N_{t-1} + wQ_tS_{t-1}. \tag{1.28}$$

1.3.3 Intermediate Goods Producers.

The goods produced in this competitive sector are sold to retailers. At the end of period (t) intermediate producers acquire (K_{t+1}) units of capital from capital goods producers. This capital is for use in the subsequent periods. At the end of period $(t+1)$ the firm has the option of reselling the undepreciated capital in the open market. There are no capital adjustment costs at the firm level.

To purchase capital, intermediate producers issue (S_t) claims for each unit of capital acquired (K_{t+1}). These contingent claims are acquired by the banks. The price of each claim is the same as of each unit of capital (Q_t). Then, the value of capital acquired is equal to the value of contingent claims

$$Q_tK_{t+1} = Q_tS_t. \tag{1.29}$$

Financial intermediation between banks and intermediate producers is frictionless. The claims (S_t) can be thought as perfectly state-contingent debt. Every period the producer pays the full return on capital to the bank.

Production of Intermediate Goods.

The production (Y_{mt}) in this sector is given by

$$Y_{mt} = A_t(U_t\xi_tK_t)^{\alpha}L_t^{1-\alpha} \tag{1.30}$$

where (A_t) is the total factor productivity, (K_t) the capital acquired in the previous period and used in this period. (L_t) is the labor demand and (U_t) the utilization rate. Following Gertler and Karadi (2011), the term (ξ_t) is an exogenous shock to the quality of capital. This shock can be interpreted as a sudden obsolescence on the capital[4] and provides an exogenous source of variation to the price of capital.

The relative price of the goods in this sector is (P_{mt}). In the appendix A.1, it is shown that from profits maximization in this sector:

Labor demand:

[4]Gertler et al. (2012) provide the microfoundations for this shock.

$$(1-\alpha)P_{mt}\frac{Y_{mt}}{L_t} = W_t.$$

Optimal utilization rate:

$$\alpha P_{mt}\frac{Y_{mt}}{U_t} = bU_t\xi_t K_t, \tag{1.31}$$

where depreciation of capital is a function of the utilization rate. It is assumed that depreciation takes the form

$$\delta_t = \delta_c + \frac{b}{1+\zeta}U_t^{1+\zeta}, \tag{1.32}$$

where (ζ) is the elasticity of depreciation respect to utilization rate.

Rate of Return on Capital.

The firms in this sector are perfectly competitive and gain zero profits state by state. Each period, the firm pays to the bank the full return on capital. It is as if banks are the owners of the capital on the firm. The return on capital is the remainder of the profits after paying the wage bill. From the optimal conditions of the maximization problem of these firms, in appendix A.1 it is shown that the return to capital is:

$$R_t^k = \frac{1}{Q_{t-1}}\{\alpha P_{mt}\frac{Y_{mt}}{K_t} + [Q_t - \delta_t]\xi_t\}. \tag{1.33}$$

1.3.4 Capital Producers.

Competitive capital producers purchase the depreciated capital from the intermediate producers at the end of the period (t). The capital is repaired and sold together with the new capital. The cost of repairing worn out capital is unity. The value of selling one unit of new capital is (Q_t). Investment adjustment cost are associated with the net investment (I_{nt}):

$$I_{nt} = I_t - \delta_t\xi_t K_t \tag{1.34}$$

where (I_t) is the total investment.

Each period the firm maximizes

$$\max E_t\sum_{\tau=t}^{\infty}\beta^{\tau-t}\Lambda_{t,\tau}\{(Q_t-1)I_{nt} - \frac{\phi_i}{2}(\left(\frac{I_{n\tau}-I_{n\tau-1}}{I_{n\tau-1}+I_{ss}}\right))^2(I_{n\tau}+I_{ss})\}. \tag{1.35}$$

The investment adjustment costs, associated with the net flow of investment, are

$$\frac{\phi_i}{2}(\left(\frac{I_{n\tau}-I_{n\tau-1}}{I_{n\tau-1}+I_{ss}}\right))^2(I_{n\tau}+I_{ss})$$

where (ϕ_i) is the inverse of the elasticity of net investment to the price of capital. Each of the firms in this sector chooses the same level of net investment. So, it is not necessary to index investment by firm. From this maximization problem the optimal price of capital

$$\begin{aligned} Q_t = \quad & 1 + \frac{\phi_i}{2}(\left(\frac{I_{nt} - I_{nt-1}}{I_{nt-1} + I_{ss}}\right))^2 \\ & +\phi_i(\left(\frac{I_{nt} - I_{nt-1}}{I_{nt-1} + I_{ss}}\right))(\left(\frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}}\right)) \\ & -E_t \beta \Lambda_{t,t+1} \phi_i(\left(\frac{I_{nt+1} - I_{nt}}{I_{nt} + I_{ss}}\right))(\left(\frac{I_{nt+1} + I_{ss}}{I_{nt} + I_{ss}}\right))^2. \end{aligned} \tag{1.36}$$

1.3.5 Retailers.

Final output is a composite of a continuum of differentiated retail goods. The only input of production is the intermediate good. Retailers purchase inputs from the intermediate producers and re-package it. The final product is aggregated according to

$$Y_t = [\int_0^1 Y_{ft}^{\frac{\varepsilon-1}{\varepsilon}} df]^{\frac{\varepsilon}{\varepsilon-1}} \tag{1.37}$$

(Y_{ft}) is the output purchased to the retailer (f). (ε) is the elasticity of substitution across varieties.

Optimal Demand for Retailers.

As shown in the appendix A.1, from cost minimization, those purchasing the final good have an optimal demand for each variety equal to

$$Y_{ft} = [\left[\frac{P_{ft}}{P_t}\right]]^{-\varepsilon} Y_t \tag{1.38}$$

which implies the optimal price index

$$P_t = [\int_0^1 (P_{ft})^{1-\varepsilon} df]^{\frac{1}{1-\varepsilon}}. \tag{1.39}$$

Profit Maximization.

The only cost of production for the retailer is the price of the intermediate good. This cost is given by (P_{mt}) because it takes only one unit of intermediate good to produce one unit of the retail good. Each period, firms can adjust their price with probability $(1 - \gamma)$. For the periods in which the firm is not able to set prices, it indexes it to the lagged rate of inflation.

In contrast to Gertler and Karadi (2011), I assume that this economy can be subject to a cost-push shock. In particular, the government imposes a distortionary tax on sales. Following

Chen et al. (2014), shocks to this tax, evolve according to

$$\ln(1-\tau_t) = \rho_\mu \ln(1-\tau_{t-1}) + (1-\rho_\mu)\ln(1-\tau) - \varepsilon_t^\mu \tag{1.40}$$

(ε_t^μ) is i.i.d. with mean zero and variance (σ_t^2).

The firm's problem in this sector is to choose the optimal price (P_t^*) to maximize its discounted expected profits:

$$\max E_t \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i}[(1-\tau_t)\frac{P_t^*}{P_{t+i}} \prod_{k=1}^{i} [\pi_{t+k-1}]^{\gamma^p} - P_{mt+i}]Y_{ft+i} \tag{1.41}$$

subject to

$$Y_{ft+i} = [\left[\frac{P_t^*}{P_{t+i}}\right]]^{-\varepsilon} Y_{t+i} \tag{1.42}$$

where π_t is the rate of inflation from $(t-i)$ to (t). And (γ^p) is a parameter with values $[0,1]$ and which measures the inflation indexation. The first order condition is

$$E_t \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i}[\frac{P_t^*}{P_{t+i}} \prod_{k=1}^{i} [\pi_{t+k-1}]^{\gamma^p} - \frac{\varepsilon}{\varepsilon-1} P_{mt+i}]Y_{ft+i} = 0. \tag{1.43}$$

As shown in the appendix A.1, the optimal price, implied by the solution to the previous problem is:

$$\frac{P_{it}^*}{P_t} = \frac{\varepsilon}{\varepsilon-1}\frac{F_t}{Z_t} \tag{1.44}$$

with

$$F_t = P_{mt} Y_t + E_t \gamma \beta \Lambda_{t,t+1} \pi_t^{-\gamma^\rho \varepsilon} \pi_{t+1}^{\varepsilon} F_{t+1} \tag{1.45}$$

and

$$Z_t = (1-\tau_t) Y_t + E_t \gamma \beta \Lambda_{t,t+1} \pi_t^{\gamma^\rho (1-\varepsilon)} \pi_{t+1}^{-(1-\varepsilon)} F_{t+1}. \tag{1.46}$$

Evolution of the price index.

Every period there is a share $(1-\gamma)$ of producers adjusting price optimally. The remaining (γ) simply index their price to the previous period inflation. Using the optimal price index (1.39) the evolution of the price index

$$P_t^{1-\varepsilon} = [(1-\gamma)(P_t^*)^{1-\varepsilon} + \gamma(\pi_{t-1}^{\gamma^\rho} P_{t-1})^{1-\varepsilon}]. \tag{1.47}$$

Price Dispersion.

As shown in the appendix A.1, price dispersion is defined as

$$\Delta_t = \int_0^1 [\left[\frac{P_{ft}}{P_t}\right]]^{-\varepsilon} df. \tag{1.48}$$

Using the law of movement of the price index and the definition of price dispersion this measure evolves according to:

$$\Delta_t = (1-\gamma)[\left[\frac{1-\gamma(\pi_{t-1}^{\gamma^\rho}\pi_t^{-1})^{1-\varepsilon}}{1-\gamma}\right]]^{\frac{-\varepsilon}{1-\varepsilon}} + \gamma[\pi_{t-1}^{\gamma^p}\pi_t^{-1}]^{-\varepsilon}\Delta_{t-1}. \tag{1.49}$$

1.3.6 Government Budget Constraint.

The government spending, which evolves exogenously, (G_t) and the payments on the debt acquired previously $(R_t B_t^g)$ are financed with a tax on sales $(\tau_t Y_t)$, issue of new government bonds (B_{t+1}^g), and using lump-sum taxation (T_t). The government's budget constraint is

$$T_t = G_t + R_t B_t^g - B_{t+1}^g - \tau_t Y_t \tag{1.50}$$

The initial level of debt (B_t^g) is zero. The lump-sum tax ensures that the debt of the government is stabilized over time and that its budget constraint is balanced, then

$$T_t = G_t - \tau_t Y_t. \tag{1.51}$$

where government consumption (G_t) is fixed at its steady state value (G). Regarding the steady state government spending to GDP ratio, $((\frac{G}{Y}))$ is 0.2, this is a conventional value, and between 1980-2010 the average was 19.8 percent (BEA NIPA table 1.1.10).

1.3.7 Aggregate Resource Constraint.

Consumption, government spending, total investment and the costs associated with the change in investment adjustment are the demand faced by the final producers. Then, the aggregate resource constraint is

$$Y_t = C_t + G_t + I_t + \frac{\phi_i}{2}(\left(\frac{I_{nt} - I_{nt-1}}{I_{nt-1} + I_{ss}}\right))^2 (I_{nt} + I_{ss}). \tag{1.52}$$

1.3.8 Law of movement of Capital.

From the law of movement of capital

$$K_{t+1} = (1-\delta_t)\xi_t K_t + I_t \tag{1.53}$$

and the definition of net investment

$$I_{nt} = I_t - \delta_t \xi_t K_t \tag{1.54}$$

capital evolves according to

$$K_{t+1} = \xi_t K_t + I_{nt}. \tag{1.55}$$

1.3.9 Monetary Policy.

Optimal policy is conducted in a Ramsey fashion. However, to gain some insights on the dynamics of this competitive economy, the following section presents the results of the model when the economy follows simple rules. I make use of the Fisher equation to relate nominal and real interest rates

$$i_t = E_t R_{t+1} \pi_{t+1}. \tag{1.56}$$

If monetary policy is not conducted in an optimal fashion, then simple rules are implemented by a central bank following a Taylor rule to set the nominal interest rate. That rule is

$$\frac{i_t}{i} = E_t[\left[\frac{i_{t-1}}{i}\right]]^{\kappa_R}[\left[\frac{\pi_t}{\pi^*}\right]]^{\kappa_\pi}[\left[\frac{Y_t}{Y}\right]]^{\kappa_Y}\varepsilon_{it}, \tag{1.57}$$

where (ε_{it}) is an exogenous monetary policy shock with mean zero and variance (σ_m^2). Eventually the policy maker can choose to smooth the interest rate, the size of this smoothing preference is controlled by (κ_R).

The set of all the equilibrium conditions is listed in the Appendix A.2.

1.4 Calibration.

The model is calibrated to a quarterly frequency. To calibrate the model I follow the work of Gertler and Karadi (2011), who in turn follow Primiceri et al. (2006). The habits parameter (h) is set to 0.815. The intertemporal elasticity of substitution (σ) is set to unity. The subjective discount factor $(\beta = 0.99)$ implies an annual real interest of 4.1 percent.

The inverse of the Frisch elasticity (φ) takes a value of 0.276. The weight of labor in the utility function is $(\chi = 3.4)$. The elasticity of capital in the production function (α) takes a value of 0.33. The depreciation in steady state is 2.5 percent per quarter and the elasticity of marginal depreciation to the utilization rate (ζ) takes a value of 7.2. The inverse of the elasticity of net investment to the price of capital (ϕ_i) is assumed to be 1.728.

The probability that a firm does not adjust its price this period $(\gamma = 0.779)$ implies that a firm keeps its price for around 4 quarters. The size of the indexation of the price to the previous period

Table 1.1: List of Parameters

Table 1.2: Variables in Steady State

inflation (γ^p) takes a value of 0.241.

The elasticity of substitution between varieties of goods is ($\varepsilon = 4.167$). The value of this coefficient is very low. This implies a very large monopolistic distortion. The results are robust to a more competitive economy. In the robustness section I make use of more standard values for this parameters. In particular, [$\varepsilon = 11$; $\varepsilon = 7$]. The coefficient measuring the reaction of the nominal interest rate to changes in inflation in the Taylor rule (κ_π) is 1.5 and the the coefficient on output deviations is (κ_Y) is 0.5. I assume that the smoothing parameter (κ_R) is zero. I assume that inflation in steady state is zero.

The persistence of the shock to productivity, the shock to the quality of capital, and the shock to government spending take the values $\rho_A = 0.95$, $\rho_\xi = 0.66$, and $\rho_g = 0.95$, respectively. The persistence of the shock to the probability of dying in the banking sector and to the cost-push shock are $\rho_\theta = 0.66$ and $\rho_\tau = 0.95$, respectively. The government spending (G) is one fifth of the total output.

Following the work of Gertler and Karadi (2011), the spread between the rate of return on capital and the riskless rate ($R^k_{t+1} - R_{t+1}$) is 25 basis points quarterly, which implies and annual spread of 1 percentage point. The leverage ratio in steady state is assumed to be 4. And the transfers to starting banks (ω), is calibrated to match the leverage ratio. The value of this parameter is 0.0022. It is assumed that the average survival time of a bank is 40 quarters, which implies a probability (θ) equal to 0.9715. The previous values for the financial variables imply a share of diverting funds equal to (0.3815). Table 1 summarizes the value of the parameters.

In order to compare some of the results to more conventional analyses of monetary policy, I make use of a model without financial frictions. This model is the conventional DSGE. Table 1 presents the list of the parameters for both cases.

In the next section I present the problem faced by a benevolent social planner who seeks to maximize the social welfare in this economy. This problem is relevant because the social planer delivers the efficient allocation in this economy. The Ramsey planner would seek to mimic that allocation.

Table 1.1: List of Parameters

Parameter		DSGE	Financial
h	Habits in consumption	0.815	0.815
β	Subjective discount factor	0.99	0.99
χ	Disutility of labor	3.41	3.41
α	Capital share	0.33	0.33
φ	Inverse Frisch elasticity of labor supply	0.27	0.27
θ	Probability of survival banks	–	0.97
λ	Share of diverting loans	–	0.3815
ω	Transfer to starting banks	–	0.002
ϕ_i	Elasticity investment adjustment costs	1.72	1.72
ζ	Elasticity of marginal depreciation to utilization	7.2	7.2
γ	Share of firms no adjusting price	0.77	0.77
γ^p	Degree of price indexation	0.241	0.241
ε	Elasticity of substitution	4.1	4.1
ρ_a	Persistence coefficient technology shock	0.95	0.95
ρ_ξ	Persistence coefficient quality shock	0.66	0.66
ρ_θ	Persistence coefficient prob. of survival banks	–	0.66
ρ_i	Persistence coefficient monetary shock	0.75	0.75
ρ_μ	Persistence coefficient cost-push shock	0.93	0.93
σ_a	St. dev. shock to productivity	0.01	0.01
σ_ξ	St. dev. shock to quality of capital	0.01	0.01
σ_θ	St. dev. shock to survival probability	0.01	0.01
σ_μ	St. dev. cost-push shock	0.0647	0.0647
σ_i	St. dev. monetary policy shock	0.01	0.01
κ_π	Inflation coefficient. Taylor rule.	1.5	1.5
κ_Y	Output coefficient. Taylor rule.	0.5	0.5
κ_R	Smoothing parameter. Taylor rule.	0	0

Table 1.2: Variables in Steady State

Variable		DSGE	Financial
C	Consumption	0.5537	0.5375
R	Real interest rate (quarterly %)	1.01	1.01
L	Labor	0.3383	0.3333
P_m	Price intermediate production	0.76	0.76
Y	Output	0.8912	0.8488
R^k	Return on capital (quarterly %)	1.01	1.26
Q	Price of capital	1	1
K	Capital	6.3676	5.6616
Y_m	Intermediate production	0.8912	0.8488
U	Utilization of capital	1	1
I	Investment	0.1592	0.1415
G	Government spending	0.1782	0.1698
Δ	Price dispersion	1	1
π	Inflation	1	1
i	Nominal interest rate (quarterly %)	1.01	1.01
$Spread$	Premium on capital (basis points)	0	25
ϕ	Leverage ratio		4
N	Wealth of banks		1.4154
N_e	Wealth surviving banks		1.4028
v	Marginal return on bank assets		0.0037
η	Marginal return on bank wealth		1.5110

1.5 Social Planner's Allocation.

In order to have a benchmark against which I can compare the results of the optimal policy exercise, in this section, I describe and solve the problem faced by a social planner who seeks to maximize the utility of the consumer subject to the resource constraint, and the production technology.

This social planner maximizes

$$E_t \sum_{t=0}^{\infty} \beta^t [\ln(C_t - hC_{t-1}) - \frac{\chi}{1+\varphi} L_t^{1+\varphi}], \tag{1.58}$$

subject to the production function

$$Y_t = A_t (U_t \xi_t K_t)^{\alpha} L_t^{1-\alpha}, \tag{1.59}$$

the evolution of depreciation

$$\delta_t = \delta_c + \frac{b}{1+\zeta} U_t^{1+\zeta}, \tag{1.60}$$

net investment

$$I_{nt} = I_t - \delta_t \xi_t K_t, \tag{1.61}$$

the evolution of capital

$$K_{t+1} - \xi_t K_t = I_{nt}, \tag{1.62}$$

and the aggregate resource constraint

$$Y_t = C_t + G_t + I_t + \frac{\phi_i}{2} (\frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}} - 1)^2 (I_{nt} + I_{ss}). \tag{1.63}$$

The solution to this problem delivers the efficient allocations (denoted with $(*)$)[5]:

$$Y^* = (\left(\frac{K^*}{L^*}\right))^{\alpha} L^* \tag{1.64}$$

with

$$U^* = \{\left\{\frac{1-\beta[1-\delta]}{b\beta}\right\}\}^{\frac{1}{\zeta}} = 1 \tag{1.65}$$

$$\frac{K^*}{L^*} = [\left[\frac{1-\beta[1-\delta]}{\alpha\beta}\right]]^{\frac{1}{\alpha-1}} \tag{1.66}$$

$$L^* = \{\frac{1-\beta h}{1-h} \frac{1-\alpha}{\chi} (\left(\frac{K^*}{L^*}\right))^{\alpha} [\left[\frac{C^*}{L^*}\right]]^{-1}\}^{\frac{1}{1+\varphi}} \tag{1.67}$$

$$\frac{C^*}{L^*} = (\left(\frac{K^*}{L^*}\right))^{\alpha} [1-\bar{G}] - [\delta] \frac{K^*}{L^*}. \tag{1.68}$$

[5]The Appendix A.3 shows the detailed derivation of these values.

