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On the Interplay between Monetary Policy and Macroprudential Policy: A Simple Analytical Framework*

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Abstract

The paper provides a simple analytical framework for analyzing the interplay between monetary policy and macroprudential policy. Three questions are analyzed: (i) Under which assumptions is coordination necessary to implement an optimal policy mix? (ii) Are the two policy instruments substitutes or complements, i.e. should they move in opposite or the same direction as response to a shock? (iii) Can "leaning against the wind" in monetary policy lead to a negative inflation bias?

Keywords: Monetary policy, Macroprudential policy, Coordination
JEL codes: E52, E58, E61

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1 Introduction

There is broad consensus that price stability is not a sufficient condition for financial stability, and that stronger regulatory measures than those that were present before the financial crisis in 2007/08 are warranted. The consensus ends there, however. What are the best tools to ensure sufficient financial stability? Should monetary policy be used also for financial stability, and if so, what should the interplay between monetary policy and macroprudential policy look like? Some argue that monetary policy could be an effective tool because interest rates "get in all the cracks" (Stein, 2013). Others, like Svensson (2017), argue that the costs of using monetary policy to reduce credit growth and house prices are far larger than the potential benefits. There are also different views on whether monetary policy and macroprudential should be coordinated within the same decision body, or whether they should be separated. Different countries have chosen different institutional setups.[1]

In this paper, I will discuss various issues related to the interplay between monetary policy and macroprodential policy. I will illustrate and discuss within a simple analytical framework some of the mechanisms analyzed in more rigorous models in the literature, and also provide some results that have not, to my knowledge, been discussed in the literature. First, I will present a simple analytical model that is useful for analyzing many of the issues in the debate about monetary and macroprudential policy. Then, I shall compare optimal coordination with separation, and show when and why separation may give a sub-optimal outcome. Specifically, separation will be sub-optimal if the financial variable that macroprudential policy seeks to stabilize also affects inflation directly. If the financial variable only affects inflation through its effect on the output gap, the two policies could be separated, so that monetary policy can focus solely on inflation and output stability, while macroprudential policy can focus on financial stability. Furthermore, I introduce two realistic extensions to the simple model: costs of adjusting the macroprudential instrument and uncertainty about policy effects. I show that both features call for coordination of monetary and macroprudential policy, and that the two instruments could turn from being strategic substitutes to being strategic complements if the adjustment costs or the degree of uncertainty are sufficiently large. In Section 3, I discuss the potential time-inconsistency problem related to a monetary policy that "leans against the wind", and show that such a policy may easily result in average inflation below target.

[1] For an overview of institutional arrangements in various countries, see IMF, FSB and BIS (2016).

2 A simple model

I shall first address the question of whether monetary policy and macroprudential policy should be coordinated, in the meaning of maximizing a common objective function, or whether they should be assigned separate targets. I will illustrate some general results using a simple analytical model, which albeit *ad hoc* represents a fairly general transmission mechanism of the two policy instrument, and it encompasses some small micro-founded models in the literature. The model is summarized as follows:

$$y_t = \alpha_{Ey} E_t y_{t+1} - \alpha_r (r_t - E_t \pi_{t+1}) - \alpha_b b_t + \alpha_q q_t + \alpha_{Eq} E_t q_{t+1} + u_{y,t}, \quad (1)$$

$$q_t = \beta_{Eq} E_t q_{t+1} - \beta_r (r_t - E_t \pi_{t+1}) - \beta_b b_t + u_{q,t}, \quad (2)$$

$$\pi_t = \kappa_{E\pi} E_t \pi_{t+1} + \kappa_y y_t + \kappa_q q_t + u_{\pi,t}, \quad (3)$$

