Evaluating monetary policy with financial stability objective: rules vs. discretion

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Evaluating monetary policy with financial stability objective: rules vs. discretion

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ABSTRACT
This article explores whether adding the goal of financial stability to the more traditional goals of output and price stability could improve optimality of monetary policy. A Dynamic Stochastic General Equilibrium model that endogenously incorporates financial frictions is used to derive optimality conditions across rule-based and discretionary monetary policy environments. The results indicate that it is optimal for the Central Bank to keep output below the potential level in the short term so as to dampen the inflationary effects arising from supply and financial shocks. When the economy is exposed to a financial shock, both leverage and credit spread rise significantly, thereby tipping the economy into a financial crisis and raising the probability of macroeconomic risk.

KEYWORDS
Financial stability; optimal monetary policy; central banking; financial frictions

JEL CLASSIFICATION
E47; E52; E58; G18

I. Introduction

During the recent global financial crisis, many wondered whether the Federal Reserve could have done a better job of preventing the onset of the crisis, thus minimizing the subsequent ‘bubble-and-bust’ of housing prices and related assets and safeguarding the economy from the events thereafter. In his analysis of the crisis, Taylor (2008) claims that the bubble in asset prices, which triggered the bust and ripple effects throughout the financial sector, resulted from the easy monetary policy followed by the Fed in the years prior to the crisis. On the other hand, Bernanke (2010) and Bernanke et al. (2011) attribute the crisis to the flawed financial regulatory framework, risk management and excessive foreign demand for high-rated US mortgage securities in the years leading up to 2007. At least in part, these sharply different characterizations arise because conventional macro and monetary policy models are either silent about how financial shocks and frictions affect the real economy or because, as Svensson (2011) claims, the extended Great Moderation period led models to underestimate the potential dangers associated with systemic risk and financial shocks to the real economy.

From a policy perspective, the core debate concerns whether monetary policy should embrace the goal of financial stability, in addition to the dual mandates of maintaining full employment and price stability, or should financial stability be treated separately from monetary policy’s more traditional goals. This article adopts the theoretical formulation in Curdia and Woodford (2009) and Woodford (2012) to show that adding financial stability to the conventional objectives of monetary policy may yield optimal results.

A number of previous studies have analysed monetary policy transmission and conduct by introducing financial frictions in a New Keynesian Dynamic Equilibrium framework. Among these are Christiano et al. (2003, 2007a, 2007b), Gertler, Gilchrist and Natalucci (2007), Iacoviello (2005), Faia and Monacelli (2007), Curdia (2008), Davig and Hakkio (2010), Curdia and Woodford (2009) and Woodford (2012). For example, Davig and Hakkio (2010) measure the impact of financial stress on economic activity using a regime-switching model that reflects two states of the economy, a crisis state and a normal state. In particular, they ask how the prevailing state of the economy could influence the impact that financial stress has on the economy and how the probability of switching between these two states is related to financial stress and economic activity.

Within the context of previous analyses of the relationships between financial stability and
monetary policy, this study uses a Linear–Quadratic (LQ) welfare loss function for the Central Bank constrained by a dynamic IS equation, the New Keynesian Phillips Curve (NKPC), and a constraint relating leverage and credit spreads. This novel approach is applied to both rule-based and discretionary monetary policy.

The model used incorporates Davig and Hakkio’s (2010) idea of an economy switching between a normal and a crisis state and extends it to a monetary policy exercise that assumes the Central Bank has full information about the current state of the economy and that, when conducting monetary policy, the Central Bank assigns two different values for the variable measuring the state of financial conditions or ‘credit friction’. While Davig and Hakkio’s paper explore the relationships between economic activity and financial conditions, this article focuses on measuring the optimality of monetary policy when incorporating the goal of financial stability into the standard loss function of the Central Bank.

The dynamic New Keynesian general equilibrium model of Curdia and Woodford (2009) is adopted in this study. In large part, they incorporate financial frictions to see if such frictions increase the model’s predictive power in response to different shocks, wherein the parameters are calibrated to align the volume of bank credit with the spread between bank deposit and lending rates throughout the US economy. This approach is extended in this study to evaluate the implications for optimality of monetary policy, monetary stabilization policy and the optimal policy response to a financial and supply shock. In addition, the model in this study differs from the one used in Curdia and Woodford in the following three respects. First, this study simply evaluates the optimality of monetary policy when the goal of financial stability is present within discretionary and rule-based environments, but does not analyse the model’s predictive power in response to different shocks. Second, the simplified version of the LQ problem is solved and calibrated where the loss function solely depends upon inflation, output and a measure of credit friction variable. Third, in Curdia and Woodford’s model, the credit friction variable is a forward-looking, moving average of the short-term credit spread – an approach that depends on the current volume of privately intermediated credit. By contrast, the measure of credit friction variable in this study is endogenously determined by leverage.

The model in this study is also influenced by Woodford (2012). However, the theoretical construct is extended and numerical optimal policy results are derived for the Central Bank under rule-based and discretionary policy environments. These points are not covered in Woodford (2012).

In general, the analysis in this study is framed towards providing possible answers for the following questions: can monetary policy help achieve financial stability while simultaneously targeting price and output stability? What trade-offs are involved when monetary policy attempts to maintain financial stability alongside price and output stability?

Two key results can be inferred from this study. First, under a rule-based monetary policy environment, a supply shock is found to be inflationary where financial institutions react by deleveraging and decreasing credit spreads to a greater extent than the increase that was set off by the initial shock. Output declines in response and shows persistence in returning back to its long-run trend level. The policy rate rises sharply after the first quarter, indicating a short-term policy rate adjustment by the Central Bank to combat inflation. The optimal response to a financial shock has all the expected contractionary effects upon the economy. Leverage ratio and credit spread sharply rise in response to the shock, which reduce the volume of intermediation in the credit market and result in the contraction of aggregate output in the short term. Based upon the state-contingent values of credit friction and leverage, the Central Bank follows an easy monetary policy in response to the tight conditions in the credit market by reducing the policy rate, which leads to transitory inflationary pressures for about eight quarters.

