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Abstract

The financial crisis and its aftermath have raised numerous questions about the appropriate role of financial stability considerations in the conduct of monetary policy. This paper develops a simple example of the possible connections between financial stability and monetary policy. We find that even without an explicit financial stability goal for monetary policy, financial stability considerations arise naturally in the context of standard models of optimal monetary policy if the potential magnitude of financial stability shocks is affected by the stance of policy. In this case, similar to the classic analysis of Brainard (1967), policymakers may seek to reduce the variance of output by scaling back the level of policy accommodation provided today in response to an aggregate demand shock relative to the level that would otherwise be provided. However, the policy implications of this possible connection between monetary policy and financial stability are complex even in the simple example considered here. In particular, financial stability considerations may also increase the relative benefits of following a commitment policy relative to a discretionary strategy.

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Faced with financial crises and the accompanying combination of very weak aggregate demand and subdued inflation, many central banks have adopted highly accommodative monetary policies over recent years to foster their macroeconomic objectives.² Moreover, many have done so by lowering their short-term policy rate to the effective lower bound and by employing extraordinary measures in the form of large-scale asset purchases and forward guidance about the future path of policy rates. These actions have put downward pressure on longer-term yields and contributed to a more general easing in broad financial market conditions that, in turn, have been aimed at supporting economic recovery and price stability. However, the resulting lengthy period low interest rates and muted volatility in financial markets coupled with anecdotal reports of investors “reaching for yield” has sparked concerns in some quarters that signs of froth in credit markets could be beginning to emerge. These developments have led to heightened interest among policymakers, researchers and the general public about the extent to which the current highly accommodative stance of monetary policy itself could be one of the factors contributing to an increase in financial imbalances and, if so, what that should imply about the appropriate response of monetary policy to developing imbalances. Recent FOMC communications, for example, have listed among the potential costs of the Federal Reserve’s large scale asset purchases (LSAPs) the risk that the associated very low interest rate environment could induce excessive risk taking now that will set the stage for adverse financial and economic developments at some point down the road. Moreover, a rapidly expanding academic literature has advanced the theoretical and empirical basis for possible connections between monetary policy and financial stability.³

In many respects, these recent concerns are a continuation of the important debate that had emerged prior to the financial crisis regarding the appropriate response of monetary policy to changes in asset prices and signs of excess in credit markets.⁴ Broadly speaking, this debate pitted those who argued that central bankers should actively lean against developing financial imbalances by tightening monetary policy against those who maintained that central banks should largely focus on forecasts for output and inflation and the risks surrounding those forecasts in conducting monetary policy. The more activist view, articulated in papers such as Borio and Lowe (2002) and Borio and White (2004), noted that financial imbalances in the form of credit market “overheating” were likely to develop during the expansion phase of the business cycle and especially in an environment with low and stable inflation. This analysis pointed to historical episodes of developing financial imbalances and argued that central banks could have spotted the warning signs of excess in credit markets and acted pre-emptively to tighten policy to rein in excessive risk-taking. Following similar logic, some authors concluded that financial stability should be established as an explicit additional objective of monetary policy in addition to the traditional focus on output and inflation (see Eichengreen et. al. 2011). The alternative view, advanced prominently by Bernanke and Gertler (2001), Kohn (2009), and Svensson (2012) among others, has questioned the ability of central banks to accurately identify developing financial imbalances in real time and has generally regarded changes in the stance of monetary policy as a blunt tool at best to address growing financial imbalances. Under this view, even assuming that monetary policy could be helpful in defusing a potentially damaging credit boom, identifying “financial imbalances” in real time based on estimates of deviations of asset prices from fundamentals or other indicators of excess in credit markets and then

² For example, see recent speeches by Bernanke (2013), Kocherlakota (2013), and Hoenig (2011), George (2013), and Yellen (2011) and the minutes of the Federal Open Market Committee, January and March 2013.

³ Adrian and Shin (2009), Gertler and Karadi (2011), Gertler, Kiyotaki, and Queralto (2011), Kiyotaki and Moore (1997), Kiley and Sim (2011), Stein (2011), Woodford (2012).

⁴ See, for example, Borio and Lowe (2002), Borio and White (2004), Bernanke and Gertler (1989 and 2001), Eichengreen et. al. (2011), Kohn (2009), Stein (2011).

calibrating an appropriate monetary policy response could be extraordinarily difficult, particularly given the lags and other uncertainties in the effects of monetary policy. Advocates of this view have generally regarded regulatory and supervisory tools as the most appropriate means of addressing signs of financial imbalances.

Of course, this debate remains far from settled, but it seems fair to say that in the current environment both the magnitude and the sign of the effect of changes in the stance of monetary policy on financial stability have not been well established. While some have argued that accommodative policy could spur excessive risk taking, others have noted that a highly accommodative stance of monetary policy could very well be supportive of financial stability by strengthening the economic recovery, helping households and businesses to shore up their balance sheets, and allowing financial and nonfinancial firms to reduce their reliance on short-term funding. These are very important fundamental issues but this paper focuses on a much narrower question. Taking a cue from some of the recent statements of policymakers on this topic, the analysis below considers how monetary policy should be conducted if there is, in fact, an important mechanism by which changes in the stance of monetary policy can predictably affect financial stability risks. That is, assuming that many of the concerns cited above regarding the difficulty of identifying financial imbalances in real time and calibrating appropriate monetary policy responses could be addressed, how should monetary policy take account of potential financial stability risks?