where y_t is the output gap, r_t is the short-term nominal interest rate, π_t is the rate of inflation, and q_t, is a financial variable (e.g. and asset price, an interest rate spread, etc). Macroprodential policy consists of many potential instruments, including capital requirements for banks, loan to value restrictions etc, and the transmission channel of macroprudential policy is complicated. I shall, however, abstract from such complications and assume that the stance of macroprudential policy can be summarized by a single (real) variable b_t. The two policy instruments are thus r_t and b_t. All real variables are measured as deviations from their steady state values. Aggregate demand, represented by (1), depends negatively on the real interest rate and also on the financial variable. If we interpret q_t as an asset price, its effect on demand may be intepreted as a (perceived) wealth effect, or alternatively as a collaterial constraint effect as in e.g., Iacoviello (2005). The coefficient α_q would then be positive. If instead q_t is interpreted as an interest rate spread, as in Woodford (2012), the coefficient would be negative. Moreover, I allow for the possibility that a stricter macroprodential policy (increase in b_t) could dampen aggregate demand directly, for example by constraining borrowing and thereby expenditure in some sectors of the economy. In the case where $\alpha_{Ey} = 1$ and $\alpha_b = \alpha_q = \alpha_{Eq} = 0$, (1) becomes the standard Euler equation. $u_{y,t}$ is an exogenous shock to aggregate demand, and all exogenous shocks are assumed to be *i.i.d.* The expectations of next-period values of the variables, e.g. $E_t q_{t+1}$, are included in order for the model to encompass the above mentioned micro founded models, but these expectations will have no role for the results under my assumptions, as shown below. The asset price (eq. (2)) depends negatively on the tightness of both macruprudential policy and monetary policy. In addition, there is an asset price shock ($u_{q,t}$). Equation (3) is a standard New Keynesian Phillips curve, except that asset prices could affect inflation directly. For example, if q_t represents house prices, an increase in house prices could lead to higher inflation directly through housing costs, or indirectly through higher wage demands. If q_t is interpreted as a credit distortion, such as an interest rate spread, the model encompasses the simple model by Woodford (2012). I will show below that whether the financial variable affects inflation or not (i.e., whether κ_q is strictly different from 0) has important implications for the interplay between monetary and macroprudential policy.

The advantage of considering a simple, but fairly general, model that encompasses other simple models in the literature, is that the results become more general. However, not using a specific micro-founded model has the obvious disadvantage that the parameters are not truly structural. Moreover, a true welfare loss function cannot be derived, and we thus have to consider an *ad hoc* loss function. The purpose of this paper is, however, to consider the implications of the monetary policy objectives, based on a simple representation of such objectives as they appear in practice and in the debate, and not what a specific model implies regarding which objectives that maximize utility for a representative household in that particular model. Thus, I shall assume that the objectives of the policy institutions are stability in inflation around the socially optimal level (inflation target), output stability, represented by the output gap, and financial stability, represented by the 'financial gap' variable, q_t. The loss function is thus

$$L_t = \pi_t^2 + \lambda_y y_t^2 + \lambda_q q_t^2. \tag{4}$$

Woodford (2012) considers a similar loss function, where in his model q_t represents is a measure of credit distortions such as a spread between borrowing and lending rates. As shown by Cúrdia and Woodford (2016), such a loss function can be derived as a second-order approximation to maximizing the utility of a representative household. Similar welfare loss functions are derived by Nisticò (2016) and De Paoli and Paustian (2017).

It should be emphasized that modelling "leaning against the wind" (LAW) as adding a quadratic term in the loss function is important for the results. Svensson (2017) has a different approach to LAW. He analyses whether LAW, in the meaning of setting a somewhat higher interest rate than what is justified by the usual monetary policy objectives, could reduce the welfare loss by lowering the probability of future financial crises sufficiently to warrant somewhat higher unemployment today. He thus focusses solely on the second term in (4), and considers which strategy - leaning *against* vs leaning *with* the wind - that gives the lowest welfare loss. The trade-off in Svensson's analysis is only in terms of unemployment today vs (expected) unemployment in the future, and not in terms of unemployment stability vs stability in relevant financial variables. The analysis thus rests on the standard loss function with inflation and output (unemployment), and not on an extended loss function like (4). A similar approach to LAW is applied by Gerdrup *et al.* (2017) and Ajello *et al.* (2016).