Second, in a discretionary monetary policy environment, it is optimal for the Central Bank to play an accommodative role by letting inflation initially rise in both transitory and persistent supply shock scenarios. When the economy experiences a financial shock, calibrated with both transitory and persistent parameters, the Central Bank optimally responds by following an easy monetary policy path in order to stabilize the financial system and bring credit spread and leverage back to normal levels while also holding output gap in negative territory so as to dampen the
transitory inflationary effects arising from the financial shock.

The article is organized as follows: Section II lays out the general equilibrium model used to derive the impulse response functions and optimal policy results; Section III provides the results and Section IV concludes.

II. Methodology

Monetary policy, credit frictions and financial stability

This study investigates the role of monetary policy in financial stability through a model that connects the policy rate, leverage, credit friction and aggregate economic variables such as output gap and inflation. The Central Bank minimizes welfare loss by targeting, price, output gap and financial stability through the conduct of monetary policy. Financial stability is represented by the movement in credit friction, which is empirically measured by the difference between yield on BAA corporate bond and a comparable maturing treasury bond. The main objective is then to simulate the effect of interest rate changes by the Central Bank on credit friction, inflation and output gap over time and measure the possible trade-offs involved in response to policy changes.

There is strong theoretical and empirical evidence describing the relationship between leverage, credit friction and the occurrence of a financial crisis, especially when the source of the change in leverage is credit driven asset price bubble. For example, Bernanke, Gertler and Ghilchrist (1999b) show that higher asset prices allow borrowers to pledge more collateral and raise leverage at lower borrowing costs. However, when asset prices start to decline, borrowers engage in speedy deleveraging that affects other borrowers in the system and lead to systemic risk and the possibility of a crisis. This type of credit-driven boom and bust was observed in the 2007/08 financial crisis.

Examining the data for credit friction (measured by the difference between 10-year BAA corporate bond and Treasury bond – BAA10YM) and lagged leverage (measured by the Chicago Fed Adjusted National Financial Conditions Index – ANFCI) for the period 1979:I–2015:IV in Fig. 1 reveals significant and positive correlation between these two variables for up to two quarters. This indicates high leverage could lead to larger credit spreads, which potentially raises the possibility of occurrence of a crisis.

The negative effect of higher credit friction on aggregate economic activity could also be observed from Fig. 2. Aggregate output measured by lagged Hodrick–Prescott filtered GDP – hp_GDPC1_PCH – is significantly negatively correlated to credit friction for up to three quarters, showing the contractionary effect of uncertainty in financial markets on real activity.

In light of these facts, it would be interesting to explore the possibility that monetary policy actions

\[1\]Credit or financial frictions include incomplete or asymmetric information, liquidity constraints, funding constraints, moral hazard stemming from policy actions like bailouts, monitoring costs or costly state verification, incentives and principle-agent problems, and regulatory arbitrage. See Brunnermeier, Eisebach and Sannikov (2012), Leeper and Nason (2014) for a survey of financial frictions.
Aggregate demand and supply relations

The Dynamic IS equation based on Curdia and Woodford (2009) describes the relationships between output, real interest rate and credit friction.

\[ y_t - g_t + \chi \Omega_t = E_t[y_{t+1} - g_{t+1} + \chi \Omega_{t+1}] \]
\[ - \sigma[i_t - E_t \pi_{t+1}] \]  

(1)

The above equation specifies the relationship between aggregate expenditure and financial frictions, where \( y_t \) is output gap, measured as the difference between actual and potential output and \( g_t \) is an exogenous government expenditure that is assumed to follow an an Autoregressive order of 1 \([\text{AR}(1)]\) process of the form,

\[ g_t = \phi_g g_{t-1} + \varepsilon_g \]

where \( 0 < \phi_g < 1 \) and \( \varepsilon_g \sim iidN(0, \sigma^2_g) \)

\( i_t \) is the Fed funds rate, \( \pi_{t+1} \) is the rate of inflation between periods \( t \) and \( t + 1 \), and all variables are in deviations from their steady states where the constants are omitted. In addition, \( \Omega_t \) measures credit friction and the coefficient \( \chi \) is positive indicating the negative effect of a higher degree of credit friction on aggregate output. The coefficient of expected real interest rate \( \sigma \) is also positive depicting the negative relationship between real interest rate and aggregate demand. Therefore, the Dynamic IS equation in (1) describes the relationships between output, exogenous changes in government spending, expected real interest rate and financial frictions.

Aggregate demand follows the simplified NKPC version of Woodford (2011) given by

\[ \pi_t = \kappa_y y_t + \kappa_\Omega \Omega_t + \beta E_t \pi_{t+1} + u_t \]  

(2)

where all variables are as defined in (1) and \( u_t \) is a composite term containing exogenous factors. The exogenous supply shock is assumed to follow an AR (1) process of the form,

\[ u_t = \phi_u u_{t-1} + \varepsilon_u \]

where \( 0 < \phi_u < 1 \) and \( \varepsilon_u \) is a white noise process with mean zero and variance \( \sigma_u^2 \).

The coefficient for output gap \( \kappa_y \) is positive, indicating the increased inflationary pressure from a higher output gap. The coefficient \( \kappa_\Omega \) is also positive, which implies that an increase in interest rate spread or higher credit friction yields higher aggregate prices.

Credit frictions and endogenous crisis

Previous studies have followed various approaches in modelling credit frictions and crises. For example, Curdia and Woodford (2009) model financial distortions as a forward-looking moving average of the short-term credit spread, which depends upon the current volume of privately intermediated credit. Alternatively, Davig and Hakkio (2010) measure financial stress through the Kansas City Fed Financial Stress Index and consider two regime change probabilities, i.e. a regime change from a distressed to a normal state (with probability, \( p \)) and from a normal to a distressed state (with probability, \( q \)). These probabilities are functions of lagged value of real economic activity measures.