After using the optimal value for utilization ($U^* = 1$) the equations for output, labor, and capital can be written as

$$Y^* = [\frac{1-\beta h}{1-h}\frac{1-\alpha}{\chi}]^{\frac{1}{1+\varphi}}[\begin{array}{c} [[\frac{1-\beta[1-\delta]}{\alpha\beta}]]^{\frac{-\alpha(1+\varphi)}{\alpha-1}}[1-\bar{G}] \\ -[\delta][[\frac{1-\beta[1-\delta]}{\alpha\beta}]]^{\frac{1-2\alpha-\alpha\varphi}{\alpha-1}} \end{array}]^{-\frac{1}{1+\varphi}} \tag{1.69}$$

$$K^* = \{\frac{1-\beta h}{1-h}\frac{1-\alpha}{\chi}\}^{\frac{1}{1+\varphi}}[\begin{array}{c} [1-\bar{G}][[\frac{1-\beta[1-\delta]}{\alpha\beta}]]^{\frac{1+\varphi}{1-\alpha}} \\ -[\delta][[\frac{1-\beta[1-\delta]}{\alpha\beta}]]^{\frac{\alpha+\varphi}{1-\alpha}} \end{array}]^{-\frac{1}{1+\varphi}} \tag{1.70}$$

$$L^* = \{\frac{1-\beta h}{1-h}\frac{1-\alpha}{\chi}\}^{\frac{1}{1+\varphi}}[\begin{array}{c} [1-\bar{G}] \\ -[\delta][[\frac{\alpha\beta}{1-\beta[1-\delta]}]] \end{array}]^{-\frac{1}{1+\varphi}}. \tag{1.71}$$

which are equations in terms of the deep parameters.

In the next section, I present and solve the Ramsey problem. I also present the main distortions of this economy. These distortions prevent the economy to achieve the efficient levels of activity. The presence of these distortions can open the door to the policy trade-offs.

1.6 Ramsey Policy and Distortions.

1.6.1 Distortions.

In this section, I present the main distortions associated with this economy. In particular: monopolistic competition and sticky prices, and a positive spread between the lending and deposit rate in the banking sector. The monopolistic competition and sticky prices are a conventional way to provide monetary policy with the ability to affect the real variables. The positive spread between the lending and the deposit rate in the banking sector is a distortion that allows the financial imperfections to affect the business cycle.

In order to have a better understanding of the effects of each of the previous distortions over the business cycle and stabilization policy, I make use of the proper subsidies just as a devices to switch individual distortions on or off in order to isolate their impact. 2

Monopolistic Competition.

In this section, I present the main distortions associated with this economy. From the optimal conditions of the competitive equilibrium, the labor market equilibrium, in steady state is given by

$$L^{\varphi+1} = [\left[\frac{1-\alpha}{\chi}\right]]U_c P_m Y, \tag{1.72}$$

where the marginal utility of consumption (U_c) in steady state is

$$U_c = [\left[\frac{1-\beta h}{C(1-h)}\right]].$$

It is possible to express the labor market equilibrium as a function of the deep parameters in the economy and the capital-labor ratio as:

$$L = \{\frac{1-\beta h}{1-h}[\left[\frac{1-\alpha}{\chi}\right]](\left(\frac{K}{L}\right))^{\alpha}[[1-\bar{G}](\left(\frac{K}{L}\right))^{\alpha} - \frac{\delta K}{L}]^{-1}P_m\}^{\frac{1}{1+\varphi}}. \tag{1.73}$$

From the Social Planner's allocation, I know that the efficient level of labor is given by

$$L^* = \{\frac{1-\beta h}{1-h}[\left[\frac{1-\alpha}{\chi}\right]](\left(\frac{K^*}{L^*}\right))^{\alpha}[[1-\bar{G}](\left(\frac{K^*}{L^*}\right))^{\alpha} - \frac{\delta K^*}{L^*}]^{-1}\}^{\frac{1}{1+\varphi}} \tag{1.74}$$

(1.73) and (1.74) would be equal if the term (P_m) would be equal to unity in (1.73). The price of the intermediated goods (P_m) is different from unity and it is a function of the parameter governing the monopolistic competition in the economy. This has the effect of distorting the levels of economic activity in steady state. Assuming, for the time being, that no other distortions exist, it is possible to get the efficient level of economic activity if a subsidy in steady state eliminates this distortion.

In steady state, the relative price of intermediate goods is given by

$$P_m = \frac{\varepsilon - 1}{\varepsilon},$$

which is different from unity. Subsidizing the sales of this good (τ^{mon}) allows me to write the equilibrium in the presence of this subsidy as:

$$1 = \frac{\varepsilon}{\varepsilon - 1}\frac{1}{1+\tau^{mon}}P_m \tag{1.75}$$

Then, the value of subsidy the that eliminates the distortion associated with monopolistic competition is equal to

$$1 + \tau^{mon} = \frac{\varepsilon}{\varepsilon - 1}. \tag{1.76}$$

Given the values of the parameters used to calibrate the model, the subsidy (τ^{mon}) is equal to 0.3158. I assume that the subsidies are financed using lump-sum taxes. This subsidy would deliver the efficient levels of the variables if no other distortion existed. However, the presence of the imperfect banking sector also contributes to distort the economy.

Positive spread.

In this model, the steady state value of the variables are also affected by the presence of a positive spread between the return on capital and the risk-free rate. From the optimal conditions of the social planner's allocation, the capital-labor ratio is

$$\frac{K^*}{L^*} = [\left[\frac{R - [1-\delta]}{\alpha}\right]]^{\frac{1}{\alpha-1}}. \tag{1.77}$$

In this financial model, the capital-labor ratio, once the subsidy on sales is present, is given by

$$\frac{K}{L} = [\left[\frac{R^k - [1-\delta]}{\alpha P_m(1+\tau^{mon})}\right]]^{\frac{1}{\alpha-1}}. \tag{1.78}$$

In models without frictions, capital is expanded until the point in which the return on capital (R^k) is equal to the real interest rate (R), which in turn equates the inverse of the households' subjective discount factor,

$$R^k = R = \frac{1}{\beta}. \tag{1.79}$$

However, in this model this is no longer possible because of the existence of a positive spread in equilibrium associated with the financial frictions. Hence,

$$R^k - R = Spread, \tag{1.80}$$

with $Spread > 0$. Substituting (1.80) in (1.78)

$$\frac{K}{L} = [\left[\frac{R + Spread - [1-\delta]}{\alpha P_m(1+\tau)}\right]]^{\frac{1}{\alpha-1}}. \tag{1.81}$$

Then, once the subsidy to the sales is in place ($P_m(1+\tau^{mon}) = 1$), the difference between (1.81) and (1.77) is due to the imperfect banking sector. A subsidy to the acquisition of capital (τ^{SP}) can eliminate the spread. In this case, the capital-labor relationship is:

$$\frac{K}{L} = [\left[\frac{R + Spread + \tau^{SP} - [1-\delta]}{\alpha}\right]]^{\frac{1}{\alpha-1}}. \tag{1.82}$$

The value of the subsidy that eliminates this distortion in equilibrium is

$$\tau^{SP} = -Spread \tag{1.83}$$

after substitution and using($R = \frac{1}{\beta}$)

$$\frac{K}{L} = [\left[\frac{1 - \beta[1-\delta]}{\alpha\beta}\right]]^{\frac{1}{\alpha-1}}. \tag{1.84}$$

which is the efficient value of the variables when the two subsidies are implemented. When this subsidy to the return on capital is present, I can eliminate the financial distortion. In this case, I return to the conventional DSGE. The presence of the two subsidies delivers the efficient allocation.

1.6.2 Welfare Cost.

In this section, I present the measure of welfare used to analyze the welfare cost associated with each distortion. In order to accurately compare welfare, I follow the work of Schmitt-Grohé and Uribe (2004, 2007) and use a second-order approximation to the full model. I measure the welfare cost as the amount of consumption that agents in the Ramsey regime are willing to renounce in order to have the same welfare as in the alternative policy scenario. The level of welfare associated with the time-invariant stochastic allocation in the Ramsey policy conditional on a particular state of the economy in period zero is

$$V_0^R = E_0 \sum_{t=0}^{\infty} \beta^t U[C_t^R, L_t^R] \tag{1.85}$$

the variables (C_t^R, L_t^R) are the contingent plans for consumption and labor under the Ramsey policy. Similarly, an implementable regime has conditional welfare equal to

$$V_0^I = E_0 \sum_{t=0}^{\infty} \beta^t U[C_t^I, L_t^I] \tag{1.86}$$

As in Schmitt-Grohé and Uribe (2007), I assume that at time zero, the value of all the variables are equal to their non-stochastic Ramsey steady-state. Using this assumption helps to ensure that the economy starts from the same initial point under all the alternative regimes. If the consumption cost of following an alternative policy regime instead of the Ramsey policy on a particular state in period zero is represented by $[W^C]$ the cost of the alternative policy is implicitly defined by

$$V_0^I = E_0 \sum_{t=0}^{\infty} \beta^t U[(1 - W^C)C_t^R, L_t^R]. \tag{1.87}$$

where $[W^C]$ is the fraction of consumption of the Ramsey regime that a household is willing to renounce in order to be indifferent between that regime and the alternative policy. Using the particular utility function

$$U = \ln(C_t - hC_{t-1}) - \frac{\chi}{1+} L_t^{1+\psi},$$

solving equation (1.87) for $[W^C]$ and approximating to a second order, the cost of choosing an alternative policy is

$$W^C \approx \frac{1}{2}(1 - \beta)[V^R_{\sigma\varepsilon\sigma\varepsilon} - V^I_{\sigma\varepsilon\sigma\varepsilon}]\sigma_\varepsilon^2. \tag{1.88}$$

Table 1.3: Steady-State and Distortions.

		Social Planner	Benchmark	DSGE τ^{SP}	τ^{Mon}	$\tau^{SP}+\tau^{Mon}$
		(1)	(2)	(3)	(4)	(5)
1.	Consumption	0.7700	0.5375	0.5537	0.7487	0.7700
2.	Investment	0.3203	0.1415	0.1592	0.2829	0.3203
3.	Labor	0.4520	0.3333	0.3383	0.4424	0.4520
4.	Capital	12.8126	5.6616	6.3676	11.3176	12.8126
5.	Government	0.2726	0.1698	0.1782	0.2579	0.2726
6.	Output	1.3628	0.8488	0.8912	1.2896	1.3628

Table 1.4: Deterministic Welfare Cost

	Social Planner	Benchmark	DSGE or τ^{SP}	τ^{Mon}
	(1)	(2)	(3)	(4)
% SPA		1.6113	1.0216	0.0640

Table 1.5: Conditional Welfare (second order approximation)

	Social Planner	Benchmark	DSGE or τ^{SP}	τ^{Mon}	Flex Prices
	(1)	(2)	(3)	(4)	(5)
% SPA		1.8517	1.2567	0.5163	0.0484

The derivation of this measure of welfare cost is detailed in the Appendix A.4.

Welfare Costs of Each Distortion.

In this section, I present the welfare costs associated with each distortion in this model. By using the appropriate subsidies, it is possible to eliminate the identified distortions: monopolistic competition, financial frictions, or it is possible return to the flexible-price equilibrium.

Table 3 presents the values of selected variables in the steady state when different subsidies are in place. The first column shows the efficient case. The second column presents the benchmark case in the presence of the monopolistic and financial distortions

The utilization of a subsidy to the excess return on capital (τ^{SP}) delivers the allocation associated with the conventional DSGE. In the column (4), I make use of a subsidy to the sales in steady state (τ^{Mon}) in order to remove monopolistic competition. Hence, the financial frictions are the sole distortion.

As shown in table 3, the largest distortion in steady state is associated with the presence of monopolistic competition. Table 4 shows the welfare cost in the non-stochastic steady state associated with each of the cases described above. The cost is the percentage of the stream of consumption of the social planner's allocation that the agents would be willing to renounce in order to have the same welfare as in the alternative case.

The monopolistic competition implies a cost of 1.02 percent, respect to the efficient allocation (column (3)). The presence of the friction in the financial sector has a cost of 0.06 percent (last column). When the two frictions are present, the welfare cost increases to 1.6 percent, this is the benchmark case. Table 5 presents the conditional welfare cost when there is uncertainty in the economy.

The highest conditional welfare cost is observed in the benchmark economy (1.85%). When there is a subsidy to the excess return on capital (τ^{SP}), the conditional welfare cost is 1.26 percent (column (3)). This is the cost of monopolistic competition and sticky prices.

When there is only a subsidy to monopolistic competition (τ^{Mon}), the conditional welfare cost is 0.52 percent (column (4)). This is the cost of the financial friction in the presence of uncertainty. In the deterministic case, the cost of the financial friction (0.064%) is a small fraction of the cost of monopolistic competition (1.02%). However, when uncertainty is present, the financial friction has a considerable welfare cost (0.52%).

1.6.3 Ramsey Policy.

In this section, I present the optimal monetary policy in the presence of financial frictions. The Ramsey planner seeks to maximize the welfare of the society subject to the competitive equilibrium conditions. I assume that the central bank is committed to follow the announced plan from a timeless perspective (Woodford (2003)). As in Schmitt-Grohé and Uribe (2005), I assume that at time (t) the Ramsey planner has been operating for an infinite number of periods.

The period (t) objective function of the Ramsey planner is the utility function

$$U_t = \ln(C_t - hC_{t-1}) - \frac{\chi}{1+} L_t^{1+\psi}. \tag{1.89}$$

I assume that the discount factor of the Ramsey planner is equal to the subjective discount factor of households in the competitive economy (β). This policy maker maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t U[C_t, L_t] \tag{1.90}$$

subject to the competitive equilibrium conditions.

Then, the central bank maximizes the welfare function (1.90) subject to the competitive equilibrium restrictions choosing at period (t) processes for the 30 endogenous variables U_{ct}, C_t, Λ_t, L_t, v_t, x_t, η_t, z_t, ϕ_t, K_{t+1}, N_t, N_{et}, N_{nt}, R_{kt+1}, Y_{mt}, Q_t, δ_t, U_t, I_{nt}, P_{mt}, G_t, I_t, Y_t, Δ_t, F_t, Z_t, π_t^*, π_t, R_t, i_t and the 29 Lagrange multipliers.

The process for the shocks A_t, τ_t, ξ_t, θ_t, g_t are the same as those described in the competitive equilibrium. The values for the variables listed above are given dated t <0, and also the values of the Lagrange multipliers associated with the competitive equilibrium constraints are given at t <0. Then, as explained in Schmitt-Grohé and Uribe (2005), the structure of the optimality conditions associated with the Ramsey equilibrium are time-invariant.

The Appendix A.5 presents the Lagrangian for the optimal policy from a timeless perspective.

In the next section, I present the optimal monetary response when the economy is hit by: a shock to the quality of capital, a shock to productivity, and a cost-push shock.

Shock to the Quality of Capital.

In the presence of a feedback loop between real and financial activity, a decrease in the quality of capital leads to a fall in the asset prices, which decrease the value of the bank. A bank's net worth is less valuable. This tightens the balance sheet constraint and reduces the supply of credit. The decrease in the supply of loans makes credit more expensive, this is reflected in the higher premium on loans. In turn, this results in lower investment. The decrease in investment and output depresses asset prices, which then feeds back into reduced net worth and investment, creating a feedback loop between the financial and real variables. This is the financial accelerator, which propagates and amplifies shocks.

The effects of not acting optimally are clearly observed in the Figure 2, in which the monetary policy is set according to the conventional Taylor rule, in that case the volatility of inflation and the real and financial variables is higher than in the optimal case. The optimizing central bank would like to smooth this financial accelerator.

Figure 1.1: Optimal Policy. Shock to Quality of Capital.

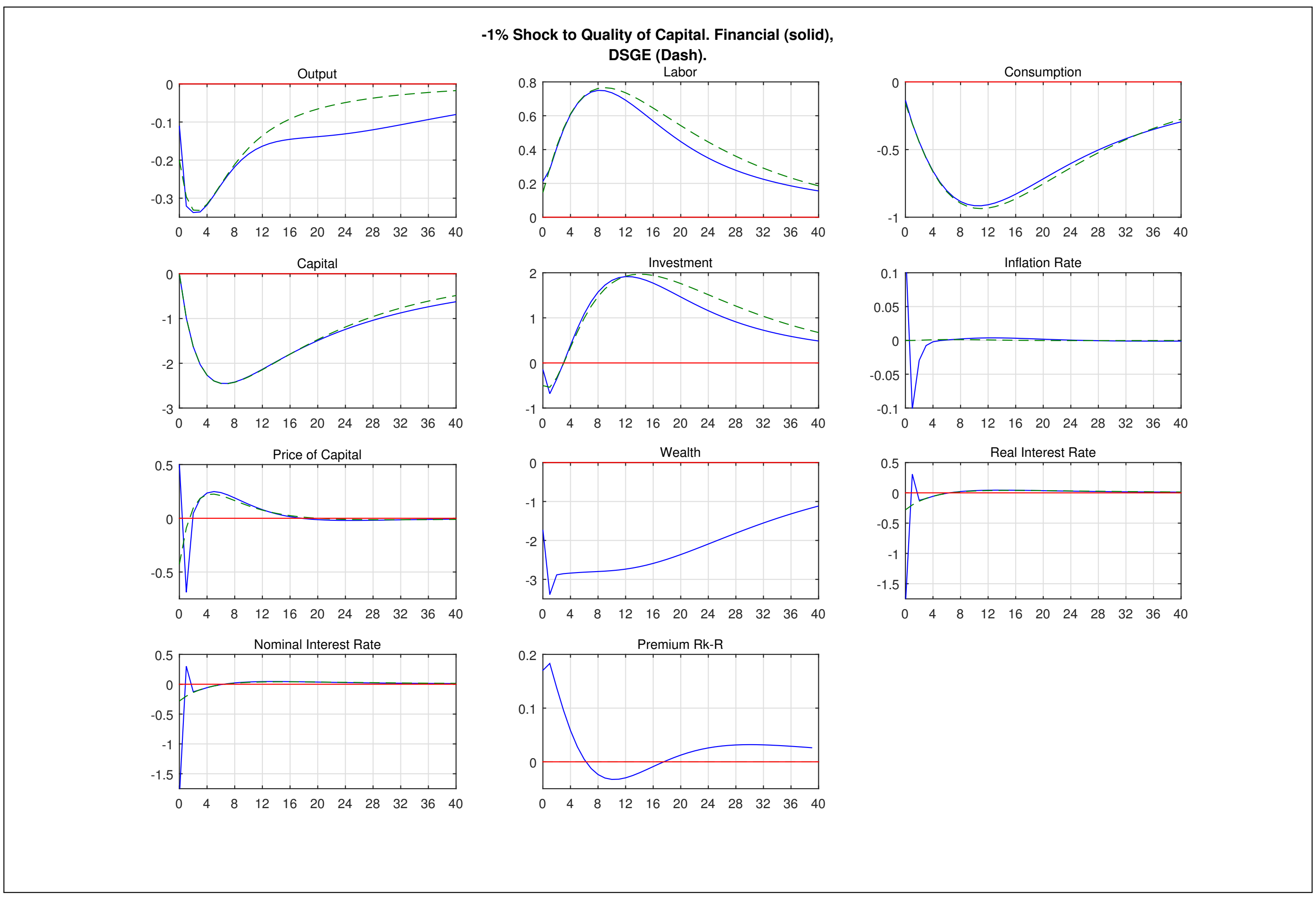

Figure 1. Optimal Policy. 1% Reduction in the Quality of Capital. Financial Model (solid) and DSGE (dashed).

In order to understand the relevance of the optimal policy in this economy with financial frictions, I conduct a series of comparisons. Firstly, figure 1 shows the optimal policy in this model with financial (solid lines) and compares the policy with that implemented in a model without financial frictions (dashed lines).