We shall focus on qualitative results that do not depend on the values of the weights, λ_y and λ_q, in the loss function, and to simplify the analytical solutions, I set unit weights, i.e.,

$$L_t = \pi_t^2 + y_t^2 + q_t^2$$

I shall consider a discretionary policy, since this makes the analytical solutions simpler with no consequences for the qualitative results that I focus on here.[2]

2.1 Optimal use of the two instruments

Under optimal coordination, we can treat the policymakers' problem as minimizing the loss function (4) with respect to the two instruments, r_t and b_t, given the constraints represented by the model (1)-(3). The first-order conditions for an optimal time-consistent policy are

$$-(\kappa_y\alpha_r + \alpha_q\beta_r\kappa_y + \beta_r\kappa_q)\pi_t - (\alpha_r + \alpha_q\beta_r)y_t - \beta_r q_t = 0, \quad (5)$$

$$-(\alpha_q\kappa_y\beta_b + \beta_b\kappa_q + \kappa_y\alpha_b)\pi_t - (\alpha_b + \alpha_q\beta_b)y_t - \beta_b q_t = 0. \quad (6)$$

The system (1)-(3), (5) and (6) determine the solutions for π_t, y_t, q_t, r_t and b_t. I assume that the coefficients on the expected one-period ahead variables (α_{Ey}, β_{Eq} and $\kappa_{E\pi}$) are equal to or smaller than unity, so that the Blanchard-Kahn conditions for a unique stationary solution become satisfied. Since the shocks are assumed *i.i.d.*, we have that $E_t y_{t+1} = E_t q_{t+1} = E_t \pi_{t+1} = 0$. The solutions for the target variables then become:

$$y_t = -\frac{\kappa_y}{1+\kappa_y^2+\kappa_q^2}u_{\pi,t}, \quad (7)$$

$$q_t = -\frac{\kappa_q}{1+\kappa_y^2+\kappa_q^2}u_{\pi,t}, \quad (8)$$

$$\pi_t = \frac{1}{1+\kappa_y^2+\kappa_q^2}u_{\pi,t}. \quad (9)$$

We see that by using two instruments, the central bank is able to insulate the target variables from the demand shock ($u_{y,t}$) and the financial shock ($u_{q,t}$). With only one instrument, the target variables would not be insulated from demand and financial shocks, and this is an important gain from using two instruments.[3] However, with only two instruments, the three target

[2] An optimal policy under commitment results in a more complicated dynamic solution, as the polikcymaker utilizes the expectations channel to achieve its objectives.

[3] To understand why the target variables would be affected by demand shocks and asset price shocks, consider a positive demand shock and the interest rate as the only instrument. If the interest rate is raised sufficiently to offset the effect on y_t of the shock,

variables cannot be perfectly stabilized. The trade-off caused by the inflation shock u_t is then optimally shared between the three target variables π_t, y_t and q_t. The optimal solutions for the instruments are:

$$r_t = \frac{1}{\alpha_r \beta_b - \alpha_b \beta_r} \left[\beta_b u_{y,t} - \alpha_b u_{q,t} + \frac{\beta_b \kappa_y - \alpha_b \kappa_q - \beta_b \alpha_q \kappa_q}{1 + \kappa_y^2 + \kappa_q^2} u_{\pi,t} \right], \quad (10)$$

$$b_t = \frac{1}{\alpha_r \beta_b - \alpha_b \beta_r} \left[-\beta_r u_{y,t} + \alpha_r u_{q,t} - \frac{\beta_r \kappa_y - \alpha_r \kappa_q - \beta_r \alpha_q \kappa_q}{1 + \kappa_y^2 + \kappa_q^2} u_{\pi,t} \right]. \quad (11)$$