Based on the framework developed below, the answer to even that narrow question involves a number of considerations. A connection between the stance of monetary policy and financial stability risks can potentially create a tradeoff for policymakers in responding to an aggregate demand shock—increasing policy accommodation now to address a shortfall in output may create greater risks to output in the future. In this case, the increased costs of monetary policy accommodation in the form of larger financial stability risks can lead central banks to provide less policy accommodation than would otherwise be the case. This is very similar to the “policy attenuation” result originally discussed in Brainard (1967). However, the potential tradeoff between monetary policy accommodation and financial stability risks can also increase the gains for central banks in following a commitment strategy—that is, a strategy in which the central bank today develops a plan for how it will react in the future and commits to abide by the plan developed today at all points in the future. A policymaker that is reluctant to follow a commitment strategy on the basis of concerns about financial stability risks could instead follow a discretionary policy. However, particularly when households and businesses are forward looking in their spending behavior, a discretionary policy can end up requiring the policymaker to provide more accommodation in the near term than under the commitment strategy and result in poorer economic outcomes on average.

In short, even in a world in which central banks understand all the connections between monetary policy and financial stability, the implications of developing financial imbalances for the conduct of monetary policy are not straightforward. In this scenario, the model developed below points to an incentive for central banks to run a somewhat tighter monetary policy than would otherwise be the case. At the same time, expectations about the future path of policy are quite important, and failure to provide an adequate degree of assurance that current and future policy will act to return output to potential may impair the central bank’s ability to foster its macroeconomic objectives. Moreover, this issue becomes more important as the sensitivity of financial stability risks to the stance of monetary policy increases.

The remainder of the paper describes these results in more detail in the context of a simple model of optimal monetary policy. Section 1 lays out the basic model and discusses a benchmark case in

which financial stability risks are entirely exogenous. Section 2 extends the model to consider the case when financial stability risks are endogenous and affected by the future path of monetary policy. Section 3 considers some comparative statics exercises examining the effects of changes in forward-looking behavior, commitment, and financial stability costs on optimal policy and economic outcomes. Section 4 provides some general observations and possible policy implications and section 5 concludes.

1. Basic Model

In the standard optimal monetary policy framework, monetary policymakers seek to minimize a loss function defined as the discounted expected value of squared deviations of output from potential (output gaps) and inflation from the central bank's inflation target.⁵ In the interest of highlighting the key factors at work, here we consider an especially simple variation of this framework in which policymakers seek to minimize only squared output gaps over two periods. The output gap in each period is defined by:

$$y_1 = \lambda y_0 + \alpha E_1\{y_2\} + x_1 \quad (1)$$

$$y_2 = \lambda y_1 + x_2 + \tilde{A} \quad (2)$$

Here the variable, x , represents the economic effect of “policy accommodation” provided by the central bank in the form of large scale asset purchases and communications regarding the future evolution of policy. This setup is admittedly highly stylistic, but it is rich enough to capture at least some important elements of monetary policy strategy. One key aspect of this structure is that output in period 1 involves forward-looking behavior. As a result, the central bank's choices for policy in the future influence output in the current period. In addition, there is persistence in the output gap, so the output gap in the future depends partly on the lagged value of output in the current period. As a result, the monetary policymaker must take account of the effect of its current period policy actions in affecting future output.

As a crude way of capturing some aspects of financial instability, the shock to the output gap in period 2 is specified as the realization of a discrete “financial stability shock” defined as:

$$\tilde{A} = \begin{cases} 0 & \text{probability } 1 - \rho \\ -A & \text{probability } \rho \end{cases}$$

Here we are assuming that the probability, ρ , is quite small so that the chance of pronounced financial instability shock in period 2 is very low. With a high probability then, the realized shock in period 2 will be zero. However, if a period of financial instability occurs, the realization of the shock, $\tilde{A}$, results in a very large output gap in period 2. This structure for the financial stability shock implies:

⁵ Important treatments of this topic include Clarida, Gali, Gertler (1999), Giannoni and Woodford(2003), and Woodford (2010).

$$E\{\tilde{A}\} = -\rho A$$

$$Mode\{\tilde{A}\} = 0$$

$$Var(\tilde{A}) = \rho(1-\rho)A^2$$

Of course, there is nothing in this financial stability shock specification that is directly connected with anything related to financial markets or institutions. The shock might just as well be an exogenous drop in household's marginal propensity to consume or any other factor that could result in a sharp drop in spending. Nonetheless, the specification is useful in the analysis below as a way of capturing at least some aspects of the effects of a severe financial stability shock in damping aggregate demand.

Given this specification, the expected value of the output gap in period 2 is given by:

$$\hat{y}_2 = E_1\{y_2\} = \lambda y_1 + x_2 - \rho A$$

Policymakers are assumed to conduct policy so as to minimize a very simple loss function given by:

$$L = E\left\{\frac{1}{2}y_1^2 + \frac{1}{2}y_2^2\right\}$$

To minimize the number of parameters, this specification of the loss function does not include a discount factor but this is not important in the two period model considered here. Of course, in a more complete model, the objective function would include deviations of inflation from target (along with a behavioral relationship describing the evolution inflation over time).