Following Woodford (2011), the variable measuring credit friction \( \Omega_t \) is modelled to take two different values: a normal state value \( \Omega \) and a crisis state value \( \overline{\Omega} \). As shown in Fig. 3, the transitions between a normal and a crisis state is contingent upon leverage taking the upper or lower bound values, respectively. The functional relationship between credit frictions and leverage is given as follows:

\[ \Omega_t = f(X_t) \]

where the specific functional relationship is given by

\[ E(\Omega_t|h_t) = \gamma_0 + \gamma_1 E(X_t|h_t) \]  

(3)

\[ \gamma_0 + \gamma_1 E(X_t|h_t) = \gamma_0 + \gamma_1 E(X_t) \]

by the Central Bank could influence leverage and credit friction and as a result achieve a stable financial system. The problem is even more interesting when one considers the primary objective of monetary policy is maintaining price stability and ensuring output growth and not financial stability. To systematically analyse this question, this study presents the dynamic IS equation and the NKPC that represent Aggregate Demand & Supply relations in the next section. Section 2.3, The derivation of the relationships between leverage and credit friction and Section 2.4 the lay out of the optimal policy welfare loss function for the Central Bank are provided in the subsequent sections.\(^2\)

\(^2\)The detailed mathematical derivations can be found in the Appendix C.
where $\gamma_0$ and $\gamma_1$ are positive constants, $h_t$ is the set of prevailing economic conditions at time $t$, $X_t$ is leverage and $E(X_t|h_t)$ is the expected value of leverage for given economic conditions. Equation (3) specifies the expected value of credit friction based upon the expected value of leverage contingent on the prevailing economic conditions at time $t$. Therefore, the state of credit frictions completely depend upon the value leverage takes at a given point in time, which consequently dictates the state of the economy. A low financial stress index is related to the normal state of the economy $\Omega$, whereas a high financial stress index is associated with a crisis state $\Omega$. Therefore, depending on a threshold value for $X_t = X$, credit friction takes two values:

- if $X_t \geq X$ then $\Omega_t = \Omega_t$ – Normal state
- if $X_t < X$ then $\Omega_t = \Omega_t$ – Crisis State

There is a positive relationship between credit friction and the factors triggering crisis such as leverage $X_t$ because the more leveraged financial institutions are, the higher is the probability of insolvency and the increased likelihood of a financial crisis (Woodford, 2011). As measured by the Chicago Fed ANFCI (Fig. 4), leverage shows an increased value within the 1981/82 and 2008/09 recessions. This indicates a positive dependence between the probability of a crisis and leverage. However, the value of this index was below zero in 1980 (prior to the full onset of the 1981 recession), as well as in the recessions of 1990 and 2001.

Following the baseline model set by Woodford (2012), the measure of financial conditions, leverage $X_t$ is formulated as a function of lagged values $X_{t-1}$, output gap $y_t$ and exogenous disturbances $v_t$ as follows:

$$X_t = \phi X_{t-1} + \xi y_t + v_t$$  (4)

The variable $v_t$ is an exogenous financial shock affecting financial institutions’ balance sheet and represents exogenous factors that affect leverage such as the level of risk financial institutions should take to finance their assets, unanticipated volatilities in the credit market that could disrupt intermediation or other financial market disturbances that are assumed to be not influenced by monetary policy. It is assumed to follow an AR (1) process of the form

$$v_t = \phi_v v_{t-1} + \epsilon_v$$

where $0 < \phi_v < 1$, $\xi > 0$ and $\epsilon_v \sim iidN(0, \sigma_v^2)$

Equations (1)–(4) are used to determine the values of the endogenous variables $\pi_t$, $y_t$ and $\Omega_t$.

**Optimal monetary policy**

The monetary authority is assumed to abide by the following welfare loss function in targeting inflation,

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3The mean value of the CFAFCI in the period 1979–2015 is 0.03 and the SD is 0.79.
minimizing output gap and stabilizing the financial system.

\[
\frac{1}{2} \sum_{t=0}^{\infty} \beta^t [\pi_t^2 + \lambda_y y_t^2 + \lambda_\Omega \Omega_t^2]
\]

(5)

where \(\beta\) is the discount factor satisfying \(0 < \beta < 1\) and \(\lambda_y, \lambda_\Omega > 0\) and this formulation follows the standard output gap and inflation stabilization objectives (Svensson 2011; Woodford, 2011). The third term, \(\lambda_\Omega \Omega_t^2\), captures the additional objective of financial stabilization and represents the effects of credit distortions on welfare. The positive coefficient of the credit friction variable \((\lambda_\Omega > 0)\) indicates the added monetary policy objective of reducing the occurrence of financial crises. The monetary authority is assumed to minimize (5) given the constraints imposed by (2)–(4)\(^4\) to choose state-contingent paths for the variables \(\pi_t, y_t\) and \(\Omega_t\).

III. Model simulation results

Rule-based monetary policy: an LQ approach

Optimal monetary policy under commitment involves the Central Bank adjusting its instrument (usually the nominal interest rate) until a certain optimal relation between target variables is satisfied. Under this rule, the Central Bank follows a policy rate pathway that it plans on using forever. Traditionally, the target variables for the Central Bank are output gap and inflation, which are key macroeconomic variables for any monetary authority. However, given the recent bubble and bust in the housing market and the related turbulence in the financial market, it is reasonable to question the optimality of monetary policy when the target variables are extended to be output gap, inflation and a measure of financial stability and credit distortion. It is also important to explore if the Central Bank could still credibly commit to lower future inflation while maintaining stable output, reduced inflation and a stable financial system in the short term.

The theoretical result in equation (22’\(^5\)) expresses the weight the Central Bank is attaching to stabilizing the marginal crisis risk as compared to the stability of output gap and price. Obviously, according to this formulation, the Central Bank is faced with a trade-off between inflation and output gap and the challenge of maintaining a stable financial system, while keeping long-term inflation at its targeted (in this case zero)\(^6\) level and output close to its efficient level. When the marginal crisis risk is above normal, it signals a looming financial crisis within the economy. Given the relationship expressed in (22’), this means that the Central Bank will adhere to tight monetary conditions that exert a downward pressure on inflation and output gap. This relationship also shows that at least in its qualitative sense, the Central Bank abides by a policy of leaning against a credit boom when leverage increases and there is accelerated growth in the credit market.