The sign of the denominator in (10) and (11) and thus the sign of the response to the shocks is ambiguous. The relative effectiveness of monetary policy in stabilizing output versus the output gap can be measured by α_r/β_r, while α_b/β_b measures the relative effectivess of macroprudential policy. If $\alpha_r/\beta_r > \alpha_b/\beta_b$, we say that monetary policy has a *comparative advantage* in stabilizing output, while macroprudential policy has a comparative advantage in stabilizing the asset price (and vice versa if the sign is turned around). If there is a positive shock to demand ($u_{y,t} > 0$), the monetary authorities should respond by increasing the interest rate if monetary policy has a comparative advantage in stabilizing output. The macroprudential authorities should, on the other hand, respond to the same shock by *loosening* macroprudential policy. **The two instruments should thus be moved in opposite directions**. In other words, in this model they should be **strategic substitutes.** The reason is that the increase in the interest rate will in isolation lead to lower asset prices. To avoid such asset price deflation, the increase in the interest rate must be counteracted by looser macroprudential policy. If there is a positive asset price shock ($u_{q,t} > 0$), macroprodential policy should be tightened, while the interest rate should be cut. The more similar the effects of the two policies are, the more aggressively should they be moved in opposite directions.

If we assume that monetary policy has a comparative advantage in stabilizing output, while macroprudential policy has a comparative advantage in stabilizing the financial variable, optimal coordination implies that monetary policy should do the opposite of "leaning against the wind". If a positive financial shock occurs, the monetary policy response should be expansionary in order to offset the contractionary effect of macroprudential policy. This result is, however, modified if we add some realistic assumptions to the model, as I will show in Section 2.3.

q_t would decrease. This would not be optimal stabilization, since decreasing the interest rate marginally from the level that offsets the shock gives a lower variability in asset price of first order magnitude, while the increase in the variability of output would be of second order. Thus, fully offsetting the demand shock cannot be optimal.

2.2 Separation and strategic interactions

Consider now the case where the monetary authorities and the macroprudential authorities are assigned separate loss functions. Since we consider three target variables, it is a natural benchmark to assume that the monetary authorities are accountable for stabilizing the standard traditional loss function with inflation and output, while the monetary authorities stabilize asset prices. Thus, we have that the monetary authorities minimize

$$L_t^r = \pi_t^2 + y_t^2, \tag{12}$$

and the macroprudential authorities minimize

$$L_t^b = q_t^2. \tag{13}$$

With one instrument and one objective for macroprudential policy, the outcome for q_t under my specification of separate objectives is of course perfect target achievement for macroprudential policy, i.e. $q_t = 0$. Thus, by construction, the optimal policy mix cannot be implemented under seperation, unless $\kappa_q = 0$, in which $q_t = 0$ also with optimal coordination as seen from (8). The solutions for the two monetary policy target variables, π_t and y_t, depend on the strategic interaction between the two policies. To show this, I will start with the optimal policy mix under separation, which I define as the optimal balance between inflation variability and output variability given that macroprudential policy is aimed to achieve $q_t = 0$.

2.2.1 The optimal policy mix under separation

The optimal policy mix is given by:

$$\min_{r,b} \left[\pi_t^2 + y_t^2 - \varphi_t q_t \right],$$

subject to (1) - (3), where φ_t is the Lagrange multiplier for the constraint that $q_t = 0$. The solution for the target variables become

$$y_t = -\frac{\kappa_y}{1+\kappa_y^2} u_{t,\pi}, \tag{14}$$

$$\pi_t = \frac{1}{1+\kappa_y^2} u_{t,\pi}, \tag{15}$$

and $q_t = 0$. **Thus, with separate targets, the optimal policy mix produces an outcome for output and inflation that is identical to the outcome under optimal time-consistent monetary policy in the simple canonical New Keynesian model**. Note that only inflation shocks affect output and inflation. The outcome of the optimal policy mix under separation is equal to the outcome of the optimal policy under coordination in the special case where $\kappa_q = 0$. This is the case where it is optimal to stabilize q_t completely. The reason why it is generally not optimal to stabilize q_t completely can be seen from the Phillips curve (3). If a positive inflation shock $u_{\pi,t}$ occurs, the trade-offs between the target variables becomes less costly if the effect on π_t can be reduced not only by reducing y_t, but also by reducing q_t. This can only be achieved if q_t affects inflation beyond its effect on y_t, that is, if $\kappa_q \neq 0$.