It is convenient to rewrite the loss function using the variance decomposition:

$$E\{y_2^2\} = E\{y_2\}^2 + Var(y_2) = \hat{y}_2^2 + \rho(1-\rho)A^2$$

The loss function can then be written as:

$$L = \frac{1}{2}y_1^2 + \frac{1}{2}\hat{y}_2^2 + \frac{1}{2}Var(y_2) = \frac{1}{2}y_1^2 + \frac{1}{2}\hat{y}_2^2 + \frac{1}{2}\rho(1-\rho)A^2 \quad (3)$$

Note that this expression for the loss function makes use of the fact that there is no uncertainty about the output gap in period 1 and the policymaker must choose the levels of policy accommodation in each period, x_1 and x_2 , prior to the realization of the financial stability shock. These assumptions imply that the variance of the output gap in period 2 is equal to the variance of the financial stability shock term $\tilde{A}$.

1.1 Benchmark Case: Exogenous Financial Stability Risks

In considering the implications of this model for optimal monetary policy, it is helpful to first consider a benchmark case when the financial shock term is entirely exogenous. In this case, the policymaker's choice of accommodation in each period has no bearing on the variance term in the objective function, $\frac{1}{2}\rho(1-\rho)A^2$. As a result, the policymaker simply chooses x_1 and x_2 to

minimize the squared output gap in period 1 and the squared value of the forecast of the output gap in period 2, $\hat{y}_2$. This, of course, is the usual result with a quadratic objective function and additive exogenous shocks—the policymaker should choose levels of policy accommodation to keep its forecasts of the output gap as close as possible to zero given the constraints represented by the behavioral relationships in equations (1) and (2).

The Lagrangean for this problem is:

$$L = \frac{1}{2}y_1^2 + \frac{1}{2}\hat{y}_2^2 + \frac{1}{2}\rho(1-\rho)A^2 + \theta_1(\lambda y_0 + \alpha \hat{y}_2 + x_1 - y_1) + \theta_2(\lambda y_1 + x_2 - \rho A - \hat{y}_2)$$

Taking derivatives with respect to $x_1, x_2, y_1, \hat{y}_2$, the associated first order conditions are:

$$y_1 - \theta_1 + \lambda \theta_2 = 0$$

$$\hat{y}_2 + \theta_1 \alpha - \theta_2 = 0$$

$$\theta_1 = \theta_2 = 0$$

And these conditions imply that:

$$y_1 = \hat{y}_2 = 0$$

So the central bank conducts policy so as to keep its forecasts for the output gap in each period equal to zero. The level of accommodation provided in each period that generates this result can be derived by imposing this condition on the behavioral equations (1) and (2):

$$x_1 = -\lambda y_0$$

and

$$x_2 = -\lambda y_1 + \rho A = \rho A$$

Intuitively, the policymaker in this case sets policy accommodation in each period so as to fully offset the effects of lagged output gaps and the expected value of the financial stability shock on the current period output gap. Following this strategy, the expected value of the output gap in each period is zero.

Even in this simple setup, some basic points are worth noting. First, the shock in this model is skewed to the downside so that the expected value of $\tilde{A}$, $-\rho A$, differs from its modal value of zero. Under the optimal policy, the expected value of the output gap in the second period is equal to zero. This implies that the modal forecast for output in period 2—that is, the most likely value of output in period 2—would be positive and equal to ρA . So a policymaker that is concerned about financial stability shocks of the type specified here should provide policy accommodation so that the modal forecast for the output gap is positive.

It is also useful to note that, in this example, the optimal policy determined by the policymaker in period 1 is time consistent. Once output in the first period has been determined, the policymaker could reconsider the optimal choice of policy accommodation in period 2. In doing so, the policymaker would minimize a loss function with only the period 2 output gap:

$$L = \frac{1}{2} \hat{y}_2^2 + \frac{1}{2} \rho(1 - \rho)A^2 + \theta_2(\lambda y_1 + x_2 - \rho A - \hat{y}_2)$$

Minimizing this loss function would again lead the policymaker to set the expected value forecast of output in period 2 equal to zero—that is, the same policy that was chosen in the first period. And that would again imply a positive value for the modal forecast of output in period 2.

2. Endogenous Financial Stability Risks

In the benchmark case considered above, the financial stability shock is exogenous and so does not capture the notion that the stance of monetary policy may be a factor contributing to the risks of financial instability. There are many possible ways the interaction between monetary policy and financial stability risks could be modeled. For example, one might specify the probability of a financial stability shock as depending in some way on the level of policy accommodation. Alternatively, the magnitude of the financial stability shock could be a function of the level of policy accommodation. This might be viewed as a crude way of capturing the idea that policy accommodation could be leading to accumulating financial imbalances that will amplify a subsequent downturn. Below, we consider the case when the magnitude of the financial stability shock is a function of the current and expected future policy accommodation, $z = x_1 + x_2$. This specification is intended to capture the notion that the central bank may contribute to financial stability risks in the future by conducting a policy that provides a great deal of policy accommodation over time.

With this modification, the shock structure is given by:

$$\tilde{A} = \begin{Bmatrix} 0 & \text{probability } 1 - \rho \\ -A(z) & \text{probability } \rho \end{Bmatrix}$$

And the mean, mode, and variance of the shock are then:

$$E\{\tilde{A}\} = -\rho A(z)$$

$$\text{Mode}\{\tilde{A}\} = 0$$

$$\text{Var}(\tilde{A}) = \rho(1 - \rho)A(z)^2 = V(z)$$

If the scale of the shock term is increasing the level of current and expected future policy accommodation, z , then increasing policy accommodation makes the expected value of the financial stability shock more negative and increases the variance the shock. In the discussion that follows, we will focus largely on a quadratic objective function for monetary policy. As result, the fact that the mean of the financial stability shock differs from the mode in this specification plays a limited role in the analysis. However, this feature would be quite important for other plausible objective functions that might place greater weight on large outliers.