The calibrated model parameters are given in Table 1. Overall, the values assigned to the structural parameters and the persistence coefficients of the shock processes are consistent with the literature. Original calibrations by Clarida, Gali and Gertler (1999, hereafter CGG) and Curdia and Woodford (2009) are used to assign values for the discount factor and for the parameters in the IS and NKPC relations. The values of the coefficients for credit distortion in these two relations are carefully tailored to reflect the influence of the turbulence in the financial market upon the real economy. As these

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\chi)</td>
<td>Coefficient of credit distortion in the IS equation</td>
<td>0.533</td>
</tr>
<tr>
<td>(\sigma)</td>
<td>Coefficient of real interest rate in the IS equation</td>
<td>1.5</td>
</tr>
<tr>
<td>(\beta)</td>
<td>Discount factor</td>
<td>0.987</td>
</tr>
<tr>
<td>(\kappa)</td>
<td>Coefficient of output gap in the NKPC</td>
<td>0.5524</td>
</tr>
<tr>
<td>(\phi)</td>
<td>Persistence parameter for leverage</td>
<td>0.1</td>
</tr>
<tr>
<td>(\lambda)</td>
<td>Coefficient of output gap in the leverage equation</td>
<td>0.87</td>
</tr>
<tr>
<td>(\lambda_\Omega)</td>
<td>Coefficient of output gap in the welfare loss function</td>
<td>0.2</td>
</tr>
<tr>
<td>(\lambda_\Omega)</td>
<td>Coefficient of credit distortion in the welfare loss function</td>
<td>0.64</td>
</tr>
<tr>
<td>(\phi)</td>
<td>Persistence parameter for supply shock</td>
<td>0.75</td>
</tr>
<tr>
<td>(\phi)</td>
<td>Persistence parameter for demand shock</td>
<td>0.25</td>
</tr>
<tr>
<td>(\phi)</td>
<td>Persistence parameter for financial shock</td>
<td>0.5</td>
</tr>
</tbody>
</table>


The theoretical moments, policy transition functions and variance decomposition from simulation of the general equilibrium model are provided in Appendix B: Tables B1–B3.

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\(^4\)The complete derivation of the optimal monetary policy problem can be found in Appendix C.

\(^5\)All prime numbered equations are given in the Appendix C and D.

\(^6\)In the case where stochastic disturbances are very small in magnitude, optimal monetary policy under commitment will choose an inflation rate that fluctuates asymptotically around zero (Curdia and Woodford 2009). Generally, optimal policy in the case of stochastic shocks, involves a long-run zero average inflation rate as far as the shocks are small enough to provide a linear approximation to the equilibrium dynamics (Woodford 2003; Benigno and Woodford 2005).
values are nonnegative, a higher value will always indicate that volatility in the financial market has a greater degree of influence upon output and inflation. Unfortunately, the literature is not rich enough to allow for a broader range of values to calibrate these parameters. In order to fill this gap, the sensitivity of output gap and inflation is tested through various calibrations of these parameters that lie between two threshold values [0.25; 3] while also checking the results against the values suggested by Curdia and Woodford (2009). The values for the coefficients in the welfare loss function are meant to reflect the trade-offs and the balance between inflation, output gap and credit risk.

For example, the value assigned to the coefficient of credit risk (0.64) is higher than the value for output gap (0.2). This indicates that the Central Bank has given more weight to stabilizing the financial sector than short-term output stability. Relatively transitory persistence values are chosen for demand (0.25) and financial shocks (0.5) and a more persistent value is assigned to the supply shock (0.75) to simulate the effect of unanticipated supply disturbances.

A Ramsey policy that minimizes the quadratic welfare loss function that is subject to the linear constraints describing the equilibrium of the economy in the household sector, firms, the government and an equation linking financial institutions’ balance sheets to the real economy are executed and the results for a 50 basis point shock in leverage and a supply shock are presented in Figs. 5 and 6.

As predicted by the Phillips curve relationship, a half per cent increase in the supply shock turned out to be inflationary. This drives prices up for the first two quarters and returns back to the long-run optimal zero inflation rate after about eight quarters. Financial institutions react to a supply shock by deleveraging: the average leverage ratio declines by 50 basis points right after the shock and then returns to the long-run trend level after 2 years. Credit spread decreases by more than the increase set off by the initial shock, which follows from the resulting decrease in the leverage ratio. Output declines in response to a cost-push shock and shows some persistence in returning back to its long-run trend level (8 quarters). The policy rate or the federal funds rate, however, declines immediately after the shock, and rises sharply after the first quarter. This indicates a short-run policy rate adjustment by the Central Bank to combat inflation. A financial shock thus has all the expected contractionary effects upon the economy. Leverage ratio and credit spread sharply rise in response to the shock thereby exacerbating the situation in the credit market for the first four quarters. Credit is tight for borrowers and banks are reluctant to lend. This reduces the volume of intermediation in the credit market and puts pressure on aggregate economic activity. This is reflected in the output decline in response to the

![Figure 5. Optimal response to a supply shock.](image-url)
shock and a return back to the long-term trend after the shock is fully dissipated in a period of six to eight quarters (Fig. 6). Based upon the state-contingent values of credit friction and leverage, the optimal policy path followed by the Central Bank is reflected in the endogenous response of the nominal interest rate. The Central Bank follows an easy monetary policy in response to the tight conditions in the credit market by reducing the policy rate. In the short run, this expansionary policy leads to transitory inflationary pressures on the economy where the rate of inflation rises by 0.2% right after the shock and then returns to its long-run equilibrium level in eight quarters.

To put the above results in perspective and illustrate how the model matches the data, the five endogenous variables\(^7\) are plotted for the sample period 1979–2015 as shown in Fig. 7(a–e)\(^8\). The shaded bars indicate the official NBER recession dates. In two of the most severe recessions in the past four decades – the early 1980s after the second oil price shock and the recent 2007/08 recessions – leverage and credit spread spiked by more than 200% from the average for the period (0.0244 and 2.243, respectively). This is similar to the impulse responses of these two variables for the financial shock. However, leverage and credit spread sharply decrease in response to cost-push shocks (Fig. 5). This type of shock could possibly be represented by the recession in the 1980s, which was related to the late 1970s oil price hikes in the world market. Leverage (Fig. 7(a)) decreases during the 1980/81 recession in a similar fashion to the impulse response of the model. In both the supply and financial shock scenarios, the output gap response of the model economy pretty much coincides with the data. In all the recessionary periods over the past four decades, the output gap declines considerably. This decline matches the impulse responses from the model economy.

An interesting observation can also be made regarding the endogenous path of the policy rate. In all recessions, the Central Bank responds by cutting the policy rate (with a lag) so as to achieve output gap and price stabilization. A different response can be observed in the aftermath of the 1980/81 recession, when the central bank tightened monetary policy by raising the nominal rate to a

\(^7\) Output Gap is HP filtered series of Real GDP (1979:1–2015:4).