Secondly, figure 2 shows the impulse response to a decrease in the quality of capital when policy is implemented via the conventional Taylor rule. The solid lines show the model with financial frictions and the dashed lines the model without such frictions.

Finally, I present the gap variables in the figure 3. In order to define the gap variables, I follow the work of Leith et al. (2015). This gap is the difference between the actual value of the variable and the value that would be chosen by a benevolent social planner as a percentage of the value chosen by this planner. In other words, the gap is the difference between the optimal and the efficient response.

Figure 1 shows that when there is optimal commitment, consumption shows similar optimal responses when financial frictions are present and when the are absent. The greatest differences are observed in the inflation, investment, financial variables, and interest rates.

Compared to the optimal policy in the conventional DSGE (figure 1), monetary policy tends to induce a larger reduction in the nominal interest rate. In the absence of financial frictions, the optimal policy is to stabilize inflation. In contrast, in the presence of these frictions, monetary policy is more expansionary. This leads to an initial burst of inflation. On impact, the expansionary policy serves to increase the price of capital. This policy seeks to appreciate the bank's assets in order to reduce the tightening of the bank's balance sheet and foster an increase in the credit supply, reducing the inefficiency associated with the financial friction. As a consequence of this policy, the bank's net worth prevented from falling as much as it would in the case of implementing policy under the conventional Taylor rule (figure 2).

Figure 1.2: Taylor Rule. Shock to Quality of Capital.

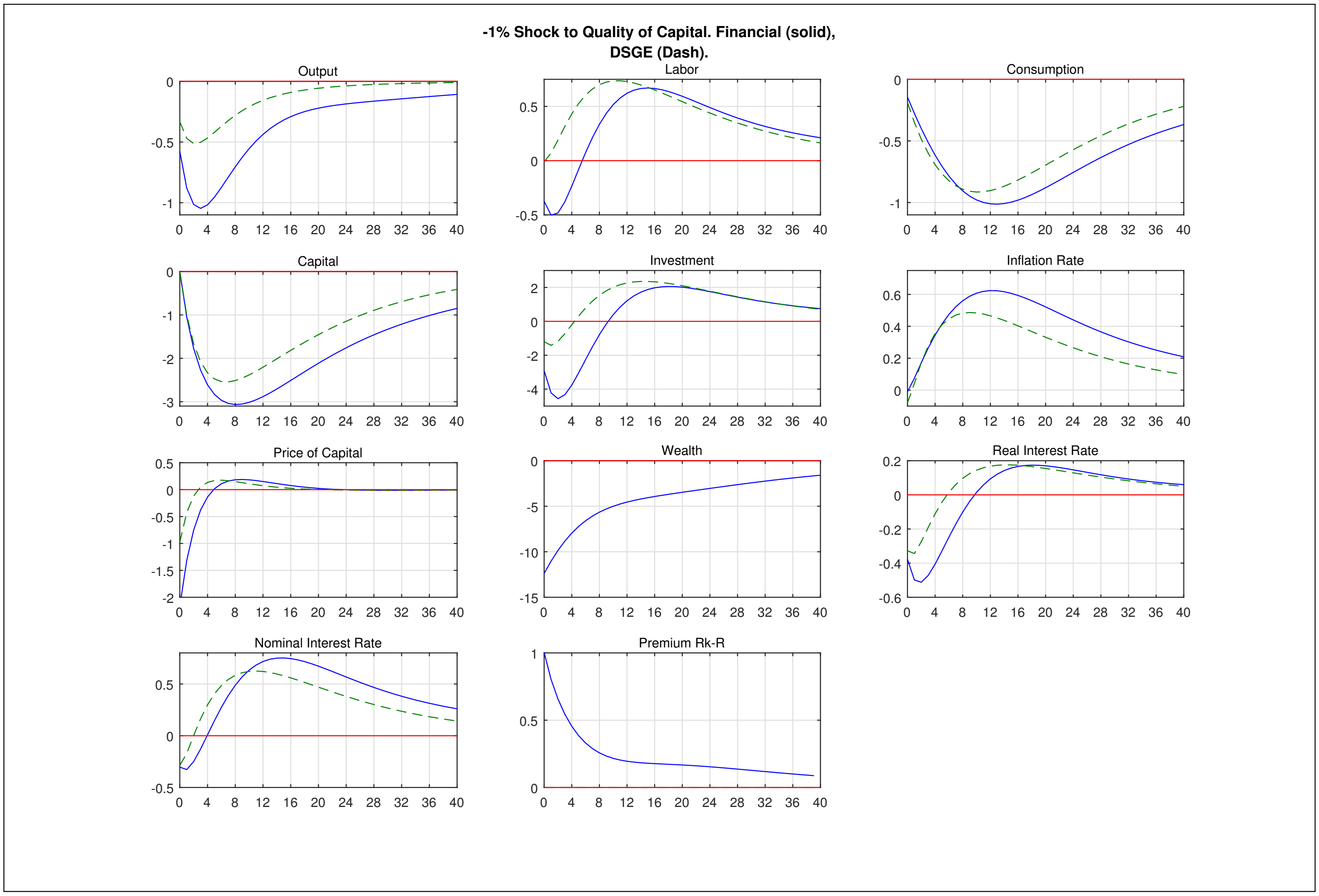

Figure 2. Taylor Rule. 1% Fall in the Quality of Capital. Financial Model (solid) and DSGE (dashed).

The optimal policy dampens the effects of the shock on the financial variables. For example, under simple rules, on impact, the net wealth of the banks falls 12.5 percent and the premium on capital jumps 100 basis points. At the deepest of the recession, output is 1 percent below equilibrium while investment is 5 percent below its long-term average. The conventional Taylor rule produces larger fluctuations in financial and real activity and it is very costly in terms of welfare (last row in table 6). In contrast, the optimal policy prevents this from happening.

The optimal policy stabilizes the financial sector at the cost of increased inflation. It is optimal to trade-off inflation for financial stability. The combination of monopolistic competition and financial frictions create a non-constant wedge between the flexible-price economy and the efficient allocation. The objective of a maximizing policy maker is to keep the economy as close as possible to the efficient allocation. This explains the initial reaction of the central bank; the strong reduction in the nominal interest rate keeps the economy as close as possible to its efficient allocation.

The central bank induces a reduction in the nominal rate, which has the effect of reducing the real rate, via the Fisher relation, and increasing inflation. The reduction in the real interest rate has two effects on the financial sector. Firstly, it appreciates the prices of the assets, by stimulating investment. Secondly, it reduces the cost of deposits for the banks. The central bank realizes that in order to stop the feedback loop between financial and real activity, it is necessary to protect the profitability of banks. If agents are content with the profitability of the banking sector, then the incentive constraint does not tighten. This avoids the inefficient jump in the premium on capital observed when the policy is conducted in a Taylor fashion.

In this way, the gap between the actual level of output and the efficient allocation remains as small as possible. If the central bank does not smooths the financial accelerator, the feedback loop between real and financial variables pushes the economy away from the efficient allocation. Inflation stabilization is suboptimal in the presence of financial frictions.

There is an additional aspect of the optimal policy which I highlight. The initial reduction of 1.5 percent in the real interest rate explains the initial increase in inflation of 15 basis points. This expansionary policy is reflected on the output. Compared to the conventional DSGE, output decreases only 0.1 percent, whereas in the DSGE the initial reduction is 0.2 percent. Given that the financial accelerator is procyclical, the optimal policy smooths its effects. However, in the subsequent periods the optimal policy is reversed.

For example, in the second period the central bank contracts the economy. The increase in the nominal and real interest rate deflate the price of the assets. The cost of credit increases in the second period and investment and net wealth falls more than in the initial period. This change in policy is explained by the desire of the central bank to achieve price-level control in the long-run.

In order to compensate for the initial increase in inflation it is optimal to reduce inflation in the next period and keep this deflation for the next three periods. After four periods, the inflation rate remains very close to its long-run equilibrium. This strategy of the central bank enables effective control of inflation in the long-run. In turn, the control of inflation in the long-run also generates price level control (once the inflation indexation has been removed) which is typical of the optimal commitment in models without financial frictions (Woodford (2003)). Even when financial frictions are present, price level control holds under commitment.

Hence, the optimal policy in the short-run is to stabilize the financial markets to prevent inefficient fluctuation of real activity. However, once the feedback loop between financial and real variable has been smoothed, the central bank can focuses on inflation control. The central bank takes advantage of its commitment technology. It commits to initially contribute to stabilize financial markets in the short-run, at the cost of an increase in inflation, while it stabilizes inflation in the long-run, reducing the attention to the financial markets. This policy maximizes the social welfare.

As a conclusion, the welfare maximizing policy is the one that protects the financial sector. The stability of the financial sector prevents undesired fluctuation of the real variables. The optimal policy trades-off financial stability for inflation. This trade-off does not exist in the absence of financial frictions. Only after stabilizing the financial sector, the central bank seeks price-level control in the long-run. Price-level control is a result of optimal policy under commitment in the benchmark New Keynesian model. This is robust to the introduction of financial frictions.

Trade-offs Faced by the Ramsey planner. In order to understand the trade-offs faced by the Ramsey planner in this economy, I make use of an additional policy instrument. Suppose that the Ramsey planner has access to an optimal subsidy that eliminates the financial distortion.

When this subsidy is in place if a shock reduces the quality of capital, the nominal interest rate decreases by a smaller amount. This stimulates the private spending and prevents deflation. In that case, the financial sector is stabilized using the subsidy to the return on capital. The nominal rate stabilizes inflation. This case is akin to the model without financial frictions (dashed lines in the figure 1).

Now, I remove the subsidy. Removing that subsidy implies that the response of the policy maker changes completely. The policy maker seeks a profitable banking sector and stable inflation. However, with only one instrument, the central bank has to renounce to stabilizing inflation in the short-run. The interest rate has to do the job of the subsidy. In this case, the optimal policy is more expansionary. In this way, the cost of capital remains as close as possible to its long-run level. In making all the banks content with their expected return on assets, the policy maker helps them to meet their balance sheet constraint, and the optimal policy switches off the financial accelerator. This policy protects the financial system and avoids contagion to the real economy. Financial health becomes a key objective of this policy maker. But, the policy maker cannot simultaneously stabilize inflation and the financial sector. This is the case shown by the solid lines in the figure 1.

Gap Variables. Figure 3 shows the gap between the response of the Ramsey policy and the benevolent Social Planner. The economy is hit by a negative shock to the quality of capital. The left panel shows the model with financial frictions. The right panel shows the model without financial frictions.

Figure 1.3: Gap Variables. Shock to Quality of Capital.

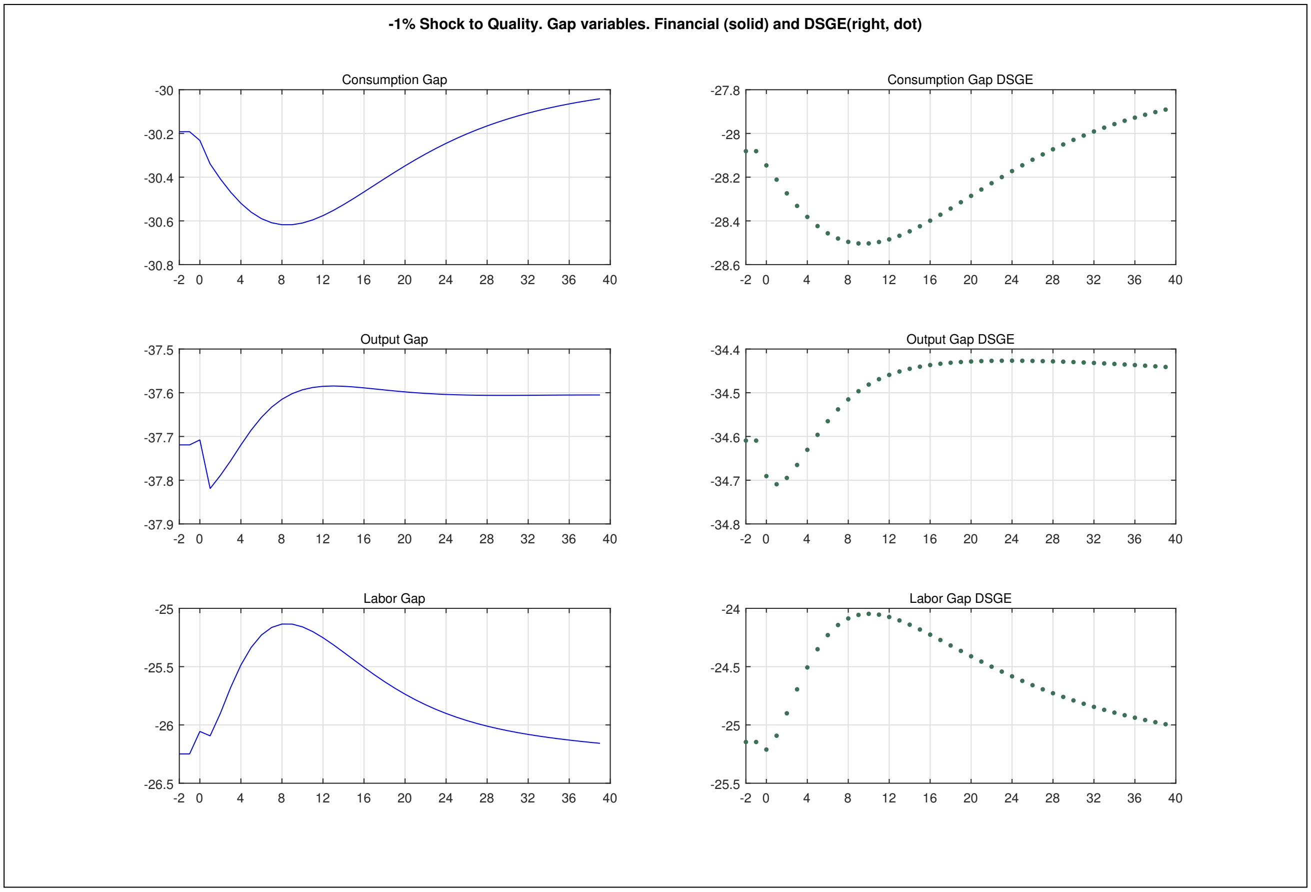

Figure 3. Gap Variables. 1% Reduction in the Quality of Capital. Financial Model (left) and DSGE (right). The gap is the difference between the actual level of the variable under the optimal policy and the efficient allocation as a percentage of the efficient allocation. A decrease in the output gap means that the economy is closer to the efficient allocation.

When the financial frictions are present, the optimal response is to reduce the nominal interest rate and increase inflation in the initial periods (figure 1). This is possible because there is an initial decrease in the output gap, the economy is closer to the efficient allocation, (left panel, figure 3). This initial decrease in the output gap contributes to the increase in the inflation. Because the financial accelerator is procyclical, the reduction in the gap smooths the feedback loop between real and financial variables. After this period, the output gap increases, which is associated with the fall in inflation in the second period. After these two periods the output gap decreases, which explains the smooth return of inflation to its long-run level and serve to stimulate the recovery of the financial variables.

This behavior is absent when the final markets are frictionless (right panel, figure 3). In this case, the optimal policy is to stabilize inflation. When the shock hits, the output gap increases and has an additional increase in the next period. After this, the output gap starts to close, in this way the central bank stabilizes inflation at its long-run level.

The figure 3 captures some of the contributions of financial frictions to the optimal policy. However, the economies in that figure feature monopolistic competition. Figure 4 shows the gap variables when there are financial frictions, but the monopolistic competition distortion has been removed. This isolates the effects of the financial friction.

In figure 4, a subsidy to the sales eliminates the distortion associated with the monopolistic competition (solid lines).

Figure 1.4: Gap Variables. Shock to Quality of Capital.

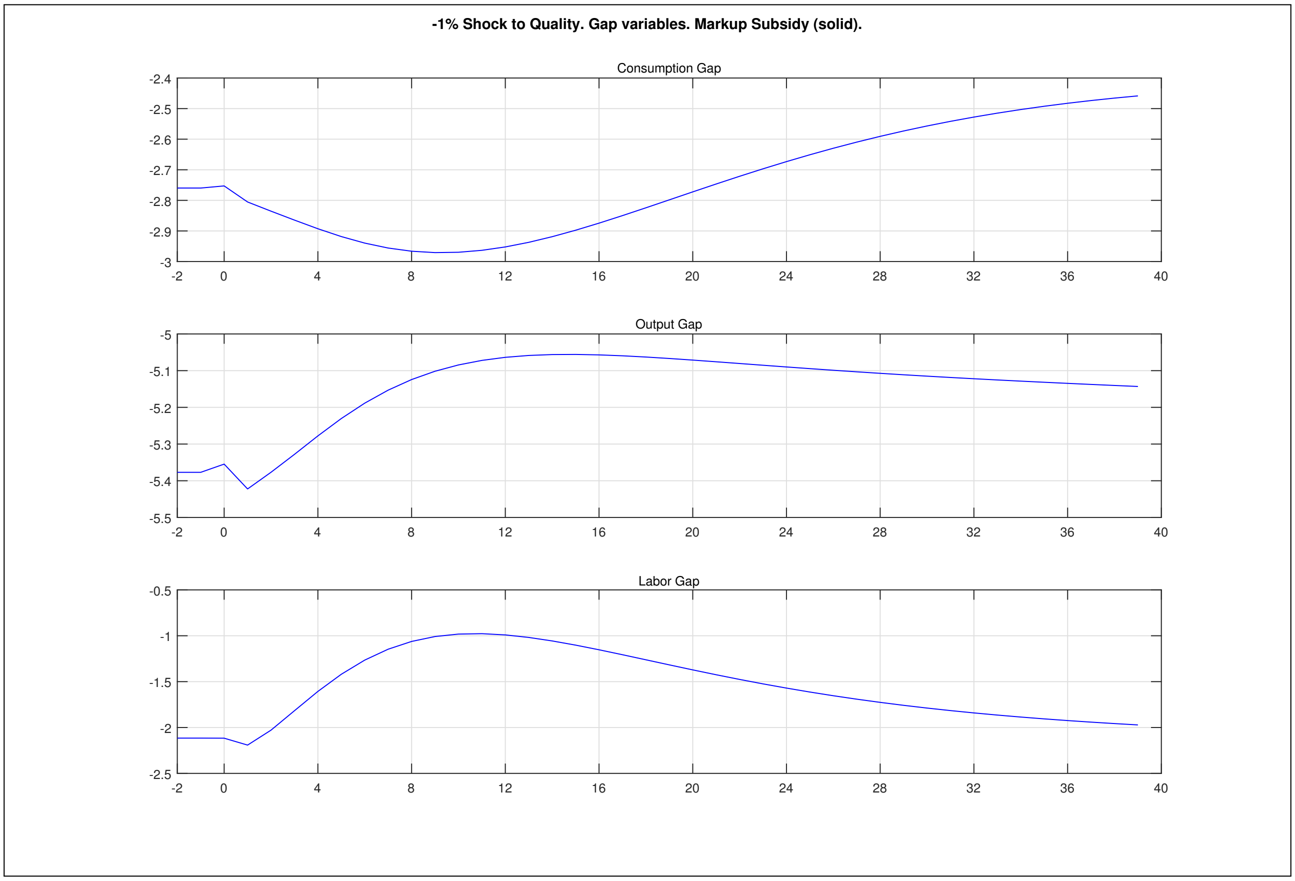

Figure 4. Gap Variables. 1% Reduction in the Quality of Capital. Financial Model (solid) . The solid lines show the gap between the economy without monopolistic competition and the efficient allocation. A decrease in the output gap means that the economy is closer to the efficient allocation.

When the financial friction is the sole distortion in steady state, the optimal response, after a shock to the quality of capital, implies a reduction in the output gap. In this way, the economy is closer to its efficient allocation and the effects of the financial accelerator are smoothed; the optimal monetary policy seeks to mimic the efficient response. This is why the central bank (figure 1) strongly reduces the interest rate in the benchmark case.

In the next section, I present the optimal policy when there is positive shock to productivity.

Shock to Productivity.