In this paper, we do not formally consider the implications of constraints on the ability of the central bank to provide policy accommodation in any given period—the variable x in each period can take on any value the central bank wishes. However, there is an important implicit constraint on the central bank's policy tools in the sense that it cannot respond to the realized value of the shock in period 2. As a result, the central bank has a strong incentive to minimize the possible magnitude of the financial stability shock if possible. That could be viewed as providing at least some sense of the

results for an alternative setup in which a financial stability shock could persist for some time but the central bank faces limitations in its ability to provide accommodation such as the zero lower bound on nominal interest rates or constraints on asset purchases.

2.1 Optimal Policy Under Commitment

With the shock structure specified as above, the Lagrangean has the same form as before but now the variance term and the expected value of the output shock in period 2 are functions of z , the total level of policy accommodation in periods 1 and 2.

$$L = \frac{1}{2}y_1^2 + \frac{1}{2}\hat{y}_2^2 + \frac{1}{2}V(z) + \theta_1(\lambda y_0 + \alpha \hat{y}_2 + x_1 - y_1) + \theta_2(\lambda y_1 + x_2 - \rho A(z) - \hat{y}_2)$$

The key difference in this expression relative to the base case is that the variance term $V(z)$ now depends on the level of policy accommodation chosen in each period. The associated first order conditions in this case are:

$$y_1 - \theta_1 + \lambda \theta_2 = 0$$

$$\hat{y}_2 + \theta_1 \alpha - \theta_2 = 0$$

$$\frac{1}{2}V'(z) + \theta_1 - \theta_2 \rho A'(z) = 0$$

$$\frac{1}{2}V'(z) + \theta_2 - \theta_2 \rho A'(z) = 0$$

And these equations can be combined as:

$$y_1 = -\frac{1}{2}(1 - \lambda)V'(z) / (1 - \rho A'(z)) \quad (4)$$

$$\hat{y}_2 = -\frac{1}{2}(1 - \alpha)V'(z) / (1 - \rho A'(z)) \quad (5)$$

The primary difference in these equations relative to the comparable equations from the benchmark case discussed above is that the policymaker must take account of the effects of policy in influencing the variance and expected value of the future financial stability shock. Holding all other variables constant, the direct effect of an increase in the level of policy accommodation provided in period 1 is to boost output in period 1 at the margin. At the same time, however, the increase in period 1 accommodation increases the magnitude (and thus the variance) of the future financial stability shock. Moreover, by increasing the expected magnitude of the financial stability shock, increasing policy accommodation reduces the expected value of output in period 2. Because output in period 1 is forward looking, any decline in the expected value of future output will tend to depress output in period 1. The first order conditions (4) and (5) above describe how these various marginal effects must be balanced to arrive at the optimal level of output in each period.

Summing the equations for the behavioral relationships in (1) and (2) implies:

$$(1 - \lambda)y_1 + (1 - \alpha)\hat{y}_2 = \lambda y_0 + z - \rho A(z) \quad (6)$$

And substituting equations (4) and (5) into this expression yields:

$$-((1-\lambda)^2 + (1-\alpha)^2)V'(z) = 2 \cdot (1-\rho A'(z))(\lambda y_0 + z - \rho A(z)) \quad (7)$$

Equation (7) can be solved for the optimal level of total policy accommodation, z , provided in periods 1 and 2. Once this value is obtained, the optimal values for y_1 and $\hat{y}_2$ can be calculated from the first order conditions (4) and (5). And the optimal values of policy accommodation in each period can then be derived as before from the behavioral equations (1) and (2).

It is useful to note some general properties of the solution in this setup. Assuming that an increase in policy accommodation results in a larger magnitude of financial stability shock ($A' > 0$ and $V' > 0$), the first order conditions (4) and (5) imply that the optimal values of y_1 and $\hat{y}_2$ are negative—that is, the policymaker conducts policy so that the expected value of output is below potential in both period 1 and period 2. This reflects the fact that increasing the level of policy accommodation provided now has a cost in reducing the expected value of output in period 2 and in increasing the variance of the financial stability shock. As a result, fully offsetting the expected financial stability shock and lagged values of output as in the base case with exogenous financial stability shocks is no longer optimal. In effect, the policymaker is willing to live with the expected value of output somewhat below potential in order to realize the gain of lower expected costs associated with the financial stability shock.

This result is similar to the classic analysis of Brainard (1967) that considered the case when the policymaker faces “parameter uncertainty” about the effects of changes in stance of monetary policy on spending.⁶ In that scenario, the policymaker must take account of the fact that changes in the stance of monetary policy may increase the variance of output. In the current model, policymakers are not uncertain about any of the underlying model parameters; however, changes in the stance of policy to address a demand shortfall in the current period do affect uncertainty about output in the future and the central bank takes this into account in developing an optimal monetary policy strategy.