\(^8\) The descriptive summary statistics for these variables can be found in Appendix A.
historically record high rate of 17.6%. Given the fact that the 1980s recession is the result of cost-push shocks, the impulse response result in the model generally depicts this optimal policy response. This type of policy, targeted towards achieving the long-run targeted inflation rate, naturally comes with a cost. In the years following, interest rate hikes output contracts and the credit market becomes tighter.

**Discretionary monetary policy**

In contrast to a rule-based monetary policy, when the Central Bank follows a discretionary monetary policy, it optimizes sequentially by re-optimizing each period without committing to abide by any future actions or past promises. Discretionary policy is also different from rule-based policy in terms of how the private sector perceives policy conduct (CGG). In an equilibrium of rational expectations under a discretionary policy, the private sector believes the Central Bank has no incentive to change its policies in an unanticipated way even though it has the right to do so. However, in a rule-based policy, the private sector derives confidence simply from the commitment that the Central Bank will stick to its policy. The optimal responses for a 50 basis point increase in supply (or cost-push shock with a persistence coefficient of 0.5)\(^9\) are presented in Fig. 8(a). The result shows the effort made by the Central Bank to dampen the inflationary effect of the cost-push shock by lowering output gap. In response, output gap declines by 4%. This is the result of tightening monetary policy through raising the nominal rate by more than 0.05% in response to a rise in inflation after the shock. This response correctly depicts the relationship described by (23\(’\)) and (24\(’\)) together with the equilibrium value for inflation in (27\(’\)).

When the supply shock is made completely transitory, as shown in Fig. 8(b), the magnitude of the initial optimal response remains the same for all the endogenous variables except the policy rate.

\(^{9}\)All the other parameters are set to the baseline calibration indicated in Table 1 to obtain the optimal impulse responses of the endogenous variables.
However, their persistence declines in accordance with the transitory shock, which then dies out completely over two quarters. In a transitory shock scenario, the magnitude of the response in the policy rate is much higher than is the case for the persistent shock (1% versus 0.06%, respectively). This indicates an aggressive response by the Central Bank so as to dampen the inflationary pressure on the economy. However, the trade-offs remain the same as in the case of a persistent shock. Output does not decrease as much, inflation adjusts to its long-term optimum level, and the financial sector responds by deleveraging and closing the gap in credit spreads.

One important point to note here is that, in both transitory and persistent supply shock scenarios, it is optimal for the Central Bank to play an accommodative role by letting inflation initially rise. When one notes what the magnitude of the rise in inflation would have been if the other two variables – output gap and credit spread – had remained unchanged, the ensuing trade-offs between the three endogenous variables become apparent. This can be deduced from the equilibrium relationship given in (27'), which will yield a larger value without changes in the two variables. When the economy experiences a financial shock with a magnitude of 5% and a persistence rate of 0.5, the optimal path for the Central Bank in a discretionary policy environment entails holding the output level below potential until the inflationary pressure completely dies out. The equilibrium relationship in (30') shows that leverage sharply increases following a financial shock, which drives credit spread up. Given that the function $\Omega_t(X_t)$ is increasing in $X_t$ and is convex, this is a typical scenario that raises the probability of transitioning to a crisis state. Such an exogenous financial shock not only causes financial institutions to become more leveraged but

Figure 8. Optimal responses to a persistent supply shock (a) $\phi_u = 0.5$, (b) $\phi_u = 0$. The details of the optimization problem for a discretionary monetary policy is provided in Appendix D.
it also ushers in more general financial distress across institutions, which makes a chain reaction throughout the whole system likely. However, the magnitude of this effect will depend on the state of the economy when the shock hits. If the economy was in a crisis state when hit by the shock, it is highly likely that the probability of dragging the economy into an even deeper crisis state will be an ever-increasing function of leverage. If the economy is in a normal state, it will be more resilient to financial shocks and the probability of transitioning to a crisis state will be low. As the results in Fig. 9(a, b) show, for both transitory and persistent shocks, the optimal discretionary policy is for the Central Bank to follow an easy monetary policy in order to stabilize the financial system and bring credit spread and leverage back to normal levels while also holding output gap in negative territory so as to dampen the transitory inflationary effects arising from the financial shock.

IV. Conclusion

The recent global financial crisis has triggered a series of questions among policy makers, Central Bankers, academics and others regarding the role of Central Banks in stabilizing financial markets. Based on the lessons learned from the crisis, a committee of prominent economists (Eichengreen et al. 2011) recently issued a report underlining the need for financial stability to be an explicit mandate of Central Banks. Woodford (2012) has also made the claim that incorporating financial stability into monetary policy objectives improves the optimality of monetary policy and results in welfare gains. On the other hand, Svensson (2011) argues that financial stability is best served by more specific instruments that can more directly control leverage and credit frictions.

The analysis in this article is motivated by this sharp difference of opinion and the absence of concrete numerical results either supporting or refuting

Figure 9. Optimal responses to a persistent financial shock (a) $\phi_v = 0.5$, (b) $\phi_v = 0$. 
the purported gains of including financial stability within the more traditional goals of monetary policy. In general, the model simulation’s optimal policy response results are in line with the theoretical predictions. When the model economy experiences a supply shock, it is optimal for the Central Bank to hold output gap below the potential level in order to shield the economy from inflationary pressures until the cost-push shock completely dies out. Monetary policy tightens, which causes both leverage and credit spread to drop sharply before returning back to their long-run equilibrium trend levels after 8–10 quarters. At least in the short run, financial shock is found to have a destabilizing effect that depends on the magnitude of the persistence coefficients for the shock. Leverage and credit spread significantly rise in response to a financial shock, thereby raising the probability that a crisis will occur.

Comparisons between rule-based and discretionary monetary policies indicate that the former has greater gains insofar as it produces less output reductions and less increase in inflation. No significant gain is observed in leverage and credit spread.