In the presence of a feedback loop between real and financial activity, an increase in productivity leads to higher asset prices, which revalues the bank's assets. This has the effect of loosening the balance sheet constraint and contributes to increase the supply of credit. The credit becomes cheaper, this is reflected in the fall of the premium on loans. In turn, this stimulates investment. The higher investment and output produce a boom in asset prices, which then feeds back into net worth and investment. This is the financial accelerator. Figure 5 shows the optimal response.

Figure 1.5: Optimal Policy. Shock to Productivity.

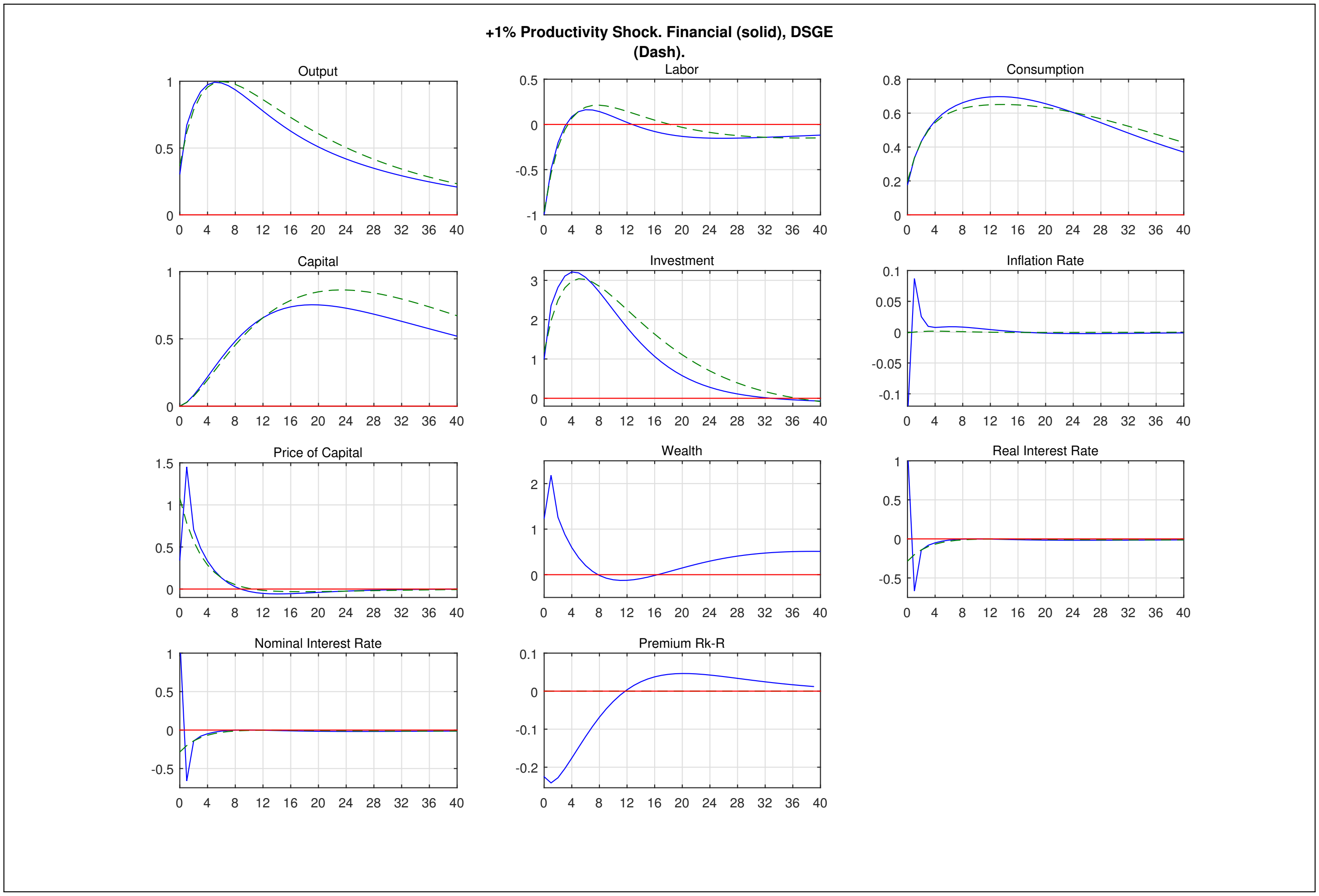

Figure 5. Optimal Policy. 1% Increase in Productivity. Financial Model (solid) and DSGE (dashed).

Compared to the optimal policy under the conventional DSGE, monetary policy tends to be contractionary. This leads to deflation. On impact, the tightening of policy serves to ameliorate the appreciation of the banks' assets. This serves to prevent an overexpansion in the supply of credit. Net worth is stopped to boom as it would be in the case of implementing policy under a Taylor rule in the presence of financial frictions (figure 6). This policy dampens the effects of the shock on the financial variables.

There is a procyclical relationship between output and the premium on capital when financial and real shocks hit the economy. Because this positive shock to productivity would reduce the premium on capital, banks could lend to non-financial firms at lower rates. This would increase investment. In order to prevent an overexpansion of investment, the central bank makes it more expensive for banks to fund new assets. This is the reason behind the increasing real interest rate in the first period.

This policy is effective at stabilizing the financial sector and preventing an overexpansion. But the cost is deflation. It is optimal to trade-off deflation for financial stability. In the case of optimal policy, less loans are granted to firms than in the case of policy implemented via simple rules (figure 6). This is so because the optimal response is to increase the nominal interest rate to keep the economy as close as possible to the efficient allocation. This prevents the boom observed under the Taylor rule.

In the presence of financial frictions, a one percent increase in productivity reduces inflation by 10 basis points. The central bank finds it optimal to undertake a monetary tightening in order to stabilize the financial markets. The monetary contraction reduces the boom in the financial sector, but at the cost of deflation. In contrast, when the financial frictions are absent, the optimal policy is expansionary, and inflation remains under control.

Figure 5 shows that in order to achieve price-level control, it is optimal for the central bank to undo its initial policy from the second period onwards. The central bank exploits the benefits of commitment in order to stabilize financial markets in the short-run and achieve price-level control in the long-run. The policy of the central bank turns expansionary in the second period, and this compensates for the initial deflation. As in the case of the shock to the quality of capital, the central bank deals initially with financial stability. Once this is achieved, the central bank can deal with inflation control. The central bank finds it optimal to keep the nominal interest rate below its long-run equilibrium for several periods. This compensates for the initial deflation.

In conclusion, when productivity shocks arise and financial frictions are present, the central banks exploits the benefits of commitment. In the short-run, it commits itself to financial stabilization. Once the inefficient fluctuation associated with the feedback loop between financial and real variables has been smoothed, it commits itself to price-level control in the long-run.

Figure 1.6: Taylor Rule. Shock to Productivity.

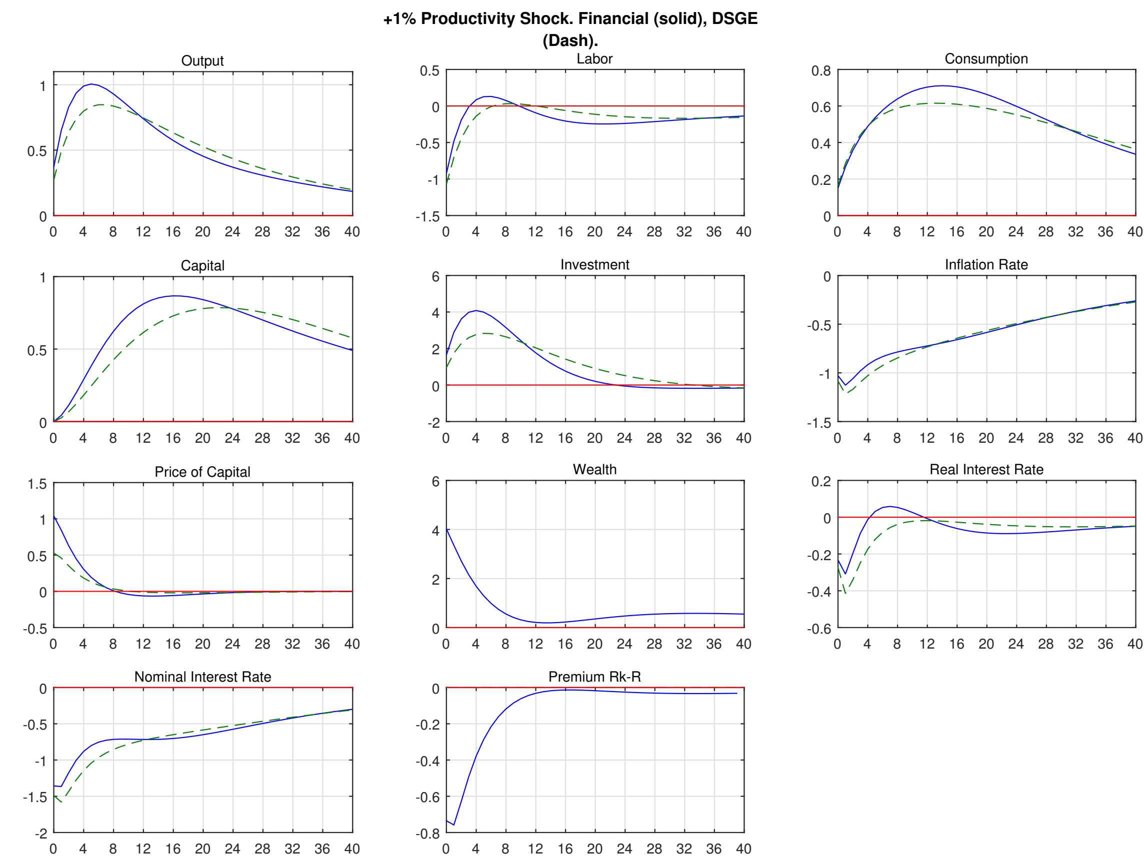

Figure 6. Taylor Rule. 1% Productivity Improvement. Financial Model (solid) and DSGE (dashed).

Cost-push shock.

In this section, I present the response of the Ramsey policy when there is a cost-push shock of one percent. Figure 7 shows the optimal response. As in the case of a shock to the quality of capital, the initial reaction needs to be very strong to prevent the starting of the financial accelerator and its contagion to the real sector. Indeed, the expansionary policy is very effective reducing the effects of this recessionary shock.

In the conventional DSGE, this shock is contractionary and inflationary and it creates a trade-off for policy. In the presence of financial imperfections, the trade-off remains. But given the presence of the financial accelerator, the trade-off is bigger. The initial reaction of the central bank is more inflationary than in the absence of financial frictions. This has the benefit of a milder recession, which prevents inefficient fluctuation of financial and real variables. In this case, the economy is kept as close as possible to the efficient allocation.

Figure 1.7: Optimal Policy. Cost-Push Shock.

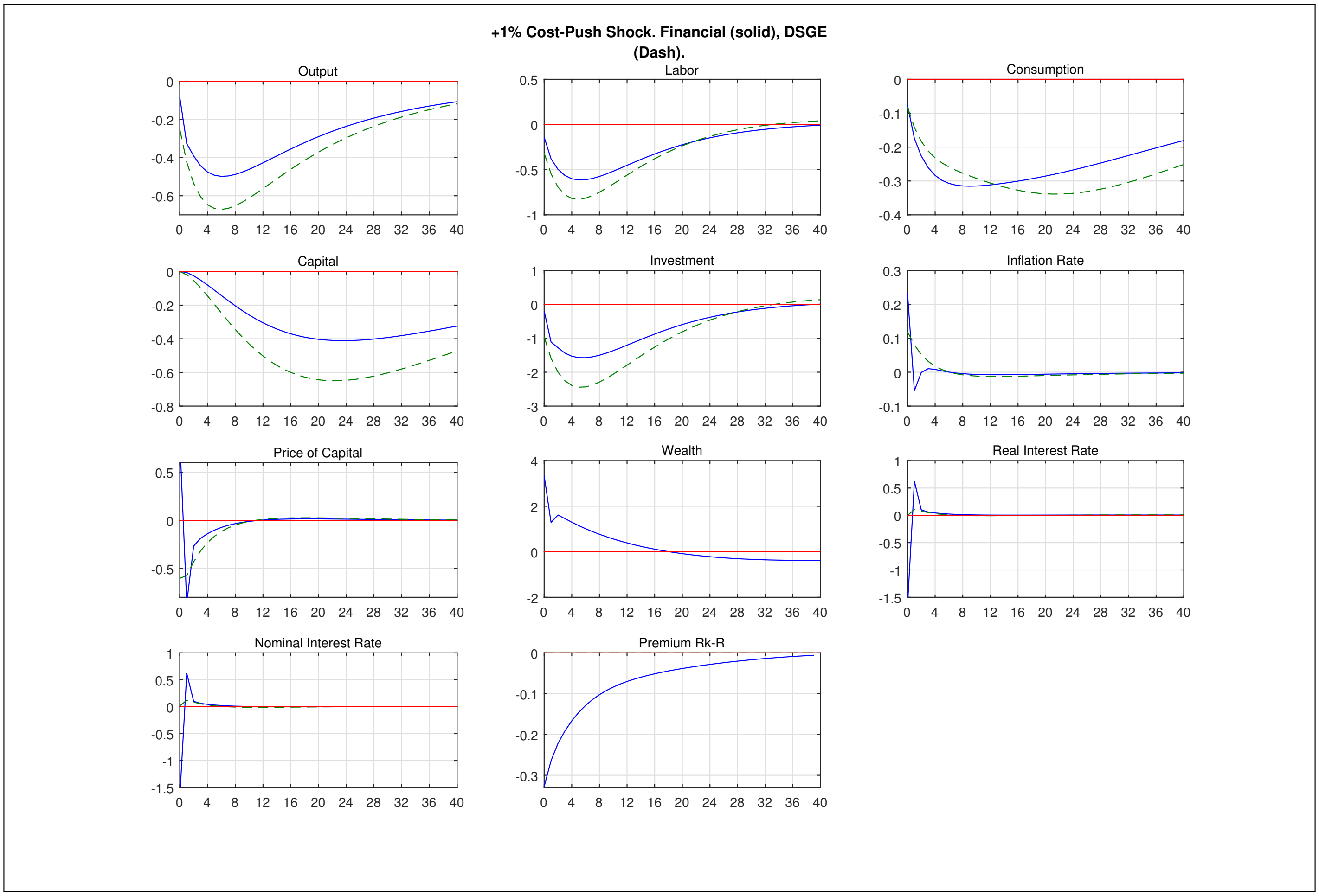

Figure 7. Optimal Policy. 1% Cost-Push Shock. Financial Model (solid) and DSGE (dashed).

In the next section, I deal with the implementation of optimal policy. In particular, I investigate whether the simple rules can implement optimal policy.

1.7 Implementation of Optimal Policy.

In this section, I deal with the implementation of optimal policy. I present the results of the welfare comparison across different regimes. Table 6 summarizes the main results. I restrict attention to policy rules that have the form

$$\begin{aligned} \ln(\left(\frac{i_t}{i}\right)) = & \quad \kappa_R \ln(\left(\frac{i_{t-1}}{i}\right)) + (1-\kappa_R)\{ \begin{array}{c} \kappa_\pi \ln((\frac{\pi_{t-m}}{\pi})) + \kappa_Y \ln((\frac{Y_{t-m}}{Y})) \\ +\kappa_{SP}[\ln E_t((\frac{R^k_{t+1}}{R_{t+1}})) - \ln((\frac{R^k}{R}))] \end{array} \}, \\ m = & \quad -1, 0, 1, \end{aligned} \tag{1.91}$$

Table 1.6: Implementation of the Optimal Policy

Table 1.7: Implementation of Optimal Policy (DSGE)

where (i_t) is the nominal interest rate and (i) is its long-run level, (π_t) is the inflation rate and (π) the long-run level of inflation. (Y_t) represents output and (Y) its steady-state level. (κ_π) is the policy coefficient on inflation deviations and (κ_Y) is the policy coefficient on output deviations. The index m can take three values 1,0, and -1. When m = 1, I refer to the interest rate rule as backward looking, when m = 0 as contemporaneous, and when i = -1 as forward looking.

Given that the optimal policy suggests stabilizing the financial variables, I explore the case in which the policy rule contains a coefficient (κ_{SP}) which measures the relevance of reacting to deviations of the premium on capital $E_t[[\frac{R^k_{t+1}}{R_{t+1}}]]$ respect to its average $[[\frac{R^k}{R}]]$.

1.7.1 Not Reacting to Financial Events.

Non-Inertial Rules.

The welfare cost represents the percentage of consumption that agents in the alternative policy scenario are loosing respect to the Ramsey regime. Optimized refers to a policy regime wherein the policy coefficients $[\kappa_\pi, \kappa_Y, \ \ \kappa_R, \ \kappa_{SP}]$ minimize the welfare cost. The search for policy coefficients was constrained to lie in the interval [0, 3].

When financial frictions are present and the optimized rule contains only the policy coefficients $[\kappa_\pi, \kappa_Y]$, the welfare-maximizing rule has policy coefficients equal to [2.325, 0]. This is shown in the first row of table 6. This policy costs 0.006 percent.

In order to have an understanding of the relevance of the coefficients in the previous rule, I compare these results to the case in which the financial frictions are absent. Table 7 presents the welfare costs of optimal rules in this case.

Initially, the search for the policy coefficients was restricted to lie in the interval $[0, 3]$. In this case, the policy coefficient on inflation takes the largest possible value and the cost is 0.003 percent (column (2)). This rule implements the optimal policy, which in the absence of financial frictions is akin to price stability.

When the upper bound on the search for optimal coefficient was removed, and it was allowed to take any non-negative value, the policy coefficient $[\kappa_\pi]$ takes a value of 305 (column(1)). This policy has a cost of 0.00001 percent. In this case, the policy coefficient $[\kappa_\pi]$ is large but finite. This reflects the desire of the optimizing policy maker to stabilize inflation in the absence of financial frictions.

One difference can be observed between the financial and non-financial models. In the conventional DSGE, the larger the value of the coefficient on inflation, the higher the welfare. Columns

(1) and (2) in table 7, show this. However, this is not the case in the financial model. For example, when the financial frictions are present, a policy rule with coefficients [5, 0] implies a welfare cost of 0.0064 percent. In the presence of financial frictions, inflation stabilization is not as desirable as it is in their absence.

One similitude can be observed between these economies. In both cases, the coefficient $[\kappa_Y]$ is equal to zero. Indeed, the costs increase as the value of the coefficient $[\kappa_Y]$ increases. For example, the policy rule [1.5, 0], in the conventional model costs 0.0044 percent. But the conventional Taylor rule, fourth column in table 7, implies a welfare cost of 0.0204 percent when financial frictions are added.

Similarly, in the financial model, the rule [1.5, 0] has a cost of 0.0105 (row 7 in table 6). The conventional Taylor rule [1.5, 0.5] costs 0.0216 percent (last row in table 6). Schmitt-Grohé and Uribe (2007) show and explain the reasons behind the optimality of not responding to changes in output in a model without financial frictions. If the monetary rule contains a cyclical component, in the face of productivity or supply shocks, the economy would not be allowed to adjust efficiently. This can create price dispersion, which in models with sticky prices is costly. After observing the results of the optimal rules, that result and explanation is robust to the presence of financial frictions.

Next, I show the effects of allowing an inertial term in the previous rules. After that section, I analyze whether a simple rule that reacts to financial variables, such as the cost of credit, can implement the optimal policy.

Inertial Rules.

In this section, I check the robustness of the previous results to the introduction of inertial policy rules. Woodford (2003, 2003b) and Sims (2013) show the advantages of introducing inertial components in the policy rules.

An inertial policy rule is a good approximation to the optimal policy under commitment. Reacting to an endogenous state variable serves the policy maker with the ability to exploit the expectational advantages of commitment. By having persistence in the rule, the central bank can anchor inflation expectations, which could in turn improve the current policy trade-offs faced when financial frictions are present.