Another point worth noting is that under the optimal strategy, the relationship between output in period 1 and period 2 as summarized in equations (4) and (5) is given by:

$$y_1 = (1-\lambda)\hat{y}_2 / (1-\alpha)$$

As a result, there is no clear implication for the magnitude of the expected output gaps in each period as in the benchmark case discussed above. If the parameters governing forward and backward looking behavior in period 1 are the same, $\alpha = \lambda$, then the magnitudes of the expected output gap in each period will be identical as in the benchmark case. If the forward looking behavior is stronger than the persistence of output, $\alpha > \lambda$, then the output gap in period 1 will be larger than the expected output gap in period 2. Intuitively, the policymaker in this case will be very interested in keeping the second period output gap close to zero because it has a strong effect on output in the first period as well. Conversely, if the persistence parameter is larger than the forward

⁶ Most of Brainard (1967) focuses on the monetary policy implications of uncertainty about the coefficients of the IS curve. However, the paper also includes a short discussion of the potential implications if the stance of monetary policy directly affected the distribution of shocks to the IS curve—very similar to the focus of this paper.

looking behavior, then the policymaker will be very interested in keeping the output gap in period 1 close to zero because of its strong indirect effect on output in period 2.

It is worth emphasizing that the influence of financial stability considerations on optimal monetary policy in this setting stems from the indirect effect of the stance of monetary policy on the variance of future output. Thus the mechanism explored here is somewhat different than in the models developed by Curdia and Woodford (2009), and Woodford (2012); those models incorporate an additional term in the central banks' objective function that captures the deviation of credit spreads from their normal level along with the traditional output and inflation gap terms. The additional credit spread term is motivated as an approximation of the welfare of the representative agent in a model with credit frictions.

Another general feature of the optimal strategy defined by equations (4) - (7) is that, unlike the benchmark case, the strategy is not time consistent. That is, after the first period has elapsed, a policymaker focused only on output in period 2 would not choose a policy for period 2 that was the same as the policy that had been planned for period 2 in period 1. As a result, implementing this policy would require some form of credible commitment by the policymaker.⁷

2.1 Discretionary Policy

Under the optimal commitment strategy described above, the policymaker has an incentive to renege on its initial plans for providing accommodation in period 2 once period 1 has passed. As an alternative to the commitment strategy, a central bank could consider a discretionary policy in which the policymaker can only set plans for the output gap and policy accommodation in the second period that are consistent with those it would actually choose in period 2 once period 1 has elapsed. With this constraint, the policymaker would need to ignore the indirect effect of expected output in period 2 on output in period 1. In this case, the first order conditions are:

$$\begin{aligned} y_1 - \theta_1 + \lambda \theta_2 &= 0 \\ \hat{y}_2 - \theta_2 &= 0 \\ \frac{1}{2}V'(z) + \theta_1 - \theta_2 \rho A'(z) &= 0 \\ \frac{1}{2}V'(z) + \theta_2 - \theta_2 \rho A'(z) &= 0 \end{aligned} \tag{8}$$

These first order conditions imply:

$$y_1 = -\frac{1}{2}(1-\lambda)V'(z) / (1-\rho A'(z)) \tag{9}$$

$$\hat{y}_2 = -\frac{1}{2}V'(z) / (1-\rho A'(z)) \tag{10}$$

And the analogue of equation (7) in this case is:

⁷ See the seminal work of Kydland and Prescott (1977) for a discussion of this issue. The appendix provides more detail on the basic time consistency issue in this model.

$$-((1-\lambda)^2 + (1-\alpha))V'(z) = 2 \cdot (1-\rho A'(z))(\lambda y_0 + z - \rho A(z)) \quad (11)$$

As before, equation (11) can be solved for the optimal level of total policy accommodation, z , in periods 1 and 2. Once that value has been determined, one can use equations (9) and (10) together with the behavioral relationships (1) and (2) to solve for the expected output gaps in each period and the optimal levels of policy accommodation to provide in each period.

The relationship between output in each period implied by equations (9) and (10) is:

$$y_1 = (1-\lambda)\hat{y}_2 \quad (12)$$

Under this discretionary policy, the expected output gaps in each period will have the same sign, but the magnitude of the output gap in period 2 will be larger than in period 1 depending on the value of the factor $1-\lambda$. As noted above, in period 2 the policymaker can no longer affect period 1 output by changing expected output in period 2. Under the discretionary policy then, the output gap in period 2 will tend to be larger than in period 1.

2.2 “Forecast-Only” Policy

Another case of interest occurs when the policymaker simply does not recognize the dependence of the magnitude of financial stability shocks on the level of policy accommodation and concentrates only on the traditional effect of policy on forecasts of the output gap. In this case, the first order conditions above reduce to those discussed above for the benchmark case of exogenous financial stability risks:

$$\begin{aligned} y_1 - \theta_1 + \lambda \theta_2 &= 0 \\ \hat{y}_2 + \theta_1 \alpha - \theta_2 &= 0 \\ \theta_1 &= 0 \\ \theta_2 &= 0 \end{aligned}$$

As in the base case, these first order conditions imply:

$$y_1 = \hat{y}_2 = 0$$

The “optimal” total level of accommodation can be derived from the analogue of equation (6):

$$\lambda y_0 + z - \rho A(z) = 0 \quad (13)$$

And the optimal choices of accommodation in each period are then given by:

$$\begin{aligned} x_1 &= -\lambda y_0 \\ x_2 &= \rho A(z) \end{aligned}$$

The forecast-only policy does not recognize the effect of policy accommodation on the magnitude of potential financial stability shocks and thus seeks to keep the expected output gap in each period equal to zero. Thus, the forecast-only policy will tend to run a somewhat more accommodative monetary policy when faced with a negative initial output gap than would either the policymaker

following a full information commitment strategy or a discretionary strategy. If the initial period output, y_0 , is positive, the forecast-only policymaker would also be somewhat more or less aggressive in tightening policy than a policymaker following the commitment strategy or discretionary strategy depending on the nature of the relationship between policy accommodation and financial stability shocks.