We can now revisit the questions raised in Section I: (1) can monetary policy help to achieve financial stability while simultaneously targeting price and output stability? (2) What trade-offs are involved when monetary policy attempts to maintain financial stability alongside price and output stability? Based on the results in this article, the Central Bank can temporarily achieve financial stability when the economy experiences unanticipated financial shocks by targeting output gap, inflation and financial stability at the same time. In addition, this short-term gain in financial stability comes at a price: inflation sharply rises and output has to be kept below the potential level until the shock completely dies out. This trade-off between stabilizing the financial system, rising inflation and contraction in aggregate output is found to be smaller when the Central Bank is in a rule-based rather than a discretionary policy environment.

Acknowledgements

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Disclosure statement

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References


Appendix A: Data Type and Descriptive Statistics

The empirical analysis for this study is based on quarterly data covering the years 1979:1–2011:4 and upon the following variables:

- Output gap – the Hodrick–Prescott filtered cyclical component of real GDP.
- Inflation: measured by log differences of quarterly Consumer Price Index.
- Policy Rate: average quarterly effective nominal fed funds rate.
- Degree of Financial Distortion: the average spread between yields on risky corporate bonds and on treasury securities.

The time series plots and the summary of descriptive statistics for all the variables are provided in Figure A1 and Table A1, respectively.

Table A1. Summary statistics Chicago Fed Adjusted National Financial Conditions Index (ANFCI), inflation (CPIAUCSL), interest rate spread (BAA10YM), output gap (GDPC1_PCH) and federal funds rate (FEDFUNDS).

<table>
<thead>
<tr>
<th>Statistic</th>
<th>ANFCI</th>
<th>BAA10YM</th>
<th>CPIAUCSL</th>
<th>FEDFUNDS</th>
<th>GDPC1_PCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.03</td>
<td>2.29</td>
<td>159.30</td>
<td>5.27</td>
<td>0.64</td>
</tr>
<tr>
<td>SE</td>
<td>0.07</td>
<td>0.06</td>
<td>3.94</td>
<td>0.34</td>
<td>0.06</td>
</tr>
<tr>
<td>Median</td>
<td>-0.13</td>
<td>2.17</td>
<td>159.82</td>
<td>5.25</td>
<td>0.72</td>
</tr>
<tr>
<td>SD</td>
<td>0.79</td>
<td>0.72</td>
<td>47.60</td>
<td>4.14</td>
<td>0.73</td>
</tr>
<tr>
<td>Sample variance</td>
<td>0.63</td>
<td>0.52</td>
<td>226.75</td>
<td>17.12</td>
<td>0.54</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>2.30</td>
<td>4.63</td>
<td>-1.14</td>
<td>0.45</td>
<td>2.54</td>
</tr>
<tr>
<td>Skewness</td>
<td>1.16</td>
<td>1.56</td>
<td>0.00</td>
<td>0.78</td>
<td>-0.97</td>
</tr>
<tr>
<td>Range</td>
<td>4.98</td>
<td>4.54</td>
<td>168.11</td>
<td>17.71</td>
<td>4.39</td>
</tr>
<tr>
<td>Minimum</td>
<td>-1.82</td>
<td>1.05</td>
<td>69.20</td>
<td>0.07</td>
<td>-2.11</td>
</tr>
<tr>
<td>Maximum</td>
<td>3.16</td>
<td>5.39</td>
<td>237.31</td>
<td>17.78</td>
<td>2.28</td>
</tr>
<tr>
<td>Sum</td>
<td>4.49</td>
<td>333.89</td>
<td>23589</td>
<td>770.09</td>
<td>94.06</td>
</tr>
<tr>
<td>Count</td>
<td>146.00</td>
<td>146.00</td>
<td>146.00</td>
<td>146.00</td>
<td>146.00</td>
</tr>
</tbody>
</table>

Figure A1. Time series plots of leverage, credit spread, output gap, inflation and federal funds rate.

Appendix B. Policy & Transition Functions and Theoretical Moments

Table B1. Policy and transition functions.

<table>
<thead>
<tr>
<th>Variable</th>
<th>y</th>
<th>g</th>
<th>Omega</th>
<th>Pi</th>
<th>L</th>
<th>l</th>
<th>U</th>
<th>v</th>
<th>ln</th>
</tr>
</thead>
<tbody>
<tr>
<td>L(–1)</td>
<td>-0.01315</td>
<td>0</td>
<td>0.045826</td>
<td>0.004762</td>
<td>0.091653</td>
<td>-0.02684</td>
<td>0</td>
<td>0</td>
<td>-0.05032</td>
</tr>
<tr>
<td>u(–1)</td>
<td>-0.44979</td>
<td>0</td>
<td>-0.14273</td>
<td>0.162851</td>
<td>-0.28547</td>
<td>0.015262</td>
<td>0.5</td>
<td>0</td>
<td>0.067249</td>
</tr>
<tr>
<td>v(–1)</td>
<td>-0.07633</td>
<td>0</td>
<td>0.225778</td>
<td>0.027636</td>
<td>0.451556</td>
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<td>0.5</td>
<td>-0.18365</td>
</tr>
<tr>
<td>y(–1)</td>
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<td>0</td>
<td>0.19689</td>
<td>0.27167</td>
<td>0.393779</td>
<td>-0.1451</td>
<td>0</td>
<td>0</td>
<td>-0.77587</td>
</tr>
<tr>
<td>g(–1)</td>
<td>0</td>
<td>0.95</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.031667</td>
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</tr>
<tr>
<td>eps_g</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.033233</td>
<td>0</td>
<td>0</td>
<td>0.134498</td>
</tr>
<tr>
<td>eps_u</td>
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<td>0</td>
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<td>0</td>
<td>0.3673</td>
</tr>
<tr>
<td>eps_v</td>
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<td>0</td>
<td>0.451556</td>
<td>0.055271</td>
<td>0.903113</td>
<td>-0.13494</td>
<td>0</td>
<td>1</td>
<td>-0.3673</td>
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</tbody>
</table>

Table B2. Theoretical moments.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>y</td>
<td>0</td>
<td>0.0613</td>
<td>0.0038</td>
</tr>
<tr>
<td>g</td>
<td>0</td>
<td>0.1601</td>
<td>0.0256</td>
</tr>
<tr>
<td>Omega</td>
<td>0</td>
<td>0.0373</td>
<td>0.0014</td>
</tr>
<tr>
<td>Pi</td>
<td>0</td>
<td>0.0183</td>
<td>0.0003</td>
</tr>
<tr>
<td>L</td>
<td>0</td>
<td>0.0746</td>
<td>0.0056</td>
</tr>
<tr>
<td>i</td>
<td>0</td>
<td>0.0145</td>
<td>0.0002</td>
</tr>
<tr>
<td>u</td>
<td>0</td>
<td>0.0577</td>
<td>0.0033</td>
</tr>
<tr>
<td>v</td>
<td>0</td>
<td>0.0577</td>
<td>0.0033</td>
</tr>
<tr>
<td>ln</td>
<td>0</td>
<td>0.0572</td>
<td>0.0033</td>
</tr>
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</table>

Table B3. Variance decomposition (in %).