Row 2 in table 6 shows the inertial rule. The fact that the optimized rule is inertial suggest that the central bank reacts more strongly to inflation in the long-run than in the short-run. This is observed also in the figures 1 and 5. The coefficient on the lagged value of the nominal interest rate takes the largest possible value. Reacting to contemporaneous inflation has a very small weight. It is optimal to not responding to output in this case. This rule welfare-dominates the non-inertial rule in the presence of financial frictions (row 1).

Backward Looking Rule.

The optimal backward looking rule also implies a zero reaction to the past level of output and to the past level of the nominal interest rate (row 3). When the nominal interest rate reacts to the past value of the variables, the cost are higher than in the contemporaneous or forward-looking rules.

Forward Looking Rule.

The forward looking rule, a rule that responds to expected inflation and the expected output deviations, also does a good job in approximating the welfare implied by the optimal commitment. This rule implies a strong reaction to future changes in inflation and zero reaction to future changes in output (row 4). When the rule is forward-looking the coefficient on the lagged value of the nominal rate is optimally driven to zero.

1.7.2 Reacting to the Financial Variables.

When the financial frictions are present, the optimized policy coefficient $[\kappa_\pi]$ takes a smaller value than in the model without these frictions. Inflation stabilization is not as desirable in this case as it would be in the absence of the financial frictions[6]. However, to what extent does reacting to changes in the cost of credit (the premium on capital) improve social welfare?

Rows 5 and 6 of table 6 provide an answer. If the monetary rule can react to changes in the spread between the return on capital and the risk-free rate, there are welfare gains. If, in addition, the rule is inertial, that rule is the welfare maximizing one (row 6).

Comparing rows 1, and 5, there is a cost-reduction of 0.0013 percent if monetary policy reacts to changes in the cost of credit. There are also welfare gains respect to the Taylor rule.

When the rule is inertial (row 6), the relevance of the feedback coefficient on the financial variable decreases but the welfare gain respect to the not reacting to changes in the cost of credit increases to 0.0036 percent (row 1 minus row 6). This is the welfare maximizing rule because making the policy rule history dependent serves to anchor inflation expectations. This allows the central bank to react to the financial events in the short-run and commit itself to increase the rate if necessary in the future. By exploiting the commitment technology, it is possible for the central bank to react to financial events in the short-run and inflation in the long-run.

1.7.3 A Summary of Optimal Implementation.

The welfare maximizing rule reduces the volatility in the financial markets. In the presence of financial frictions, inflation stabilization is not as desirable as it is in their absence.

[6] The determinacy properties are not altered by the introduction of the term reacting to changes in the spread on capital. The Taylor principle continues holding.

A simple rule that reacts to changes in the cost of credit is able to implement the optimal policy. Making that rule history dependent allows the central bank to smooth financial volatility in the short-run and commit itself, if necessary, to revert its policy in the future to achieve price-level control. This rule mimics the Ramsey policy.

1.8 Robustness Checks.

1.8.1 Monopolistic Competition.

The main distortion in the model is due to the presence of monopolistic competition. The elasticity of substitution across goods (ε) governs the degree of monopolistic competition in steady state. The value of this parameter used in the benchmark calibration follows the estimation results of Primiceri et al. (2006). However, this implies a markup of around 30 percent, which is in the upper bound of the conventional values. Hence, as a robustness check, I use a more competitive economy by increasing the value of (ε).

In the financial accelerator model, monopolistic competition is important because it results in a non-constant gap between the efficient and the natural allocation. And then, this can create a trade-off between inflation and financial stabilization.

In order to understand if the policy trade-offs remain in a more competitive economy, I derive optimal policy and its implementation for the case in which the economy is more competitive. For example, choosing a value of $\varepsilon = 11$, which would imply a markup of about 10 percent in steady state. The optimal policy is similar to that in the benchmark case. It is optimal to allow inflation to increase after a shock to productivity, a financial shock, or a markup shock. However, the size of the trade-off decreases. This is in line with Leduc and Natal (2015), who found in a model with a financial accelerator, similar to that in Bernanke, Gertler and Gilchrist (1999) that the policy trade-offs under monopolistic competition, price stickiness and financial frictions are increasing in the monopolistic competition.

1.8.2 Only Shocks to Productivity.

Optimized Rules.

When financial frictions are present and only productivity shocks are considered, the policy rule that implements the optimal policy, is inertial. These results are shown in table 8.

A central result is that when financial frictions are present, and the economy is subject only to a productivity shock, the coefficient on inflation is large, but it is several orders of magnitude smaller than when these frictions are absent. For example, in the conventional model, if there are only productivity shocks the welfare cost decreases in the size of the coefficient on inflation.

Table 1.8: Welfare comparison. Productivity shock

Figure 1.8: Welfare and Productivity Shocks

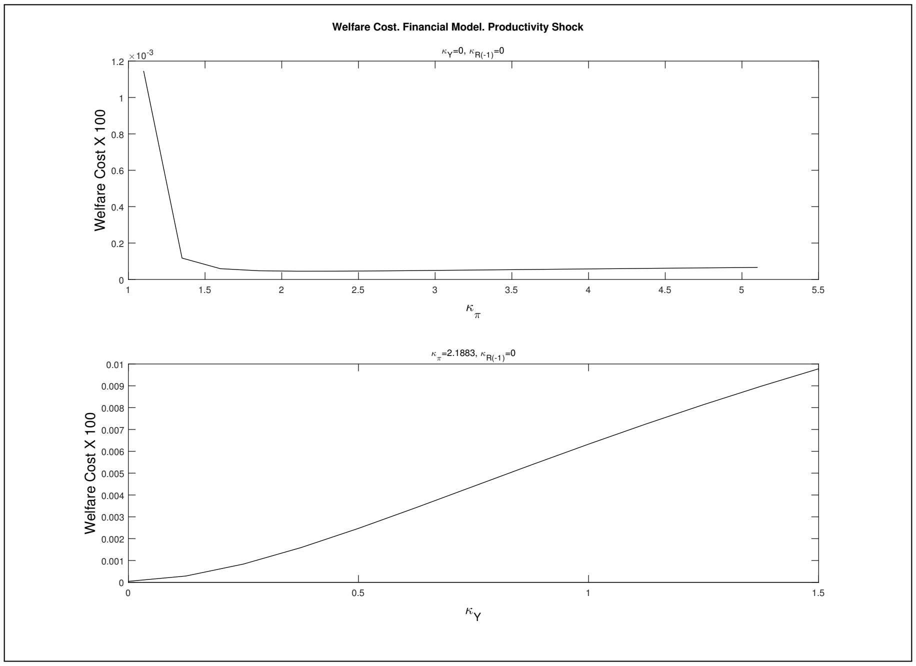

Figure 8. Welfare Cost in a Model with Financial Frictions and only Productivity Shocks. Top panel shows the welfare cost of increasing the feedback coefficient on inflation. Bottom panel shows the welfare cost of increasing the feedback coefficient on output.

Figure 1.9: Welfare and Productivity Shocks (DSGE)

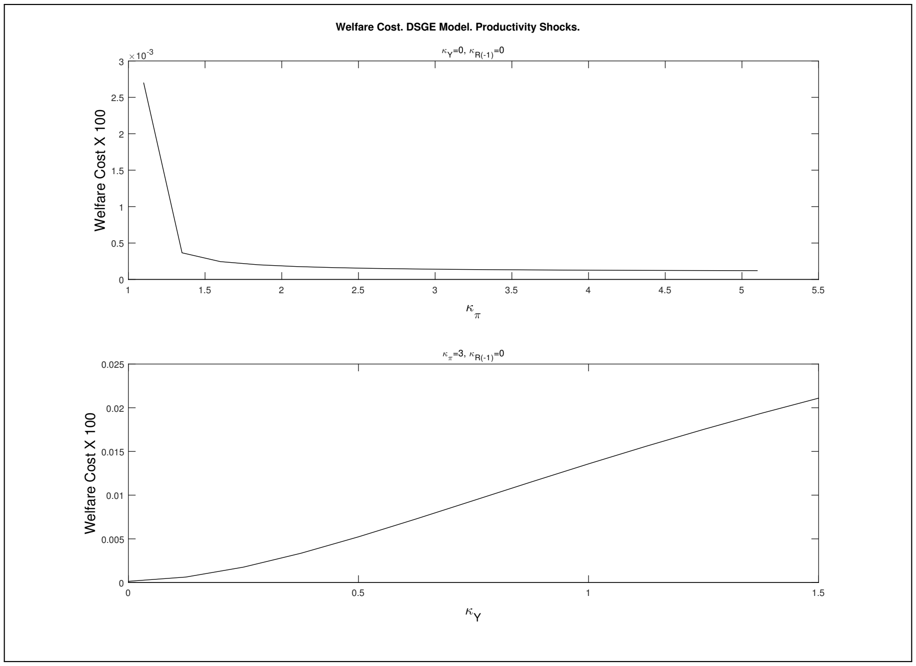

Figure 9. Welfare Cost in the DSGE Model and Only Shocks to Productivity. Top panel shows the welfare cost of increasing the feedback coefficient on inflation. Bottom panel shows the welfare cost of increasing the feedback coefficient on output.

Figure 8 shows that when financial frictions are present, welfare decreases if the weight of inflation in the policy rule is larger than 2.1883. Welfare costs are also increasing as the coefficient on output increases. Finally, figure 11 shows the same information as in figure 10 but for the conventional DSGE. In contrast, welfare costs are decreasing as the inflation coefficient increases. In this case, the policy rule would select a very large coefficient on inflation.

1.8.3 When all the shocks are present.

Figures 10 and 11 show the welfare cost if a shock to the quality of capital, a cost-push shock, and a shock to productivity are present. The top plot of figure 10 shows the welfare cost as the inflation coefficient increases in the presence of financial frictions. Figure 11 shows the case for the conventional model.

Figure 1.10: Welfare and Shocks

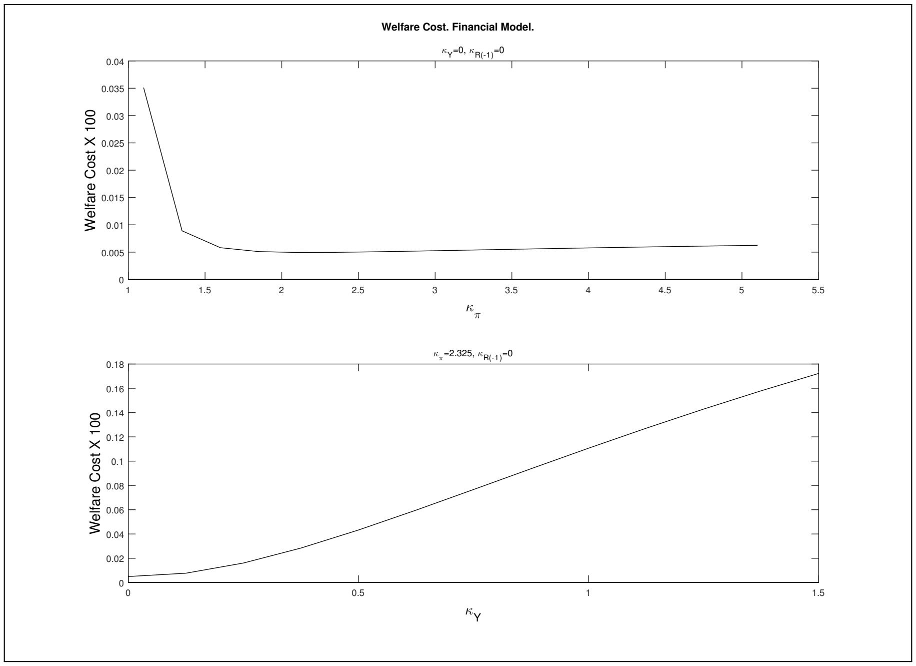

Figure 10. Welfare Cost in a Model with Financial Frictions and Various Shocks. The shocks are: a productivity shock, a shock to the quality of capital and a cost-push shock. Top panel shows the welfare cost of increasing the feedback coefficient on inflation. Bottom panel shows the welfare cost of increasing the feedback coefficient on output.

In figure 10, the analysis consider a set of shocks: a technology shock, a shock to the quality of capital and a cost-push shock. These shocks have been introduced previously in the text and the equation for them are contained in the quations 30, 31 and 34 in the Appendix A.5. In particular, the shock to the quality of capital follows Gertler and Karadi (2011) and it is introduced to mimic a financial crisis. The technology shock is a sudden decrease in the productivity in the economy, following previous literature, and the cost-push shock is a sudden increase in the markup of the firms.

The key difference between the two cases is that in the conventional model the cost decreases on the inflation coefficient (κ_π), while in the financial model there is a maximum value for this coefficient. In the conventional model, after a value of 5 the cost is closely flat. For small values of (κ_π) this cost decreases quickly as the inflation coefficient increases. In the financial model the cost is also decreasing for small values of (κ_π). But, this cost has a minimum at 2.325. For larger values the cost increases. These plots reflect the results of table 6. In both cases, welfare decreases as the coefficient on output increases.

Figure 1.11: Welfare and Shocks (DSGE)

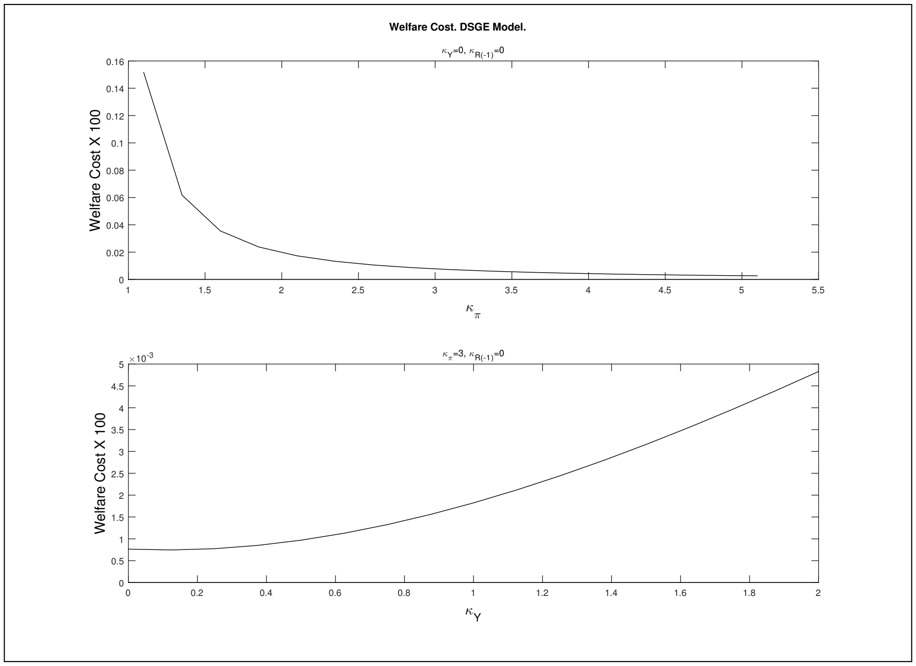

Figure 11. Welfare Cost in the DSGE Model and Various Shocks. The shocks are: a productivity shock, a shock to the quality of capital and a cost-push shock. Top panel shows the welfare cost of increasing the feedback coefficient on inflation. Bottom panel shows the welfare cost of increasing the feedback coefficient on output.

1.9 Conclusion.

In a standard New Keynesian model with a banking sector that faces balance sheet constraints, the optimal policy seeks to stabilize the financial markets by reducing the volatility of the cost of credit; a healthy financial sector is desirable. In this framework, there is a trade-off between inflation stabilization and financial stabilization. This holds if the economy is subject only to a productivity shock or if the economy becomes more efficient by reducing the monopolistic competition.

The implementation of optimal policy suggests stabilizing the spread between the return on capital and the risk-free rate. When a shock hits the economy, this policy suggests an aggressive reaction in the initial periods.

The simple rule that mimics optimal policy suggests a zero coefficient on changes in output, and a non-zero coefficient to changes in the premium on capital with respect to its long-run average. Stabilizing the financial sector enhances social welfare. In contrast, a strong anti-inflationary stance may be welfare decreasing. Additionally, inertial rules serve to anchor inflation expectations in the long-run, while stabilizing financial markets in the short-run, mimicking the optimal policy under commitment.

Appendix A

Appendix Chapter 1.

A.1 Derivation of Equations.

A.1.1 Households.

The maximization problem of the household can be expressed using the Lagrangian:

$$L = E_t\left\{ \begin{array}{c} \sum_{i=0}^{\infty} \beta^i [\ln(C_{t+i} - hC_{t+i-1}) - \frac{\chi}{1+\varphi} L_{t+i}^{1+\varphi}] \\ +\lambda_{t+i}[W_{t+i}L_{t+i} + \Pi_{t+i} + T_{t+i} + R_{t+i}[D_{t+i} + B_{t+i}^g] - [D_{t+i+1} + B_{t+i+1}^g] - C_{t+i}] \end{array} \right\}$$

The first order conditions are:

Respect to Consumption:

$$E_t\lambda_{t+i} = E_t[\frac{1}{(C_{t+i} - hC_{t+i-1})} - h\beta\frac{1}{(C_{t+i+1} - hC_{t+i})}] \tag{A.1}$$

Respect to labor:

$$\chi E_t L_{t+i}^{\varphi} = E_t\lambda_{t+i}W_{t+i} \tag{A.2}$$

Respect to Savings:

$$E_t\lambda_{t+i} = E_t\lambda_{t+i+1}R_{t+i+1} \tag{A.3}$$

And the Budget constraints:

$$W_{t+i}L_{t+i} + \Pi_{t+i} + R_{t+i}[D_{t+i} + B_{t+i}^g] - [D_{t+i+1} + B_{t+i+1}^g] + T_{t+i} = C_{t+i} \tag{A.4}$$

The marginal utility of consumption at period ($i = 0$) can be expressed as:

$$U_{ct} = E_t[\frac{1}{(C_t - hC_{t-1})} - h\beta\frac{1}{(C_{t+1} - hC_t)}] \tag{A.5}$$

Then, optimal labor supply is

$$\frac{\chi L_t^{\varphi}}{U_{ct}} = W_t \tag{A.6}$$

And the consumption-saving decision

$$1 = E_t\beta\frac{U_{ct+1}}{U_{ct}}R_{t+1}$$

It is defined

$$\Lambda_{t,t+i} = \frac{U_{ct+i}}{U_{ct}} \tag{A.7}$$

A.1.2 Financial Intermediaries.

incentive constraint and Maximization of Banks Final Wealth.

The bank is interested in maximizing its terminal net wealth (N_{jt+i}). It has a finite horizon and the probability of surviving from today to tomorrow is (θ_t). At the end of period t, the surviving bank maximizes its terminal wealth for the end of period $(t+1)$ on.

The bank's net wealth evolves as the difference between the return on its assets and the cost of funding them, eq.(1.9) in the main text

$$N_{jt+1} = [R_{t+1}^k - R_{t+1}]Q_tS_{jt} + R_{t+1}N_{jt}$$

and because the bank is not interested in funding projects with an expected discounted cost larger than its expected discounted return, the next condition should apply for the bank to operate

$$E_t\beta^{1+i}\Lambda_{t,t+1+i}[R_{t+1+i}^k - R_{t+1+i}] \geq 0 \tag{A.8}$$

in any period ($i \geq 0$).