3. Comparing Alternative Strategies: An Example

To make more progress in analyzing the solutions described above under the various strategies requires specifying exactly how the magnitude of the financial stability shock depends on total policy accommodation, z . There are many plausible specifications one might choose. In the discussion below, we will assume that the magnitude of the financial stability shock is given by equation (14) below:

$$A(z) = \bar{A} + \frac{1}{2}\delta z^2 \quad (14)$$

This expression for the magnitude of the financial stability shock assumes that there is some portion of the shock, $\bar{A}$, that is exogenous and another part, $\frac{1}{2}\delta z^2$, that is a function of the current and expected future level of policy accommodation. We assume the function is quadratic so that both very accommodative policy, $z \gg 0$, and very tight monetary policy, $z \ll 0$, increase the magnitude of a potential financial stability shock. Moreover, this specification implies that the marginal costs of additional accommodation increase with the level of total policy accommodation.

Of course, it is by no means clear that the magnitude of financial stability shocks depends on policy accommodation in this way and empirically identifying the linkage between financial stability risks and policy accommodation is very difficult given the infrequency of large financial stability shocks. Here we simply take on board the basic hypothesis that monetary policy choices can influence the magnitude of financial stability shocks in this way and consider the implications of that possible connection for the conduct of monetary policy.

Given the expression for the magnitude of financial stability shocks in equation (14), the derivatives of $A(z)$ and $V(z)$ are given by:

$$A'(z) = \delta z \quad \text{and} \quad V'(z) = 2\rho(1-\rho)A(z)\delta z$$

These expressions can be substituted into the expressions above to solve for the optimal level of total policy accommodation, z , under each strategy. The resulting expressions, however, boil down to a cubic equation in z ; this equation can be solved analytically, but the solution is not especially intuitive. Tables 1-3 below provide a sense of some of the basic properties of the solution under each strategy.⁸

⁸ As noted above, the optimal values of z under each strategy are given by equations (7), (11) and (13). Given the specification in (14), equations (7) and (11) are third degree polynomials in z and equation (13) is a quadratic equation in z . However, for the parameterizations considered here, equations (7) and (13) have only one real root. Equation (13) could have two real roots but only one satisfies the relevant second order conditions.

Table 1 below reports results for the three basic strategies discussed above—optimal commitment, discretion and forecast-only—under a baseline set of assumptions about the model parameter values (shown in green). The baseline parameter settings include a moderate amount of persistence and forward looking behavior in the output equation, $\lambda = \alpha = 0.5$, and a relative low setting for the endogenous response of the magnitude of financial stability shocks, $\delta = 0.5$. The initial output gap is set at large negative value -4 so the exogenous component of output in period 1, λy_0 , is equal to -2. The exogenous component of the shock term $\bar{A}$ is set at 1; so absent any policy accommodation, there is some possibility of an adverse shock in period 2 that would depress output relative to potential by one percentage point. And the probability of a financial stability shock, ρ , is set at 0.05. The model rules out a financial stability shock in the first period. So if each period is viewed as equal to 1 year, this setting for the probability of a financial stability shock would imply that a major financial stability shock would occur about once every forty years.

With these parameter settings, the alternative strategies all produce fairly similar outcomes. Each strategy provides total policy accommodation, z , of about 2 and most of this accommodation is provided in period 1. The output gaps in each period are small under each strategy, and the value of the central bank's loss function, L , is about the same under each strategy.

Even at these settings, however, there are some perceptible differences among the different strategies. Under the *forecast-only policy*, the central bank does not recognize any feedback from its policy choices to the financial stability shock in period 2. As a result, the forecast-only policymaker is quite aggressive in addressing the large negative initial period output gap. The forecast-only policymaker sets the output gap in each period equal to 0 and provides the most policy accommodation. The downside of this policy is that the magnitude of the financial stability shock, $A(z)$, and the variance term in the central bank's loss function, $V(z)$, are largest under the forecast-only policy. Under the *commitment policy*, the policymaker announces significant levels of policy accommodation in both periods 1 and 2, but somewhat lower than the settings selected by the forecast-only policymaker. As a result, the expected output gaps in both periods are slightly negative. However, as shown in the next to last row of the table, the modal output gap in period 2 is positive under the commitment strategy. With less total policy accommodation, z , than under the forecast-only policy, the magnitude of the financial stability shock is a bit smaller under the commitment policy. Under the *discretionary policy*, the central bank provides less total policy accommodation than under the commitment strategy. As result, the magnitude of the financial stability shock is smaller than under the commitment policy. However, the central bank provides more policy accommodation in period 1 than under the commitment policy and less in period 2. In effect, the discretionary policymaker is forced to provide more accommodation in period 1 because households and businesses recognize that it will be optimal for the central bank to run a tighter policy in the second period. The expectation of tighter policy in the second period influences spending in period 1 through the expectations component of the output equation. It is interesting to note that under the discretionary policy, the worst case outcome for output in period 2—that is, when the large negative realization of $\bar{A}$ is realized—is lower than that under the commitment strategy. Even though the magnitude of the financial stability shock is somewhat smaller under the discretionary strategy than under the commitment strategy, the underlying level of output in period 2 absent a financial stability shock is lower than under the commitment strategy. As a result, if the financial stability shock does occur, output ends up lower in period 2 under the discretionary strategy.