<table>
<thead>
<tr>
<th>Variable</th>
<th>eps_g</th>
<th>eps_u</th>
<th>eps_v</th>
</tr>
</thead>
<tbody>
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<td>y</td>
<td>0</td>
<td>96.85</td>
<td>3.15</td>
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<tr>
<td>g</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Omega</td>
<td>0</td>
<td>50.41</td>
<td>49.59</td>
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<td>Pi</td>
<td>0</td>
<td>97.22</td>
<td>2.78</td>
</tr>
<tr>
<td>L</td>
<td>0</td>
<td>50.41</td>
<td>49.59</td>
</tr>
<tr>
<td>i</td>
<td>13.48</td>
<td>58.13</td>
<td>28.4</td>
</tr>
<tr>
<td>u</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>v</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>ln</td>
<td>0.87</td>
<td>87.84</td>
<td>11.28</td>
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</tbody>
</table>

Appendix C: Optimality Conditions

Given the loss function expressed in (5) and assuming that the minimum attainable value takes the form of $V_t(G, X_{t-1}; \Omega_t)$, the task of choosing the values of $y_t, X_t$ and the state-contingent commitment $\pi_{t+1}()$ so as to minimize (5) can be stated as

$$\frac{1}{2} \left[ \pi_t^2 + \lambda_y y_t^2 + \lambda_i i_t^2 \right] + \beta E[V_{t+1}(\pi_{t+1}, X_t; \Omega_{t+1})]$$  \hspace{1cm} (1')

when this is also subject to the constraints imposed by (2)–(4) and the prior commitment towards inflation expressed in $\pi_t$. Note here that the values of $\pi_t$ and $\Omega_t$ are given and that problem of (1') reduces to one of minimizing (2) for the given constraints

$$\frac{1}{2} \lambda_y y_t^2 + \beta E[V_{t+1}(\pi_{t+1}, X_t; \Omega_{t+1})|h_t]$$  \hspace{1cm} (2')

where $h_t$ represents the past history of realized shocks up until period $t$.

Using (4), we can also substitute out $y_t$ and rewrite the minimization problem as

$$\frac{\lambda_y}{2\phi^2} (X_t - \phi X_{t-1} - v_t)^2 + \beta \Gamma_t(X_t; \Omega_t) \Delta V_{t+1}[t]$$

$$+ \beta E[V_{t+1}(\pi_{t+1}, X_t; \Omega)|h_t, \Omega_{t+1} = \Omega]$$  \hspace{1cm} (3')
Subject to $\pi_t$ and constraint (2), where $\Delta V_{t+1|t} = E[\Delta V_{t+1}|h_t, \Omega_{t+1}] = 0$ and $\Gamma_t(X_t; \Omega_t)$ is the conditional probability of the crisis state occurring in period $t+1$, the Lagrangian for this problem can be stated as

$$L_{x_t, \pi_{t+1}} = \frac{\lambda_y}{\xi^2} (X_t - \phi X_{t-1} - v_t)^2 + \beta \Gamma_t(X_t; \Omega_t) \Delta V_{t+1|t}$$

$$+ \frac{\lambda_y}{\xi^2} (X_t - \phi X_{t-1} - v_t)^2 + \beta \Gamma_t(X_t; \Omega_t) \Delta V_{t+1|t}$$

$$+ \phi (\pi_t - \kappa_y y_t - \kappa_\Omega \Omega_t - \beta E_t \pi_{t+1} - u_t)$$

(4')

Accordingly, the first-order conditions with respect to $X_t$ and $\pi_{t+1}$, respectively, are

$$X_t: z_t + \beta \xi E_t[V_{X_t, t+1}(\pi_{t+1}, X_t; \Omega_{t+1})]$$

$$+ \phi (\pi_t - \kappa_y y_t - \kappa_\Omega \Omega_t - \beta E_t \pi_{t+1} - u_t) = 0$$

(5')

where $z_t = \lambda_y y_t - \kappa_y \phi_t$.

$$\pi_{t+1}: V_{\pi_{t+1}, t+1}(\pi_{t+1}, X_t; \Omega_{t+1}) - \phi_t = 0$$

(6')

After solving the partial derivatives of the value function $V_t(\cdot)$ with respect to $X_t$ and $\pi_t$ and applying the envelope theorem, this then yields

$$V_{\pi_{t+1}, t+1}(\pi_{t+1}, X_t; \Omega_{t+1}) = \pi_t + \beta \xi E_t[V_{\pi_{t+1}, t+1}(\pi_{t+1}, X_t; \Omega_{t+1})]$$

(7')

$$V_{X_t, t}(\pi_t, X_{t-1}; \Omega_t) = -\frac{\phi}{\xi} z_t$$

(8')

Solving equation (7') forward one period and then substituting it back into (6'), we can write the first-order condition with respect to $\pi_{t+1}$ as

$$\pi_{t+1} + \phi_{t+1} - \phi_t = 0$$

(9')

Also substituting (8') in the first-order condition (5') for $V_{x,t}$, we get

$$z_t = \beta \phi E_t z_{t+1} - \beta \xi M_t$$

(10')

where $M_t$ is defined as

$$M_t = \Gamma_t(X_t; \Omega_t) \Delta V_{t+1|t}$$

(11')

Assumptions made about the transition between the crisis and normal states imply that the marginal conditional probability with respect to $X_t$ takes the form $\Gamma_t(X_t; \Omega_t) = \Omega_t'(X_t)$ when the economy is in a normal state and $\Gamma_t(X_t; \Omega_t) = 0 > \Delta$ during a crisis state. Hence, under the normal state of the economy, the variable $M_t$ takes the form

$$M_t = \Omega_t'(X_t) \cdot \Delta V_{t+1|t}$$

(12')

This variable measures the degree by which a financial crisis could increase the expected welfare loss. It could be termed as a marginal crisis risk (Woodford, 2011) in which the optimal policy criterion not only depends upon the paths of inflation and the output gap but also upon the forecasted future evolution of this variable.