At the end of period (t), a surviving bank has a probability of dying tomorrow equal to $(1-\theta_{t+1})$. If a bank survives that period with probability (θ_{t+1}), it will have a probability of leaving the industry in $(t+2)$ equal to $(1-\theta_{t+2})\theta_{t+1}$. Banks surviving that period, with probability (θ_{t+2}), have a probability of leaving the industry in $(t+3)$ equal to $(1-\theta_{t+3})\theta_{t+2}\theta_{t+1}$. So, the probability of dying in the period $(t+i)$ is $(1-\theta_{t+1+i})[\Pi_{k=t+1}^{t+i}\theta_k]$ for ($i \geq 0$). Then, at the end of period t, the bank maximizes its expected discounted terminal wealth according to

$$V_{jt} = \max E_t\sum_{i=0}^{\infty}(1-\theta_{t+1+i})[\Pi_{k=t+1}^{t+i}\theta_k]\beta^{i+1}\Lambda_{t,t+1+i}(N_{jt+1+i}) \tag{A.9}$$

which takes into account the evolution of terminal wealth (1.9), the discount factor ($\beta^{i+1}\Lambda_{t,t+1+i}$) and the survival pattern. Substituting the evolution of wealth eq.(1.9)

$$V_{jt} = \max E_t \sum_{i=0}^{\infty} (1-\theta_{t+1+i})[\Pi_{k=t+1}^{t+i}\theta_k]\beta^{i+1}\Lambda_{t,t+1+i}\left(\begin{array}{c} (R^k_{t+1+i} - R_{t+1+i})Q_{t+i}S_{jt+i} \\ +R_{t+1+i}N_{jt+i} \end{array} \right) \tag{A.10}$$

I can split the right-hand side of eq. $(A.10)$ in one term associated with total assets and other associated with the equity part. Then, the problem of the bank can be expressed as

$$V_{jt} = V^v_{jt} + V^\eta_{jt} \tag{A.11}$$

with

$$V^v_{jt} = \max E_t \sum_{i=0}^{\infty} (1-\theta_{t+1+i})[\Pi_{k=t+1}^{t+i}\theta_k]\beta^{i+1}\Lambda_{t,t+1+i}(R^k_{t+1+i} - R_{t+1+i})Q_{t+i}S_{jt+i} \tag{A.12}$$

and

$$V^\eta_{jt} = \max E_t \sum_{i=0}^{\infty} (1-\theta_{t+1+i})[\Pi_{k=t+1}^{t+i}\theta_k]\beta^{i+1}\Lambda_{t,t+1+i}R_{t+1+i}N_{jt+i} \tag{A.13}$$

Assets.

Now, working with the assets part eq.$(A.12)$

$$V^v_{jt} = \max E_t \sum_{i=0}^{\infty} (1-\theta_{t+1+i})[\Pi_{k=t+1}^{t+i}\theta_k]\beta^{i+1}\Lambda_{t,t+1+i}(R^k_{t+1+i} - R_{t+1+i})Q_{t+i}S_{jt+i} \tag{A.14}$$

the update one period-ahead of the previous equation is

$$V^v_{jt+1} = \max E_t \sum_{i=0}^{\infty} (1-\theta_{t+2+i})[\Pi_{k=t+2}^{t+1+i}\theta_k]\beta^{i+1}\Lambda_{t+1+i,t+2+i}(R^k_{t+2+i} - R_{t+2+i})Q_{t+1+i}S_{jt+1+i} \tag{A.15}$$

Eq. $(A.14)$ can be expressed as

$$\begin{aligned} V^v_{jt} = \quad & E_t(1-\theta_{t+1})\beta^1\Lambda_{t,t+1}(R^k_{t+1} - R_{t+1})Q_tS_{jt} + \\ & E_t \sum_{i=1}^{\infty} (1-\theta_{t+1+i})[\Pi_{k=t+1}^{t+i}\theta_k]\beta^{i+1}\Lambda_{t,t+1+i}(R^k_{t+1+i} - R_{t+1+i})Q_{t+i}S_{jt+i} \end{aligned}$$

and the second part of the right-hand side can be expressed as

$$V_{jt}^{v} = \quad E_t(1-\theta_{t+1})\beta\Lambda_{t,t+1}(R_{t+1}^{k}-R_{t+1})Q_tS_{jt}+ \\ E_t(\theta_{t+1})\beta\Lambda_{t,t+1}\sum_{i=0}^{\infty}(1-\theta_{t+2+i})[\Pi_{k=t+2}^{t+1+i}\theta_k]\beta^{i+1}\Lambda_{t+1+i,t+2+i}[\begin{array}{c}(R_{t+2+i}^{k}-R_{t+2+i})\\ Q_{t+i+1}S_{jt+i+1}\end{array}]$$

and using A.15

$$V_{jt}^{v} = \quad E_t(1-\theta_{t+1})\beta\Lambda_{t,t+1}(R_{t+1}^{k}-R_{t+1})Q_tS_{jt}+ \\ E_t(\theta_{t+1})\beta\Lambda_{t,t+1}V_{jt+1}^{v}$$

Multiplying by $((\frac{1}{Q_tS_{jt}}))$

$$\frac{1}{Q_tS_{jt}}V_{jt}^{v} = (1-\theta_{t+1})E_t\beta\Lambda_{t,t+1}(R_{t+1}^{k}-R_{t+1}) + E_t\theta_{t+1}\beta\Lambda_{t,t+1}\frac{1}{Q_tS_{jt}}V_{jt+1}^{v} \tag{A.16}$$

I can use the definitions ($v_t = \frac{V_{jt}^{v}}{Q_tS_{jt}}$) which implies ($v_{t+1} = \frac{V_{jt+1}^{v}}{Q_{t+1}S_{jt+1}}$). Substituting this in the previous equation

$$v_t = E_t(1-\theta_{t+1})\beta\Lambda_{t,t+1}(R_{t+1}^{k}-R_{t+1}) + E_t\theta_{t+1}\beta\Lambda_{t,t+1}\frac{1}{Q_tS_{jt}}v_{t+1}Q_{t+1}S_{jt+1}$$

defining the gross growth of asset between period (t) and $(t+i)$ as

$$x_{t,t+i} = \frac{Q_{t+i}S_{jt+i}}{Q_tS_{jt}}$$

I arrive to

$$v_t = E_t(1-\theta_{t+1})\beta\Lambda_{t,t+1}(R_{t+1}^{k}-R_{t+1}) + E_t\theta_{t+1}\beta\Lambda_{t,t+1}x_{t,t+1}v_{t+1} \tag{A.17}$$

Equity.

Working with the net wealth part eq. $(A.13)$

$$V_{jt}^{\eta} = \max E_t\sum_{i=0}^{\infty}(1-\theta_{t+1+i})[\Pi_{k=t+1}^{t+i}\theta_k]\beta^{i+1}\Lambda_{t,t+1+i}R_{t+1+i}N_{jt+i}$$

updating one period-ahead the previous equation

$$V_{jt+1}^{\eta} = \max E_t\sum_{i=0}^{\infty}(1-\theta_{t+2+i})[\Pi_{k=t+2}^{t+1+i}\theta_k]\beta^{i+1}\Lambda_{t+1+i,t+2+i}R_{t+1+i}N_{jt+i}$$

I can separate (V_{jt}^{η}) as

$$V_{jt}^{\eta} = E_t(1-\theta_{t+1})\beta\Lambda_{t,t+1}R_{t+1}N_{jt}+ E_t\sum_{i=1}^{\infty}(1-\theta_{t+1+i})[\Pi_{k=t+1}^{t+i}\theta_k]\beta^{i+1}\Lambda_{t,t+1+i}(R_{t+1+i})N_{jt+i}$$

starting the summation from zero

$$V_{jt}^{\eta} = E_t(1-\theta_{t+1})\beta\Lambda_{t,t+1}R_{t+1}N_{jt}+ E_t(\theta_{t+1})\beta\Lambda_{t,t+1}\sum_{i=0}^{\infty}(1-\theta_{t+2+i})[\Pi_{k=t+2}^{t+1+i}\theta_k]\beta^{i+1}\Lambda_{t+1+i,t+2+i}(R_{t+2+i})N_{jt+i+1}$$

the term in the summation is the one period-ahead update of (V_{jt}^{η}). Then

$$V_{jt}^{v} = E_t(1-\theta_{t+1})\beta\Lambda_{t,t+1}R_{t+1}N_{jt}+ E_t(\theta_{t+1})\beta\Lambda_{t,t+1}V_{jt+1}^{v}$$

I define now $(\eta_t = \frac{V_{jt}^{\eta}}{N_{jt}})$ and $(\eta_{t+1} = \frac{V_{jt+1}^{\eta}}{N_{jt+1}})$. Multiplying the previous equation by $((\frac{1}{N_{jt}}))$

$$V_{jt}^{\eta}\frac{1}{N_{jt}} = E_t(1-\theta_{t+1})\beta\Lambda_{t,t+1}R_{t+1} + E_t\theta_{t+1}\beta\Lambda_{t,t+1}\frac{N_{jt+1}}{N_{jt}}\eta_{t+1}$$

the gross rate of net wealth between period (t) and $(t+i)$ can be defined as

$$z_{t,t+i} = \frac{N_{jt+i}}{N_{jt}}$$

Then, the previous equation can be written as

$$\eta_t = E(1-\theta_{t+1})\beta\Lambda_{t,t+1}R_{t+1} + E_t\theta_{t+1}\beta\Lambda_{t,t+1}z_{t,t+1}\eta_{t+1} \tag{A.18}$$

Equation $(A.11)$ is equal to

$$V_{jt} = \nu_t Q_t S_{jt} + \eta_t N_{jt} \tag{A.19}$$

Which is the conjectured solution to the banks problem.

A.1.3 Non-financial Intermediate Producers Firms.

The firm production function is

$$Y_{mt} = A_t(U_t\xi K_t)^{\alpha} L_t^{1-\alpha} \tag{A.20}$$

The income for the firms is the value of its product ($P_{mt}Y_{mt}$) plus the income coming from the reselling the undepreciated capital $(1-\delta_t)\xi_t K_t$.

The costs are: the wage bill (W_tL_t), the return on the capital acquired in the previous period and paid in this $(R_t^k)Q_{t-1}K_t$ and assuming that cost of replacement of worn out capital is unit, the profits problem for the firm in this period is to choose (U_t) and (L_t) to maximize

$$P_{mt}Y_{mt} + [Q_t - \delta_t]\xi_t K_t - R_t^k Q_{t-1}K_t - W_t L_t \tag{A.21}$$

subject to eq.($A.20$). The first order condition respect to labor is

$$(1-\alpha)P_{mt}\frac{Y_{mt}}{L_t} = W_t \tag{A.22}$$

Respect to Utilization rate.

$$\alpha P_{mt}\frac{Y_{mt}}{U_t} = bU_t^{\zeta}\xi_t K_t \tag{A.23}$$

I am assuming the depreciation function:

$$\delta_t = \delta_c + \frac{b}{1+\zeta}U_t^{1+\zeta} \tag{A.24}$$

$$\delta^{'}(U_t) = bU_t^{\zeta}$$

Return to Capital.

The return to capital is the remaining of the profits after paying the wage bill and the other costs of production. Substituting the optimal condition ($A.22$) in the profits equation ($A.21$) total profits should be zero as long as the firms pays all the return to capital to the banks

$$P_{mt}Y_{mt} + [Q_t - \delta_t]\xi_t K_t - R_t^k Q_{t-1}K_t - (1-\alpha)P_{mt}Y_{mt} = 0$$

simplifying and solving for the return to capital

$$R_t^k = \{\alpha P_{mt}\frac{Y_{mt}}{K_t} + [Q_t - \delta_t]\xi_t\}\frac{1}{Q_{t-1}} \tag{A.25}$$

where the value of the marginal productivity of capital is

$$\alpha P_{mt}\frac{Y_{mt}}{K_t}$$

A.1.4 Capital Producers.

Each period the firms chooses the level of net investment to solve

$$\max E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \Lambda_{t,\tau} \{(Q_t - 1) I_{nt} - f(\left(\frac{I_{n\tau} + I_{ss}}{I_{n\tau-1} + I_{ss}}\right))(I_{n\tau} + I_{ss})\}$$

with

$$f(\left(\frac{I_{n\tau} + I_{ss}}{I_{n\tau-1} + I_{ss}}\right)) = \frac{\phi_i}{2}(\frac{I_{n\tau} + I_{ss}}{I_{n\tau-1} + I_{ss}} - 1)^2 \tag{A.26}$$

The first order condition respect to net investment is

$$\begin{aligned} Q_t = \quad & 1 + \frac{\phi_i}{2}(\frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}} - 1)^2 + \phi_i(\frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}} - 1)(\left(\frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}}\right)) \\ & -\beta E_t \Lambda_{t,t+1} \phi_i(\frac{I_{nt+1} + I_{ss}}{I_{nt} + I_{ss}} - 1)(\left(\frac{I_{nt+1} + I_{ss}}{I_{nt} + I_{ss}}\right))^2 \end{aligned}$$

A.1.5 Retailers.

Demand for Final Product.

Each of the consumers of the final good must minimize the cost of buying one unit of the composite good. This good is aggregated according to:

$$Y_t = [\int_0^1 Y_{ft}^{\frac{\varepsilon-1}{\varepsilon}} df]^{\frac{\varepsilon}{\varepsilon-1}} \tag{A.27}$$

where (ε) is the elasticity of substitution between varieties.

Then, the minimization problem is

$$L_t = \int_0^1 P_{ft} Y_{ft} df + \lambda_t \{Y_t - [\int_0^1 Y_{ft}^{\frac{\varepsilon-1}{\varepsilon}} df]^{\frac{\varepsilon}{\varepsilon-1}}\}$$

The first order condition respect to (Y_{ft}) is

$$P_{ft} = \lambda_t [\int_0^1 Y_{ft}^{\frac{\varepsilon-1}{\varepsilon}} df]^{\frac{1}{\varepsilon-1}} Y_{ft}^{-\frac{1}{\varepsilon}} \tag{A.28}$$

Using the definition of the composite good

$$P_{ft} = \lambda_t Y_t^{\frac{1}{\varepsilon}} Y_{ft}^{-\frac{1}{\varepsilon}}$$

Solving for the demand of individual good (Y_{ft})

$$Y_{ft} = [\left[\frac{P_{ft}}{\lambda_t}\right]]^{-\varepsilon} Y_t \tag{A.29}$$

Substituting eq.$(A.29)$ in $(A.27)$

$$\lambda_t = [\int_0^1 (P_{ft})^{1-\varepsilon} df]^{\frac{1}{1-\varepsilon}} \tag{A.30}$$

The Lagrange multiplier can be though as the correct price index. Then,

$$\lambda_t = P_t \tag{A.31}$$

where the price index is defined as

$$P_t = [\int_0^1 (P_{ft})^{1-\varepsilon} df]^{\frac{1}{1-\varepsilon}}$$

Substituting eq.$(A.31)$ in $(A.29)$

$$Y_{ft} = [\left[\frac{P_{ft}}{P_t}\right]]^{-\varepsilon} Y_t \tag{A.32}$$

Which is the optimal demand for the final good (f). And substituting this in the definition of spending

$$\int_0^1 P_{ft} Y_{ft} df = S_t \tag{A.33}$$

I can write the aggregate spending of the consumer of the final good as

$$Y_t P_t = \int_0^1 P_{ft} Y_{ft} df \tag{A.34}$$

Evolution of the price index.

From the previous section we know that the price index is equal to:

$$P_t = [\int_0^1 (P_{ft})^{1-\varepsilon} df]^{\frac{1}{1-\varepsilon}}$$

Given that the fraction $(1-\gamma)$ of the firms reoptimize price in period (t) and that a fraction (γ) is not able to reoptimize in this period, and that those firms not reoptimizing this period partially index (γ^p) their price to the past period inflation$(\pi_{t-1}^{\gamma^\rho})$ and allowing for the optimal price to be (P_t^*), equation (1.39) can be written as:

$$P_t = [\int_0^{1-\gamma} (P_{ft}^*)^{1-\varepsilon} df + \int_{1-\gamma}^{\gamma} (\pi_{t-1}^{\gamma^\rho} P_{ft-1})^{1-\varepsilon} df]^{\frac{1}{1-\varepsilon}} \tag{A.35}$$

then,

$$P_t^{1-\varepsilon} = (1-\gamma)(P_t^*)^{1-\varepsilon} + \gamma(\pi_{t-1}^{\gamma^\rho} P_{t-1})^{1-\varepsilon} \tag{A.36}$$

Dividing $(A.36)$ by $(P_t^{1-\varepsilon})$

$$1 = (1-\gamma)(\left(\frac{P_t^*}{P_t}\right))^{1-\varepsilon} + \gamma(\pi_{t-1}^{\gamma^\rho}\pi_t^{-1})^{1-\varepsilon} \tag{A.37}$$

solving for the relative price

$$\frac{P_t^*}{P_t} = [\left[\frac{1-\gamma(\pi_{t-1}^{\gamma^\rho}\pi_t^{-1})^{1-\varepsilon}}{(1-\gamma)}\right]]^{\frac{1}{1-\varepsilon}} \tag{A.38}$$

Equation $(A.37)$ is the evolution of the optimal price.

A.1.6 Price setting.

Following Christiano et al. (2005), Ascari and Sbordone (2014) and Hornstein (2007), In each period there is a fixed probability $(1-\gamma)$ that a firm can reoptimize its price P_t^*. For those firms not reoptimizing this period they index their price to previous period inflation. This happens with a probability (γ). In this case

$$P_{it}^* = \pi_{t-1}^{\gamma^\rho} P_{it-1}$$

with the parameter $\rho \in [0,1]$ indicating the degree of indexation to previous period inflation. The problem is then

$$\max_{P_{it}^*} E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j}\gamma^j[(1-\tau_{t+j})\frac{P_{it}^*\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}Y_{it+j} - P_{mt+j}Y_{it+j}] \tag{A.39}$$

subject to the demand function

$$Y_{it+j} = (\left(\frac{P_{it}^*\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}\right))^{-\varepsilon}Y_{t+j} \tag{A.40}$$

The cumulative inflation between period (t) and $(t+j)$ is

$$\Pi_{t,t+j} = \begin{array}{cc} 1 & \text{for } j=0 \\ \frac{P_{t+1}}{P_t}\frac{P_{t+2}}{P_{t+1}}\frac{P_{t+3}}{P_{t+2}}\cdots\frac{P_{t+k}}{P_{t+k-1}} & \text{for } j \geq 1 \end{array}$$

$$\Pi_{t-1,t+j-1} = \begin{array}{cc} 1 & \text{for } j=0 \\ \frac{P_t}{P_{t-1}}\frac{P_{t+1}}{P_t}\frac{P_{t+2}}{P_{t+1}}\cdots\frac{P_{t+k-1}}{P_{t+k-2}} & \text{for } j \geq 1 \end{array}$$

Substituting demand eq.$(A.40)$ in eq.$(A.39)$

$$\max_{P_{it}^*} E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j}\gamma^j[\begin{array}{c} (1-\tau_{t+j})\frac{P_{it}^*\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}(\left(\frac{P_{it}^*\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}\right))^{-\varepsilon}Y_{t+j} \\ -P_{mt+j}(\left(\frac{P_{it}^*\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}\right))^{-\varepsilon}Y_{t+j} \end{array}] \tag{A.41}$$

which is equal to

$$\max_{P_{it}^*} E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j} \gamma^j [\begin{array}{c} (1-\tau_{t+j})((\frac{P_{it}^* \Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}))^{1-\varepsilon} Y_{t+j} \\ -P_{mt+j}((\frac{P_{it}^* \Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}))^{-\varepsilon} Y_{t+j} \end{array}] \tag{A.42}$$

the first order condition

$$E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j} \gamma^j [\begin{array}{c} (1-\varepsilon)(1-\tau_{t+j})((\frac{P_{it}^* \Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}))^{-\varepsilon} \frac{\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}} Y_{t+j} \\ -(-\varepsilon) P_{mt+j}((\frac{P_{it}^* \Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}))^{-\varepsilon-1}((\frac{\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}})) Y_{t+j} \end{array}] = 0 \tag{A.43}$$

simplifying

$$E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j} \gamma^j [\begin{array}{c} P_{it}^{*-\varepsilon}(1-\tau_{t+j})((\frac{\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}))^{1-\varepsilon} Y_{t+j} \\ -\frac{\varepsilon}{\varepsilon-1} P_{mt+j} P_{it}^{*-\varepsilon-1}((\frac{\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}))^{-\varepsilon} Y_{t+j} \end{array}] = 0 \tag{A.44}$$

solving for the optimal price

$$P_{it}^* E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j} \gamma^j (1-\tau_{t+j})(\left(\frac{\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}\right))^{1-\varepsilon} Y_{t+j} \tag{A.45}$$

$$= \frac{\varepsilon}{\varepsilon-1} E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j} \gamma^j P_{mt+j}(\left(\frac{\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}\right))^{-\varepsilon} Y_{t+j}$$

dividing by $((\frac{P_t}{P_t}))$

$$\frac{P_{it}^*}{P_t} P_t E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j} \gamma^j (1-\tau_{t+j})(\left(\frac{\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}\right))^{1-\varepsilon} Y_{t+j}$$

$$= \frac{\varepsilon}{\varepsilon-1} E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j} \gamma^j P_{mt+j}(\left(\frac{\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}\right))^{-\varepsilon} Y_{t+j} \tag{A.46}$$

using

$$P_t = P_t^{1-\varepsilon+\varepsilon}$$

and solving for the optimal price

$$\frac{P_{it}^*}{P_t} = \frac{\varepsilon}{\varepsilon-1} \frac{E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j} \gamma^j P_{mt+j}((\frac{\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}))^{-\varepsilon} Y_{t+j}}{E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j} \gamma^j (1-\tau_{t+j})((\frac{\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}}))^{1-\varepsilon} Y_{t+j}} P_t^{-(1-\varepsilon)-\varepsilon} \tag{A.47}$$

introducing the price inside the parenthesis in the numerator and denominator

$$\frac{P_{it}^*}{P_t} = \frac{\varepsilon}{\varepsilon - 1} \frac{E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j} \gamma^j P_{mt+j} (\frac{\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}} P_t)^{-\varepsilon} Y_{t+j}}{E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j} \gamma^j (1 - \tau_{t+j}) (\frac{\Pi_{t-1,t+j-1}^{\gamma^\rho}}{P_{t+j}} P_t)^{1-\varepsilon} Y_{t+j}} \tag{A.48}$$

using the definition of cumulative inflation

$$\frac{P_{it}^*}{P_t} = \frac{\varepsilon}{\varepsilon - 1} \frac{E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j} \gamma^j P_{mt+j} ((\frac{\Pi_{t-1,t+j-1}^{\gamma^\rho}}{\Pi_{t,t+j}}))^{-\varepsilon} Y_{t+j}}{E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j} \gamma^j (1 - \tau_{t+j}) ((\frac{\Pi_{t-1,t+j-1}^{\gamma^\rho}}{\Pi_{t,t+j}}))^{1-\varepsilon} Y_{t+j}} \tag{A.49}$$

Which is the optimal relative price for the firm.