Table 2 reports similar results when the degree of forward looking behavior in output is larger. In this case, the parameter α is set at 0.9. The same basic patterns noted in Table 1 are apparent in Table 2. One notable change though is that the increase in forward-looking behavior provides a stronger incentive to keep the output gap in period 2 close to zero under the commitment strategy. Intuitively, as the degree of forward looking behavior increases, the policymaker acting under commitment will want to keep the output gap in period 2 closer to zero because of its relatively strong influence on output in period 1.

Table 3 reports the results with both a high level of forward looking behavior in output ($\alpha = 0.9$) and a larger effect of policy accommodation on the magnitude of the financial stability shock ($\delta = 1.5$). Here the differences across the three strategies are quite distinct. The forecast-only policymaker still seeks to set the output gap in each period equal to zero. To do so, the central bank will find that it needs to provide more accommodation in period 2 to offset an expected value of the financial stability shock that is larger in magnitude. Under the commitment policy, the central bank aims to keep the output gap in each period fairly close to zero, and the output gap in period 2 is smaller than that in period 1. Moreover, the modal value of the output gap in period 2 remains positive (and even a little larger in magnitude than in the case shown in Table 2). The discretionary policymaker is forced to run a quite accommodative policy in period 1 because households and businesses understand that the central bank will run a very tight policy in the second period. In the second period, the discretionary policymaker runs a sizable negative output gap; even the modal value of output in period 2 is significantly negative in this case. The commitment strategy, by construction, ends up with the lowest value of the loss function. The value of the loss function for the discretionary policymaker is considerably higher than under the commitment strategy and even higher than that for the forecast-only policymaker.

4. Observations

As evidenced by the results for the commitment policy and the forecast-only policy, the attenuation result discussed in Brainard (1967) is present in this model as well. When the central bank recognizes that its current policy actions may affect the future variance of output, the central bank responds less aggressively in response to shocks. While much of the discussion above focused on a scenario in which a central bank is attempting to counter weak aggregate demand, similar logic would apply in the case when the central bank faces a scenario in which output has been running well above potential. In this case, the forecast-only policymaker would respond relatively aggressively in tightening policy to return output to potential. With the financial stability specification discussed above, this tightening in policy would contribute to larger financial stability risks. The optimal commitment policy then would also respond to the elevated level of aggregate demand by tightening policy, but not by as much as the forecast-only policymaker. In a more complete model in which the policymaker is also concerned about deviations of inflation from target, this basic attenuation property would also imply that the central bank should respond less aggressively to deviations of inflation from target in a world with endogenous financial stability risks than would otherwise be the case.

The results for the commitment policy and the discretionary policy highlight some potential pitfalls in conducting policy in a world with endogenous financial stability risks. Concerns about the effects of policy accommodation on financial stability risks could lead policymakers to be wary of following a commitment strategy in addressing a large shortfall (or excess) in aggregate demand relative to potential. The results for the discretionary strategy above, however, suggest that failure to follow a

credible commitment strategy could significantly impair the central bank's ability to achieve its objectives. As shown in Table 3, in a scenario with weak aggregate demand, a discretionary strategy can result in undesirable outcomes with output substantially below potential. Moreover, even though the discretionary strategy results in a somewhat lower variance of output, the worst case outcome for the deviation output below potential—that is, when the financial stability shock occurs—is actually larger than under the commitment strategy.

The model developed above is highly stylized, so drawing any firm policy conclusions from these selective results is difficult at best. That said, the results at least raise some broad issues about the potential interactions between monetary policy and financial stability that seem worthy of further study. As noted above, the nature of the interaction between policy accommodation and financial stability is far from clear. But even starting from a maintained hypothesis that monetary policy accommodation can amplify financial stability risks, the implications for monetary policy appear to be fairly complex in forward-looking models. As intuition might suggest, a linkage of this type may incline policymakers to scale back somewhat the total amount of policy accommodation they wish to provide to address a shortfall in aggregate demand. The magnitude of this effect, however, seems likely to be quite specific to the particular way the model is specified and calibrated. Moreover, a possible connection between policy accommodation and financial stability of this type may boost the potential gains for policymakers in following a commitment strategy to address an aggregate demand shock rather than a discretionary strategy. Under a commitment strategy, the central bank could accept somewhat higher financial stability risks than would be the case following a discretionary policy but this cost could be offset by improved economic outcomes in periods without a financial stability shock.

A second general point is that the conclusions from any model like the one described above will be highly dependent on the particular way in which the endogenous financial stability risks are modeled. The analysis above simply assumes that the financial stability risks increase with the level of policy accommodation, consistent with an often expressed concern discussed by policymakers and others. But as noted above, it seems plausible to conjecture that financial stability risks could depend on variables such as the current and expected value of the output gap. In that case, the tradeoffs between the level of policy accommodation and financial stability described above would largely disappear, and policymakers would instead have quite strong incentives to conduct monetary policy so as to keep output gaps close to zero. This observation points to the need for additional empirical work aimed at better understanding the connection between the stance of monetary policy and the magnitude of financial stability shocks.