Rewriting our definition for $z_t$ in the form

$$\phi_t = \frac{\lambda_y}{\xi^2} y_t - \frac{1}{\kappa_y} z_t$$

(13')

And using the fact that under an optimal policy commitment, (9') implies the existence of a constant log price level $p^*$ such that $\phi_t = p^* - p_t$ for all $t \geq 0$, which then implies

$$(p_t - p^*) + \frac{\lambda_y}{\xi^2} y_t = \frac{1}{\kappa_y} z_t \quad \text{for all } t \geq 0$$

(14')

To get an expression for the target price level $p^*$ under the optimal policy commitment, we can solve forward (10') and obtain

$$z_t = (\beta \phi') E_t z_{t+j} - \beta \xi \sum_{j=0}^{\infty} (\beta \phi') E_t (M_{t+j})$$

(15')

Since the first term on the right hand side goes to zero as $j \to \infty$, we can alternatively express (15') as

$$z_t = -\beta \xi \sum_{j=0}^{\infty} (\beta \phi') E_t (M_{t+j})$$

(16')

Substituting (16') back into (14') yields an expression for the target price level

$$p^* = p_t + \frac{\lambda_y}{\xi^2} y_t + \frac{\beta \xi}{\kappa_y} E_t \sum_{j=0}^{\infty} (\beta \phi') E_t (M_{t+j})$$

(17')

### Appendix D:

#### Discretionary Monetary Policy

Under a discretionary policy the Central Bank is assumed to choose the sequence of the endogenous variables $y_t$, $\pi_t$, $\Omega_t$ for each period in order to minimize the loss function:

$$\pi_t^2 + \lambda_y y_t^2 + \lambda_\Omega \Omega_t^2$$

subject to

$$\pi_t = \kappa_y y_t + \kappa_\Omega \Omega_t + \xi_t$$

(19')

where $\xi_t = \beta E_t \pi_{t+1} + u_t$. In a discretionary policy environment the Central Bank takes all this as a given because $u_t$ is an exogenous process and the term $E_t \pi_{t+1}$ itself a function of future expectations regarding the output gap and credit spreads, cannot be influenced by the bank’s current policy.

Setting up the Lagrangian and solving this optimization problem yields the first-order conditions of:

$$\pi_t: 2\pi_t + \psi = 0$$

(20')

$$y_t: 2\lambda_y y_t - \psi \kappa_y = 0$$

(21')

$$\Omega_t: 2\lambda_\Omega \Omega_t - \psi \kappa_\Omega = 0$$

(22')

Combining the first-order conditions (20') and (21') results in the optimal relationship between output gap and inflation:

$$y_t = \frac{\psi}{\lambda_y} \pi_t$$

(23')
Condition (23) can be interpreted as a ‘leaning against the wind’ policy where the Central Bank holds output below the potential output level in order to reduce or dampen the effect of inflation that was triggered by a positive supply shock. Therefore, in a discretionary policy environment, the central bank follows this optimal policy path every time for \( t = 1, 2, 3, \ldots \) until condition (23) is fulfilled. Similarly, combining the first-order conditions (20) and (21) yields the optimality conditions between credit friction and inflation:

\[
\Omega_t = -\frac{\kappa_\Omega}{\lambda_\Omega} \pi_t
\]  

(24′)

Condition (24) shows that the Central Bank, in a scenario of inflationary pressure within the economy, follows an optimal path such that the spread in the credit market narrows down. Whenever the economy experiences an exogenous cost-push shock, the policy rate rises and credit spread drops. This dynamic provides stability to the financial market and balances the destabilizing effect coming from the supply side of the economy.

Using optimality conditions (23) and (24) to substitute for \( y_t \) and \( \Omega_t \) in the NKPC (2) yields the difference equation for inflation:

\[
\pi_t = A \pi_{t+1} + \Theta u_t
\]  

(25′)

where \( A = \left( \frac{\lambda_\pi \lambda_\Omega \beta}{\lambda_\pi \lambda_\Omega + \lambda_\Omega \kappa^2_\pi + \lambda_\gamma \kappa^2_\Omega} \right) \) and \( \Theta = \frac{\lambda_\gamma \lambda_\pi}{\lambda_\gamma \lambda_\Omega + \lambda_\Omega \kappa^2_\pi + \lambda_\gamma \kappa^2_\Omega} \)

Solving (25′) forward and applying the Law of Iterated Expectations yields

\[
\pi_t = A \pi_{t+1} + \Theta \sum_{j=0}^{\infty} A^j \pi_{t+j} \]  

(26′)

Since \( 0 < A < 1 \) and \( u_t \) are given by the AR (1) process, \( u_t = \rho_u u_{t-1} + \varepsilon_u \) where \( \varepsilon_u \sim iidN(0, \sigma_u^2) \), the equilibrium value of inflation under the optimal discretionary policy, is given by

\[
\pi_t = \Theta A \rho^2_u u_t
\]  

(27′)

Substituting (27′) in the optimality conditions (23′) and (24′) yields the equilibrium condition for output gap and credit spread, respectively, expressed as

\[
y_t = -\frac{\kappa_y}{\lambda_y} \left( \Theta A \rho^2_u u_t \right)
\]  

(28′)

and

\[
\Omega_t = -\frac{\kappa_\Omega}{\lambda_\Omega} \left( \Theta A \rho^2_u u_t \right)
\]  

(29′)

The equilibrium condition for leverage is obtained by plugging in the equilibrium value of output gap in (28′) and making the further assumption that the past realized value of leverage is equal to the current value in a discretionary policy environment. This yields

\[
X_t = -\left( \frac{\xi}{1 - \phi} \right) \left[ \frac{\kappa_y}{\lambda_y} \left( \Theta A \rho^2_u u_t \right) \right] + \left( \frac{1}{1 - \phi} \right) y_t
\]  

(30′)

The equilibrium condition (30′) predicts that leverage negatively responds to a supply shock while a financial shock generates an increase in the leverage of financial institutions.