Evolution of Inflation.

The price index is eq.$(A.31)$

$$P_t = [\int_0^1 (P_{ft})^{1-\varepsilon} df]^{\frac{1}{1-\varepsilon}}$$

Distributing between the $(1-\gamma)$ setting price optimally this period and this (γ) indexing their price to the previous period inflation

$$P_t = [\int_0^{1-\gamma} (P_{ft}^*)^{1-\varepsilon} df + \int_{1-\gamma}^1 (\pi_{t-1}^{\gamma^\rho} P_{ft-1})^{1-\varepsilon} df]^{\frac{1}{1-\varepsilon}}$$

integrating across each group

$$P_t^{1-\varepsilon} = [(1-\gamma)(P_t^*)^{1-\varepsilon} + \gamma(\pi_{t-1}^{\gamma^\rho} P_{t-1})^{1-\varepsilon}]$$

dividing by$(P_t^{1-\varepsilon})$

$$\frac{P_t^{1-\varepsilon}}{P_t^{1-\varepsilon}} = [(1-\gamma)(\left(\frac{P_t^*}{P_t}\right))^{1-\varepsilon} + \gamma(\pi_{t-1}^{\gamma^\rho} \frac{P_{t-1}}{P_t})^{1-\varepsilon}]$$

using inflation definition

$$1 = [(1-\gamma)(\left(\frac{P_t^*}{P_t}\right))^{1-\varepsilon} + \gamma(\pi_{t-1}^{\gamma^\rho} \pi_t^{-1})^{1-\varepsilon}] \tag{A.50}$$

A.1.7 Price Dispersion.

At the firm level demand must be equal to the supply, then

$$Y_{mft} = [\left[\frac{P_{ft}}{P_t}\right]]^{-\varepsilon} Y_t \tag{A.51}$$

From the intermediate good production

$$Y_{mft} = A_t(U_t\xi_t K_{ft})^\alpha L_{ft}^{1-\alpha} \tag{A.52}$$

Aggregate labor is

$$L_t = \int_0^1 L_{ft} df \tag{A.53}$$

Aggregate effective capital is

$$K_t = \int_0^1 K_{ft} df \tag{A.54}$$

And aggregating eq.(A.51)over all the firms and taking into account the definitions of aggregate variables

$$A_t(U_t\xi_t K_t)^\alpha L_t^{1-\alpha} = Y_t \int_0^1 [\left[\frac{P_{ft}}{P_t}\right]]^{-\varepsilon} df \tag{A.55}$$

Defining price dispersion as

$$\Delta_t = \int_0^1 [\left[\frac{P_{ft}}{P_t}\right]]^{-\varepsilon} df \tag{A.56}$$

Then, the aggregate resource constraint can be written as

$$Y_{mt} = Y_t \Delta_t \tag{A.57}$$

A.1.8 Evolution of Price Dispersion.

Price dispersion was defined as

$$\Delta_t = \int_0^1 [\left[\frac{P_{ft}}{P_t}\right]]^{-\varepsilon} df \tag{A.58}$$

Each period there is a fraction $(1-\gamma)$ choosing price optimally and (γ) indexing the price to the previous period inflation

$$\Delta_t = \int_0^{1-\gamma} [\left[\frac{P_{ft}^*}{P_t}\right]]^{-\varepsilon} df + \int_{1-\gamma}^1 [\pi_{t-1}^{\gamma^p} \frac{P_{ft-1}}{P_t}]^{-\varepsilon} df$$

multiplying inside the second integral by $((\frac{P_{t-1}}{P_{t-1}}))$

$$\Delta_t = \int_0^{1-\gamma} [\left[\frac{P_{ft}^*}{P_t}\right]]^{-\varepsilon} df + \int_{1-\gamma}^1 [\pi_{t-1}^{\gamma^p} \frac{P_{t-1}}{P_t} \frac{P_{ft-1}}{P_{t-1}}]^{-\varepsilon} df$$

integrating over the firms

$$\Delta_t = (1-\gamma)[\left[\frac{P_t^*}{P_t}\right]]^{-\varepsilon} + \gamma[\pi_{t-1}^{\gamma^p}\pi_t^{-1}]^{-\varepsilon}\Delta_{t-1} \tag{A.59}$$

from the price index, eq.$(A.38)$ I know

$$\{[1-\gamma(\pi_{t-1}^{\gamma^\rho}\pi_t^{-1})^{1-\varepsilon}]\frac{1}{1-\gamma}\}^{\frac{1}{1-\varepsilon}} = (\left(\frac{P_t^*}{P_t}\right))$$

substituting in $(A.59)$

$$\Delta_t = (1-\gamma)[\left[\frac{1-\gamma(\pi_{t-1}^{\gamma^\rho}\pi_t^{-1})^{1-\varepsilon}}{1-\gamma}\right]]^{\frac{-\varepsilon}{1-\varepsilon}} + \gamma[\pi_{t-1}^{\gamma^p}\pi_t^{-1}]^{-\varepsilon}\Delta_{t-1} \tag{A.60}$$

A.2 Set of Equilibrium Conditions. Conventional Monetary Policy

List of variables (36).

$$U_{ct}, C_t, R_t, \Lambda_{t,t+1}, L_t, P_{mt}, Y_t$$

$$v_t, R^k_{t+1}, x_{t,t+1}, \phi_t, z_t, \eta_t,$$

$$Q_t, K_t, N_t, N_{et}, N_{nt},$$

$$Y_{mt}, U_t,$$

$$I_{nt}, \delta_t, I_t, G_t, \tau_t,$$

$$\xi_t, g_t, A_t, \theta_t,$$

$$\Delta_t, \pi_t, F_t, Z_t, \pi^*_t,$$

$$i_t, S_{pt}$$

Households.

1. Marginal Utility of Consumption (U_{ct})

$$U_{ct} = E_t[(C_t - hC_{t-1})^{-1} - \beta h(C_{t+1} - hC_t)^{-1}]$$

2. Euler Equation. Consumption Saving (C_t)

$$\beta E_t \Lambda_{t,t+1} R_{t+1} = 1$$

3. Stochastic Discount Factor ($\Lambda_{t,t+1}$)

$$E_t \Lambda_{t,t+1} = E_t \frac{U_{ct+1}}{U_{ct}}$$

4. labor Market Equilibrium (L_t)

$$\frac{\chi}{(1-\alpha)} \frac{L_t^{\varphi+1}}{U_{ct}} = P_{mt} Y_{mt}$$

Banks.

5. Marginal Return on Bank's Assets (v_t)

$$v_t = E_t(1-\theta_{t+1})\beta\Lambda_{t,t+1}(R^k_{t+1} - R_{t+1}) + E_t\theta_{t+1}\beta\Lambda_{t,t+1}x_{t,t+1}v_{t+1}$$

6. Gross Growth of Bank Assets ($x_{t,t+1}$)

$$x_{t,t+1} = E_t\frac{\phi_{t+1}}{\phi_t}z_{t,t+1}$$

7. Marginal Return on Bank's Wealth (η_t)

$$\eta_t = E(1-\theta_{t+1})\beta\Lambda_{t,t+1}R_{t+1} + E_t\theta_{t+1}\beta\Lambda_{t,t+1}z_{t,t+1}\eta_{t+1}$$

8. Gross Growth of Bank Wealth ($z_{t,t+1}$)

$$z_{t,t+1} = E_t[(R^k_{t+1} - R_{t+1})\phi_t + R_{t+1}]$$

9. Leverage Ratio (ϕ_t)

$$\phi_t = \frac{\eta_t}{\lambda - v_t}$$

10. Aggregate Capital (K_t)

$$Q_tK_{t+1} = \phi_tN_t$$

11. Net worth in the banking sector (N_t)

$$N_t = N_{et} + N_{nt}$$

12. Existing wealth (N_{et})

$$N_{et} = \theta_{t-1}[(R^k_t - R_t)\phi_{t-1} + R_t]N_{t-1}$$

13. Wealth of new banks (N_{nt})

$$N_{nt} = wQ_t\xi_tK_t$$

Intermediate Producers.

14. Return to capital (R_{kt})

$$R^k_t = \frac{\xi_t}{Q_{t-1}}[\alpha\frac{P_{mt}Y_{mt}}{\xi_tK_t} + Q_t - \delta_t]$$

15. Production of Intermediate goods (Y_{mt})

$$Y_{mt} = A_t(U_t\xi_tK_t)^\alpha L_t^{1-\alpha}$$

Capital Goods Producers.

16. Investment (Q_t)

$$Q_t = \quad 1 + \frac{\phi_i}{2}(\frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}} - 1)^2 + \phi_i(\frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}} - 1)\frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}}$$
$$-E_t \beta \Lambda_{t,t+1} \phi_i (\frac{I_{nt+1} + I_{ss}}{I_{nt} + I_{ss}} - 1)(\left(\frac{I_{nt+1} + I_{ss}}{I_{nt} + I_{ss}}\right))^2$$

17. Depreciation function (U_t)

$$\delta_t = \delta_c + \frac{b}{1+\zeta} U_t^{1+\zeta}$$

18. Optimal Capacity Utilization (P_{mt})

$$\alpha P_{mt} \frac{Y_{mt}}{U_t} = b U_t^{\zeta} \xi_t K_t$$

19. Net Investment (δ_t)

$$I_{nt} = I_t - \delta_t \xi_t K_t$$

20. Law of movement of capital (I_{nt})

$$K_{t+1} = \xi_t K_t + I_{nt}$$

21. Exogenous government consumption (G_t)

$$G_t = G g_t$$

22. Aggregate resources (I_t)

$$Y_t = C_t + G_t + I_t + \frac{\phi_i}{2}(\frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}} - 1)^2 (I_{nt} + I_{ss})$$

Retailers

23. Final Production (Y_t)

$$Y_{mt} = Y_t \Delta_t$$

24. Price Dispersion (Δ_t)

$$\Delta_t = (1-\gamma)[\left[\frac{1 - \gamma(\pi_{t-1}^{\gamma^\rho} \pi_t^{-1})^{1-\varepsilon}}{1-\gamma}\right]]^{\frac{-\varepsilon}{1-\varepsilon}} + \gamma[\pi_{t-1}^{\gamma^p} \pi_t^{-1}]^{-\varepsilon} \Delta_{t-1}$$

25. Optimal Price Choice (F_t)

$$F_t = P_{mt} Y_t + E_t \gamma \beta \Lambda_{t,t+1} \pi_t^{-\gamma^\rho \varepsilon} \pi_{t+1}^{\varepsilon} F_{t+1}$$

26. (Z_t)

$$Z_t = (1-\tau_t)Y_t + E_t\gamma\beta\Lambda_{t,t+1}\pi_t^{\gamma^\rho(1-\varepsilon)}\pi_{t+1}^{-(1-\varepsilon)}Z_{t+1}$$

27. Optimal choice of price (π_t^*)

$$\pi_t^* = \frac{\varepsilon}{\varepsilon-1}\frac{F_t}{Z_t}\pi_t$$

28. Evolution of inflation (π_t)

$$\pi_t^{1-\varepsilon} = [(1-\gamma)(\pi_t^*)^{1-\varepsilon} + \gamma(\pi_{t-1}^{\gamma^\rho})^{1-\varepsilon}]$$

Policy and Exogenous Variables.

29. Fisher Equation (R_t)

$$i_t = E_t R_t \pi_{t+1}$$

30. Monetary policy (i_t)

$$\frac{i_t}{i} = E_t[\left[\frac{i_{t-1}}{i}\right]]^{\phi_R}[\left[\frac{\pi_t}{\pi}\right]]^{\phi_\pi}[\left[\frac{Y_t}{Y}\right]]^{\phi_Y}\varepsilon_{it}$$

31. Technology Shock

$$\ln A_t = \rho_a \ln A_{t-1} - \varepsilon_{at}$$

32. Capital Quality Shock (ξ_t)

$$\ln \xi_t = \rho_\varepsilon \ln \xi_{t-1} - \varepsilon_{\xi t}$$

33. Government Shock (g_t)

$$\ln g_t = \rho_g \ln g_{t-1} - \varepsilon_{gt}$$

34. Shock to the Probability of dying (θ_t)

$$\ln \theta_t = \rho_\theta \ln \theta_{t-1} - \varepsilon_{\theta t}$$

35. Markup shock (τ_t)

$$\ln(1-\tau_t) = \rho_\mu \ln(1-\tau_{t-1}) + (1-\rho_\mu)\ln(1-\tau) - \varepsilon_t^\mu$$

36. Premium (Sp_t)

$$S_{pt} = R_{kt} - R_t$$

Summary of Variables (36) **and Equations** (36).

A.3 Social Planner's Problem.

The Social Planner's Problem.

Introducing eq.(1.62) in eq.(1.63)

$$Y_t = C_t + G_t + I_t + \frac{\phi_i}{2}(\left(\frac{K_{t+1} - K_t[1+\xi_t] + \xi_{t-1}K_{t-1}}{K_t - \xi_{t-1}K_{t-1} + I_{ss}}\right))^2(K_{t+1} - \xi_t K_t + I_{ss}). \tag{A.61}$$

Combining eq.(1.62) with eq.(1.61) and introducing in eq.(A.61)

$$\begin{aligned} Y_t = \quad & C_t + G_t + K_{t+1} - (1-\delta_t)\xi_t K_t \\ & + \frac{\phi_i}{2}(\left(\frac{K_{t+1} - K_t[1+\xi_t] + \xi_{t-1}K_{t-1}}{K_t - \xi_{t-1}K_{t-1} + I_{ss}}\right))^2(K_{t+1} - \xi_t K_t + I_{ss}). \end{aligned} \tag{A.62}$$

Now, substituting eq.(1.60) in eq.(A.62)

$$\begin{aligned} Y_t = \quad & C_t + G_t + K_{t+1} - [1 - \delta_c - \frac{b}{1+\zeta}U_t^{1+\zeta}]\xi_t K_t \\ & + \frac{\phi_i}{2}(\left(\frac{K_{t+1} - K_t[1+\xi_t] + \xi_{t-1}K_{t-1}}{K_t - \xi_{t-1}K_{t-1} + I_{ss}}\right))^2(K_{t+1} - \xi_t K_t + I_{ss}). \end{aligned} \tag{A.63}$$

Finally, substituting eq.(1.59) in the previous equation

$$\begin{aligned} A_t(U_t\xi_t K_t)^\alpha L_t^{1-\alpha} = \quad & C_t + G_t + K_{t+1} - [1 - \delta_c - \frac{b}{1+\zeta}U_t^{1+\zeta}]\xi_t K_t \\ & + \frac{\phi_i}{2}(\left(\frac{K_{t+1} - (1+\xi_t)K_t + \xi_{t-1}K_{t-1}}{K_t - \xi_{t-1}K_{t-1} + I_{ss}}\right))^2(K_{t+1} - \xi_t K_t + I_{ss}). \end{aligned} \tag{A.64}$$

Then, the social planner chooses $[C_t, L_t, U_t \text{ and } K_{t+1}]$ to maximize the utility of the consumer eq.(1.58) subject to the restriction eq.(A.64). The Lagrangian for the problem is

$$\begin{aligned} L = \quad & E_t \sum_{t=0}^{\infty} \beta^t [\ln(C_t - hC_{t-1}) - \frac{\chi}{1+\varphi} L_t^{1+\varphi}] \\ & + E_t \sum_{t=0}^{\infty} \beta^t \lambda_t [\begin{array}{c} A_t(U_t\xi_t K_t)^\alpha L_t^{1-\alpha} \\ -C_t - G_t - K_{t+1} + [1 - \delta_c - \frac{b}{1+\zeta}U_t^{1+\zeta}]\xi_t K_t \\ -\frac{\phi_i}{2}((\frac{K_{t+1} - K_t(1+\xi_t) + \xi_{t-1}K_{t-1}}{K_t - \xi_{t-1}K_{t-1} + I_{ss}}))^2(K_{t+1} - \xi_t K_t + I_{ss}). \end{array}] \end{aligned} \tag{A.65}$$

The first order conditions are:

$$C_t : \frac{1}{(C_t - hC_{t-1})} - \lambda_t - E_t(\left(\frac{\beta h}{C_{t+1} - hC_t}\right)) = 0 \tag{A.66}$$

$$L_t : -\chi L_t^{\varphi} + \lambda_t(1-\alpha)A_t(U_t\xi_t K_t)^{\alpha} L_t^{-\alpha} = 0 \tag{A.67}$$

$$U_t : \lambda_t \alpha A_t \frac{(U_t\xi_t K_t)^{\alpha} L_t^{1-\alpha}}{U_t} - b\lambda_t \xi_t K_t U_t^{\zeta} = 0 \tag{A.68}$$

$$\begin{aligned} K_{t+1} : \quad & 0 = -\lambda_t - \lambda_t \phi_i E_t(\left(\frac{K_{t+1} - K_t(1+\xi_t) + \xi_{t-1}K_{t-1}}{K_t - \xi_{t-1}K_{t-1} + I_{ss}}\right))\times \\ & (K_{t+1} - \xi_t K_t + I_{ss})(\left(\frac{1}{K_t - \xi_{t-1}K_{t-1} + I_{ss}}\right)) \\ & -\lambda_t \frac{\phi_i}{2} E_t(\left(\frac{K_{t+1} - K_t(1+\xi_t) + \xi_{t-1}K_{t-1}}{K_t - \xi_{t-1}K_{t-1} + I_{ss}}\right))^2 \end{aligned} \tag{A.69}$$

$$\begin{aligned} & +\beta E_t \lambda_{t+1} \alpha \frac{A_{t+1}(U_{t+1}\xi_{t+1}K_{t+1})^{\alpha} L_{t+1}^{1-\alpha}}{K_{t+1}} + \beta E_t \lambda_{t+1}[1 - \delta_c - \frac{b}{1+\zeta} U_{t+1}^{1+\zeta}]\xi_{t+1} \\ & -\beta E_t \lambda_{t+1} \phi_i \left[\begin{array}{c} ((\frac{K_{t+2} - K_{t+1}(1+\xi_{t+1}) + \xi_t K_t}{K_{t+1} - \xi_t K_t + I_{ss}}))\times \\ (K_{t+2} - \xi_{t+1}K_{t+1} + I_{ss})\times \\ ((\frac{-(1+\xi_{t+1})(K_{t+1} - \xi_t K_t + I_{ss}) - (K_{t+2} - K_{t+1}(1+\xi_{t+1}) + \xi_t K_t)}{(K_{t+1} - \xi_t K_t + I_{ss})^2})) \end{array} \right] \\ & +\beta E_t \lambda_{t+1} \frac{\phi_i}{2} (\left(\frac{K_{t+2} - K_{t+1}(1+\xi_{t+1}) + \xi_t K_t}{K_{t+1} - \xi_t K_t + I_{ss}}\right))^2 (\xi_{t+1}) \end{aligned} \tag{A.70}$$

and the resource constraint

$$\begin{aligned} A_t(U_t\xi_t K_t)^{\alpha} L_t^{1-\alpha} = \quad & C_t + G_t + E_t K_{t+1} - [1 - \delta_c - \frac{b}{1+\zeta} U_t^{1+\zeta}]\xi_t K_t \\ & + \frac{\phi_i}{2} E_t(\left(\frac{K_{t+1} - (1+\xi_t)K_t + \xi_{t-1}K_{t-1}}{K_t - \xi_{t-1}K_{t-1} + I_{ss}}\right))^2 (K_{t+1} - \xi_t K_t + I_{ss}). \end{aligned} \tag{A.71}$$

The Social Planner's Steady State.