5. Conclusion

The framework developed above could be usefully extended along a number of dimensions. A more complete model would incorporate an economic process for inflation and an inflation target for the central bank. The underlying behavioral relationships for households and businesses could be more firmly rooted in optimizing behavior. The time horizon for the analysis could be extended beyond the simple two-period case and it would be useful to examine the implications of constraints on the ability of the central bank to provide accommodation. Perhaps most importantly, it clearly would be desirable to incorporate a well-defined financial sector in which the connection between monetary policy and financial stability risks arises from the interaction of households and businesses with financial markets and institutions. As discussed in Woodford (2012), in a model of this type, one could examine optimal monetary policy more carefully and also develop and evaluate the performance of possible simple policy rules that could approximate optimal policy. Recent advances

in incorporating a financial sector and financial stability issues in a dynamic stochastic general equilibrium framework would appear to be a promising starting point for that type of analysis.⁹ That said, it seems reasonable to conjecture that some of the basic issues raised above would remain important in a more fully developed model. In particular, some of the basic mechanisms at work in models that incorporate financial stability risks such as changes in the value of borrower's net worth, or collateral constraints, or the presence of moral hazard might generate a linkage between the level of policy accommodation and the magnitude of potential financial shocks. In that case, the basic policy tradeoff discussed above—the potential gains from policy actions aimed at moving output and inflation back to target levels in the near term versus the possible cost of greater variability in output and inflation later on—seems likely to remain an important consideration for the conduct of monetary policy. And particularly in models with forward looking behavior, the connections between financial stability considerations and the gains from commitment strategies seem likely to remain important as well.

⁹ For example, see Gertler and Karadi (2011), Gertler, Kiyotaki, and Queralto (2011), and Stein (2011).

Table 1: Baseline Comparison of Strategies					
Parameters	Values	Variables	Commitment	Discretion	Forecast-Only
lam	0.5	z	2.05	2.02	2.10
alph	0.5	A(z)	2.05	2.02	2.11
y0	-4	V(z)	0.20	0.19	0.21
rho	0.05	L	0.10	0.10	0.11
abar	1	y1	-0.05	-0.05	0.00
del	0.5	x1	1.97	2.00	2.00
		E{y2}	-0.05	-0.10	0.00
		x2	0.08	0.02	0.11
		y2_mode	0.05	0.00	0.10
		y2_worst_case	-2.00	-2.03	-2.00
Table 2: Effects of Stronger Forward Looking Behavior in Output					
Parameters	Values	Variables	Commitment	Discretion	Forecast-Only
lamda	0.5	z	2.08	2.07	2.10
alpha	0.9	A(z)	2.08	2.07	2.11
y0	-4	V(z)	0.20	0.20	0.21
rho	0.05	L	0.10	0.11	0.11
abar	1	y1	-0.05	-0.05	0.00
delta	0.5	x1	1.96	2.04	2.00
		E{y2}	-0.01	-0.11	0.00
		x2	0.12	0.02	0.11
		y2_mode	0.09	0.00	0.11
		y2_worst_case	-1.98	-2.07	-2.00
Table 3: Effects of Stronger Forward Looking Behavior and Higher Financial Stability Costs					
Parameters	Values	Variables	Commitment	Discretion	Forecast-Only
lamda	0.5	z	2.02	1.97	2.24
alpha	0.9	A(z)	4.07	3.91	4.76
y0	-4	V(z)	0.79	0.73	1.07
rho	0.05	L	0.46	0.62	0.54
abar	1	y1	-0.35	-0.32	0.00
delta	1.5	x1	1.72	2.26	2.00
		E{y2}	-0.07	-0.64	0.00
		x2	0.31	-0.29	0.24
		y2_mode	0.13	-0.45	0.24
		y2_worst_case	-3.94	-4.36	-4.52

Appendix: Time Consistency

As discussed above, the policy described in equations (4)-(7) is not time consistent. Once period 1 has elapsed, the policymaker will be focused on maximizing the Lagrangean for just the second period given by:

$$L = \frac{1}{2} \hat{y}_2^2 + \frac{1}{2} V(z) + \theta_2 (\lambda y_1 + x_2 - \rho A(z) - \hat{y}_2)$$

In this case, y_1 is fixed and the optimal policy then would imply:

$$\frac{1}{2} V'(z) + \hat{y}_2 - \hat{y}_2 \rho A'(z) = 0 \quad \text{or}$$

$$\hat{y}_2 = -\frac{1}{2} V'(z) / (1 - \rho A'(z))$$

This expression is very similar to the corresponding expression under the optimal commitment strategy given by equation (5) but it excludes the term $(1-\alpha)$ in the numerator. Intuitively, in period 1, the policymaker chooses a value for output in period 2 based both on its direct effect on the central bank's objective function and its indirect effect operating through the influence of expected output in period 2 on the level of output in period 1. Once period 1 has passed, however, that latter influence is no longer present. So the policymaker in period 2 will have an incentive to recalculate a new optimal value for output and policy accommodation in period 2 to reflect the changed objective function. In particular, the policymaker will tend to put more weight on keeping the variance of the financial stability shock low and will be more willing to run a tighter monetary policy than under the optimal commitment strategy described by equations (4) to (7).

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