In this section I present the steady state that faces the Social Planner's Allocation. This steady state is calculated when $[Y_{t+1} = Y_t = Y_{t-1} = Y^*]$ for each variable. Eq.$(A.66 - A.71)$ can, respectively, be written in steady state as

$$\lambda = \frac{[1 - \beta h]}{C(1-h)} \tag{A.72}$$

$$L = [\lambda \frac{(1-\alpha)}{\chi} (UK)^{\alpha}]^{\frac{1}{\varphi+\alpha}} \tag{A.73}$$

$$U = [\frac{\alpha}{b}(\left(\frac{K}{L}\right))^{\alpha-1}]^{\frac{1}{1+\zeta-\alpha}} \tag{A.74}$$

$$\frac{K}{L} = [\left[\frac{1-\beta[1-\delta]}{\alpha\beta}\right]]^{\frac{1}{\alpha-1}}\frac{1}{U} \tag{A.75}$$

and the resource constraint

$$C = (UK)^{\alpha}L^{1-\alpha} - G - \delta K \tag{A.76}$$

where the value of shock to the quality of capital and to productivity in steady state $[\xi = A = 1]$ and the depreciation in steady state

$$\delta = \delta_c + \frac{bU^{1+\zeta}}{1+\zeta}$$

were used.

Inserting eq.($A.74$) into ($A.75$) and solving for the capital labor ratio

$$\frac{K^*}{L^*} = [\left[\frac{1-\beta[1-\delta]}{\alpha\beta}\right]]^{\frac{1}{\alpha-1}}. \tag{A.77}$$

The government spending was assumed as a fraction of the total output. That fraction is $[\bar{G}]$ then $[G = \bar{G}Y]$ with

$$Y^* = (K^*)^{\alpha}L^{*1-\alpha} \tag{A.78}$$

solving the resource constraint for $((\frac{C^*}{L^*}))$ and using the efficient rate $[[\frac{K^*}{L^*}]]$ eq.($A.76$) becomes

$$\frac{C^*}{L^*} = (\left(\frac{K^*}{L^*}\right))^{\alpha}[1-\bar{G}] - \delta\frac{K^*}{L^*} \tag{A.79}$$

with

$$U^* = \{\left\{\frac{1-\beta[1-\delta]}{b\beta}\right\}\}^{\frac{1}{\zeta}} = 1 \tag{A.80}$$

after substituting $[[\frac{K^*}{L^*}]]$ in eq.($A.74$).

Substituting eq.($A.72$) in eq.($A.73$) and using the efficient values of the variables

$$L^* = \{\frac{1-\beta h}{1-h}\frac{1-\alpha}{\chi}(\left(\frac{K^*}{L^*}\right))^{\alpha}[\left[\frac{C^*}{L^*}\right]]^{-1}\}^{\frac{1}{1+\varphi}}. \tag{A.81}$$

Finally, using the efficient values of $[[\frac{K^*}{L^*}]]$ and $[U^*]$

$$U^*\frac{K^*}{L^*} = \{\left\{\frac{1-\beta[1-\delta]}{\alpha\beta}\right\}\}^{[[\frac{1}{\alpha-1}]]}. \tag{A.82}$$

After using the optimal value for utilization ($U^* = 1$) the equations for consumption, labor and capital can be written as

$$Y^* = [\frac{1-\beta h}{1-h}\frac{1-\alpha}{\chi}]^{\frac{1}{1+\varphi}}[\begin{array}{c} [[\frac{1-\beta[1-\delta]}{\alpha\beta}]]^{\frac{-\alpha(1+\varphi)}{\alpha-1}}[1-\bar{G}] \\ -[\delta][[\frac{1-\beta[1-\delta]}{\alpha\beta}]]^{\frac{1-2\alpha-\alpha\varphi}{\alpha-1}} \end{array}]^{-\frac{1}{1+\varphi}} \tag{A.83}$$

$$K^* = \{\frac{1-\beta h}{1-h}\frac{1-\alpha}{\chi}\}^{\frac{1}{1+\varphi}}[\begin{array}{c} [1-\bar{G}][[\frac{1-\beta[1-\delta]}{\alpha\beta}]]^{\frac{1+\varphi}{1-\alpha}} \\ -[\delta][[\frac{1-\beta[1-\delta]}{\alpha\beta}]]^{\frac{\alpha+\varphi}{1-\alpha}} \end{array}]^{-\frac{1}{1+\varphi}} \tag{A.84}$$

$$L^* = \{\frac{1-\beta h}{1-h}\frac{1-\alpha}{\chi}\}^{\frac{1}{1+\varphi}}[\begin{array}{c} [1-\bar{G}] \\ -[\delta][[\frac{\alpha\beta}{1-\beta[1-\delta]}]] \end{array}]^{-\frac{1}{1+\varphi}} \tag{A.85}$$

which are equations in terms of the deep parameters.

A.4 Derivation of the Welfare Cost.

Following Schmitt-Grohé and Uribe (2007) I compare the welfare cost of each alternative policy relative to the time invariant equilibrium of the Ramsey policy. The welfare associated with the optimal Ramsey policy conditional on a particular state of the economy in period zero is

$$V_0^R = E_0 \sum_{t=0}^{\infty} \beta^t U[C_t^R, L_t^R] \tag{A.86}$$

and the welfare associated with an alternative implementable regime is

$$V_0^I = E_0 \sum_{t=0}^{\infty} \beta^t U[C_t^I, L_t^I]. \tag{A.87}$$

If the consumption cost of following an alternative policy regime instead of the Ramsey policy on a particular state in period zero is represented by $[W^C]$ the cost of the alternative policy is implicitly defined by

$$V_0^I = E_0 \sum_{t=0}^{\infty} \beta^t U[(1-W^C)C_t^R, L_t^R]. \tag{A.88}$$

where $[W^C]$ is the fraction of consumption of the Ramsey regime that a household is able to renounce in order to be indifferent between that regime and the alternative policy. As in Schmitt-Grohé and Urib I assume that at time zero the variables of the economy equal their respective Ramsey steady state value.

Substituting the particular form of the utility function in $(A.88)$

$$V_0^I = E_0 \sum_{t=0}^{\infty} \beta^t [\ln[(1-W^C)C_t^R - h(1-W^C)C_{t-1}^R] - \frac{\chi}{1+\psi} L_t^{R1+\psi}]. \tag{A.89}$$

Equation $[A.89]$ can be written

$$V_0^I = \frac{\ln(1-W^C)}{1-\beta} + E_0 \sum_{t=0}^{\infty} \beta^t [\ln[C_t^R - hC_{t-1}^R] - \frac{\chi}{1+\psi} L_t^{R1+\psi}]. \tag{A.90}$$

Solving this equation for the welfare cost

$$\frac{1}{(1-\beta)} \ln(1-W^C) = V_0^I - V_0^R \tag{A.91}$$

which makes use of $[A.86]$. Noting that

$$\ln(1+x) \approx x,$$

the welfare cost $[A.91]$ can be written as

$$W^C = [1-\beta][V_0^R - V_0^I], \tag{A.92}$$

which is the welfare cost function that is necessary to approximate up to second order in order to have accurate welfare comparisons across regimes.

Approximating the welfare cost up to second order.

Equation ($A.92$) can be approximated up to second order around the deterministic Ramsey steady state $(x_0, \sigma_\varepsilon)$ with $[x_0 = x]$ and $\sigma_\varepsilon = 0$. Because in equilibrium V_0^R and V_0^I are functions of the initial state vector (x_0) and the parameter scaling the standard deviations of the shocks (σ_ε), the conditional welfare cost can be written as

$$W^C(x_0, \sigma_\varepsilon) = [1-\beta][V_0^R(x_0, \sigma_\varepsilon) - V_0^I(x_0, \sigma_\varepsilon)] \tag{A.93}$$

Because I want to compare the welfare results using the same deterministic Ramsey steady state, only the first and second order derivatives of the cost respect to (σ_ε) have to be considered (see Schmitt-Grohé and Uribe (2007)). Following this, the second order approximation of the previous equation can be written in general terms as

$$W^C \approx W^C(x_0, \sigma_\epsilon) + W^C_{\sigma_\epsilon}(x_0, \sigma_\epsilon)\sigma_\epsilon + \frac{1}{2} W^C_{\sigma_\epsilon \sigma_\epsilon}(x_0, \sigma_\epsilon)\sigma_\epsilon^2. \tag{A.94}$$

Now, because all the regimes are approximated across the same deterministic Ramsey steady state, the constant term $[W^C(x_0, \sigma_\epsilon)]$ in eq. ($A.94$) disappears in the comparison. This means that

$$W^C(x_0, \sigma_\epsilon) = 0.$$

The terms containing the first order approximation of the policy function $[W^C_{\sigma_\epsilon}(x_0, \sigma_\epsilon)\sigma_\epsilon]$ are zero. This is shown in Schmitt-Grohé and Uribe (2004). Up to a first order of approximation, the derivative of the policy function respect to the parameters scaling the variance of the shocks is zero. For this particular case

$$W^C_{\sigma_\epsilon}(x, 0)\sigma_\epsilon = [1-\beta][V^R_{0\sigma\varepsilon}(x, 0) - V^I_{0\sigma\varepsilon}(x, 0)]\sigma_\epsilon = 0$$

The term containing the second order approximation is

$$W^C_{\sigma\varepsilon\sigma\varepsilon}(x, 0) = \frac{1}{2}[1-\beta][V^R_{0\sigma\varepsilon\sigma\varepsilon}(x, 0) - V^I_{0\sigma\varepsilon\sigma\varepsilon}(x, 0)]\sigma_\varepsilon^2 \tag{A.95}$$

which is the welfare measure used in the main text.

A.5 Optimal Policy. Timeless Perspective.

The optimal policy problem is solved from a timeless perspective. The Ramsey planner maximizes the discounted utility function subject to the competitive equilibrium conditions. Following Schmitt-Grohé and Uribe (2011), the portion of the Lagrangian that is relevant for optimal policy from a timeless perspective is

$$L^R = E_0[\sum_{\tau=0}^{\infty} \beta^\tau U_\tau[C_\tau, L_\tau] + \sum_{\tau=0}^{\infty} \beta^\tau Lm'_\tau C_\tau(\cdot)] \tag{A.96}$$

where the period t utility function is

$$U_t = \ln(C_t - hC_{t-1}) - \frac{\chi}{1+\varphi} L_t^{1+\varphi}$$

(β) is the Ramsey planner's discount factor, which I assume to be identical to that of the competitive equilibrium. The vector $[Lm_t^{'}]$ contains the 29 Lagrange multiplier associated with the 29 equilibrium conditions in period t $C_t(\cdot)$. Those equilibrium conditions in period t are:

1. Marginal Utility of Consumption (U_{ct})

$$U_{ct} - E_t[(C_t - hC_{t-1})^{-1} - \beta h(C_{t+1} - hC_t)^{-1}] = 0.$$

2. Euler Equation. Consumption-Saving (C_t)

$$\beta E_t \Lambda_{t,t+1} R_{t+1} - 1 = 0.$$

3. Stochastic Discount Factor ($\Lambda_{t,t+1}$)

$$E_t \Lambda_{t,t+1} - E_t \frac{U_{ct+1}}{U_{ct}} = 0.$$

4. Labor Market Equilibrium (L_t)

$$\frac{\chi}{(1-\alpha)} \frac{L_t^{\varphi+1}}{U_{ct}} - P_{mt} Y_{mt} = 0.$$

5. Marginal Return on Bank's Assets (v_t)

$$-v_t + E_t(1-\theta_{t+1})\beta\Lambda_{t,t+1}(R_{t+1}^k - R_{t+1}) + E_t\theta_{t+1}\beta\Lambda_{t,t+1}x_{t,t+1}v_{t+1} = 0.$$

6. Gross Growth of Bank Assets (x_t)

$$x_{t,t+1} - E_t \frac{\phi_{t+1}}{\phi_t} z_{t,t+1} = 0.$$

7. Marginal Return on Bank's Wealth (η_t)

$$-\eta_t + E(1-\theta_{t+1})\beta\Lambda_{t,t+1}R_{t+1} + E_t\theta_{t+1}\beta\Lambda_{t,t+1}z_{t,t+1}\eta_{t+1} = 0.$$

8. Gross Growth of Bank Wealth (z_t)

$$z_{t,t+1} - E_t[(R^k_{t+1} - R_{t+1})\phi_t + R_{t+1}] = 0.$$

9. Leverage Ratio (ϕ_t)

$$\phi_t - \frac{\eta_t}{\lambda - \upsilon_t} = 0.$$

10. Aggregate Capital. Loans (K_t)

$$Q_tK_{t+1} - \phi_tN_t = 0.$$

11. Net worth in the banking sector (N_t)

$$-N_t + N_{et} + N_{nt} = 0.$$

12. Existing wealth (N_{et})

$$N_{et} - \theta_{t-1}[(R^k_t - R_t)\phi_{t-1} + R_t]N_{t-1} = 0.$$

13. Wealth of new banks (N_{nt})

$$N_{nt} - wQ_t\xi_tK_t = 0$$

14. Return to capital (R_{kt})

$$R^k_t - \frac{\xi_t}{Q_t - 1}[\alpha\frac{P_{mt}Y_{mt}}{\xi_tK_t} + Q_t - \delta_t] = 0.$$

15. Production of Intermediate goods (Y_{mt})

$$Y_{mt} - A_t(U_t\xi_tK_t)^\alpha L_t^{1-\alpha} = 0.$$

16. Investment (Q_t)

$$-Q_t + 1 + \frac{\phi_i}{2}(\frac{I_{nt}+I_{ss}}{I_{nt-1}+I_{ss}} - 1)^2 + \phi_i(\frac{I_{nt}+I_{ss}}{I_{nt-1}+I_{ss}} - 1)\frac{I_{nt}+I_{ss}}{I_{nt-1}+I_{ss}}$$
$$-E_t\beta\Lambda_{t,t+1}\phi_i(\frac{I_{nt+1}+I_{ss}}{I_{nt}+I_{ss}} - 1)(\left(\frac{I_{nt+1}+I_{ss}}{I_{nt}+I_{ss}}\right))^2 = 0.$$

17. Depreciation function (U_t)

$$-\delta_t + \delta_c + \frac{b}{1+\zeta} U_t^{1+\zeta} = 0.$$

18. Optimal Capacity Utilization (P_{mt})

$$\alpha P_{mt} Y_{mt} - b U_t^{1+\zeta} \xi_t K_t = 0.$$

19. Net Investment (δ_t)

$$-I_{nt} + I_t - \delta_t \xi_t K_t = 0.$$

20. Law of movement of capital (I_{nt})

$$-K_{t+1} + \xi_t K_t + I_{nt} = 0.$$

21. Exogenous government consumption(G_t)

$$-G_t + G g_t = 0.$$

22. Aggregate resources (I_t)

$$-Y_t + C_t + G_t + I_t + \frac{\phi_i}{2} \left(\frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}} - 1\right)^2 (I_{nt} + I_{ss}) = 0.$$

23. Final Production (Y_t)

$$Y_{mt} - Y_t \Delta_t = 0.$$

24. Price Dispersion (Δ_t)

$$-\Delta_t + (1-\gamma) [\left[\frac{1 - \gamma(\pi_{t-1}^{\gamma^\rho} \pi_t^{-1})^{1-\varepsilon}}{1-\gamma}\right]]^{\frac{-\varepsilon}{1-\varepsilon}} + \gamma [\pi_{t-1}^{\gamma^p} \pi_t^{-1}]^{-\varepsilon} \Delta_{t-1} = 0.$$

25. Optimal Price Choice (F_t)

$$-F_t + P_{mt} Y_t + E_t \gamma \beta \Lambda_{t,t+1} \pi_t^{-\gamma^\rho \varepsilon} \pi_{t+1}^{\varepsilon} F_{t+1} = 0.$$

26. (Z_t)

$$-Z_t + (1-\tau_t) Y_t + E_t \gamma \beta \Lambda_{t,t+1} \pi_t^{\gamma^\rho (1-\varepsilon)} \pi_{t+1}^{-(1-\varepsilon)} Z_{t+1} = 0.$$

27. Optimal choice of price (π_t^*)

$$\pi_t^* - \frac{\varepsilon}{\varepsilon - 1} \frac{F_t}{Z_t} \pi_t = 0.$$

28. Evolution of inflation (π_t)

$$-\pi_t^{1-\varepsilon} + [(1-\gamma)(\pi_t^*)^{1-\varepsilon} + \gamma(\pi_{t-1}^{\gamma^\rho})^{1-\varepsilon}] = 0.$$

29. Fisher Equation (R_t)

$$i_t - E_t R_t \pi_{t+1} = 0.$$

Then the Ramsey planner solves the above problem choosing at period t processes for the 30 endogenous variables U_{ct}, C_t, Λ_t, L_t, v_t, x_t, η_t, z_t, ϕ_t, K_{t+1}, N_t, N_{et}, N_{nt}, R_{kt}, Y_{mt}, Q_t, δ_t, U_t, I_{nt}, P_{mt}, G_t, I_t, Y_t, Δ_t, F_t, Z_t, π_t^*, π_t, R_t, i_t and the 29 Lagrange multipliers associated with the competitive equilibrium relationships. The 5 exogenous processes for the shocks are given by

30. Technology Shock (A_t)

$$\ln A_t = \rho_a \ln A_{t-1} - \varepsilon_{at}.$$

31. Capital Quality Shock (ξ_t)

$$\ln \xi_t = \rho_\varepsilon \ln \xi_{t-1} - \varepsilon_{\xi t}.$$

32. Government Shock (g_t)

$$\ln g_t = \rho_g \ln g_{t-1} - \varepsilon_{gt}.$$

33. Shock to the Probability of dying (θ_t)

$$\ln \theta_t = \rho_\theta \ln \theta_{t-1} - \varepsilon_{\theta t}.$$

34. Markup shock (τ_t)

$$\ln(1-\tau_t) = \rho_\mu \ln(1-\tau_{t-1}) + (1-\rho_\mu)\ln(1-\tau) - \varepsilon_t^\mu.$$

The values for the variables listed above are given dated t <0, and also the values of the Lagrange multipliers associated with the competitive equilibrium constraints are given at t <0. Then, as explained in Schmitt-Grohé and Uribe (2005) the structure of the optimality conditions associated with the Ramsey equilibrium are time invariant.

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