2.2.2 Nash equilibrium

Consider first the case where each policymaker takes the action of the other policymaker as given. That is, they do not internalize the other policymaker's reaction function.[4] The first-order condition for the monetary policy authorities is

$$-(\kappa_y \alpha_r + \alpha_q \beta_r \kappa_y + \beta_r \kappa_q)\pi_t - (\alpha_r + \alpha_q \beta_r) y_t - \beta_r q_t = 0, \tag{16}$$

and the corresponding condition for the macroprudential authorities is (trivially)

$$q_t = 0. \tag{17}$$

The solutions for y_t and π_t in the Nash equilibrium become

$$y_t = -\frac{\kappa_q \beta_r + \alpha_r \kappa_y + \alpha_q \beta_r \kappa_y}{\alpha_r + \alpha_q \beta_r + \alpha_r \kappa_y^2 + \alpha_q \beta_r \kappa_y^2 + \kappa_q \beta_r \kappa_y} u_{\pi,t}, \tag{18}$$

$$\pi_t = \frac{\alpha_r + \alpha_q \beta_r}{\alpha_r + \alpha_q \beta_r + \alpha_r \kappa_y^2 + \alpha_q \beta_r \kappa_y^2 + \kappa_q \beta_r \kappa_y} u_{\pi,t}. \tag{19}$$

This implies that separation still implies an optimal policy response to demand shocks and asset price shocks. The response to inflation shocks is, however, not generally optimal. When the last term in the denominator, $\kappa_q \beta_r \kappa_y$, is positive, output responds more to inflation shocks, and inflation responds less than under the optimal policy mix. **The Nash equilibrium thus implies a too agressive interest rate response to inflation shocks.** The intuition is that when the monetary authorities do not internalize that a change in the interest rate will lead to a response from the macroprudential authorities to offset the effect on q_t, monetary policy appears more effective in controlling inflation, as it also influences inflation directly through the financial variable ($\kappa_q q_t$). Given this perceived effectiveness of controlling inflation, the monetary authorities have incentives to stabilize inflation relatively more than output compared with the case where the monetary authorities recognize that they cannot affect inflation directly through the financial variable.

[4] This may be interpreted as a case of limited information of the other policymaker's objectives/incentives.

2.2.3 Stackelberg equilibrium

Assume now that the monetary authorities know the reaction function of the macroprudential authorities, and that they are able to commit to an action that minimizes the loss when the other player's reaction is taken into account. The monetary authorities may then act as a Stackelberg leader in the strategic game. Technically, the monetary authorities minimize (12) given the constraints (1), 2), (3) and (17). Recognizing that monetary policy cannot affect q_t given the offsetting reaction by macroprudential policy, the first-order condition for optimal monetary policy becomes

$$\kappa_y \pi_t + y_t = 0, \tag{20}$$

which results in the same solutions for inflation and output as under the optimal polixy mix with separation, i.e. (14) and (15). Note that (20) is not a time-consistent policy for the monetary authorities, since given the macroprudential action, the monetary authorities have an incentive to increase the interest rate further (assuming a positive inflation shock).

2.3 Adjustment costs

Macroprudential instruments, which normally imply some sort of regulation, could have welfare costs, so that aggressive use of the instruments may not be warranted. To model this in a simple way, assume that there are quadratic adjustment costs of using the macroprudential instrument, so that the coordinated loss function becomes

$$L_t = \pi_t^2 + y_t^2 + q_t^2 + \gamma b_t^2.$$

The first-order condition (6) then becomes

$$-(\alpha_b + \alpha_q \beta_b)\kappa_y \pi_t - (\alpha_b + \alpha_q \beta_b) y_t - \beta_b q_t + \gamma b_t = 0.$$

Having quadratic adjustment costs is in effect equivalent to having four targets, and the effects of demand shocks and financial shocks on the target variables will no longer be fully neutralized by monetary and macroprudential policies. The solution for the optimal use of the macroprudential instrument is:

$$b_t = -\frac{1}{(\alpha_r \beta_b - \alpha_b \beta_r) + \hat{\gamma}} \left[\beta_r u_{y,t} - \alpha_r u_{q,t} + \frac{\beta_r \kappa_y - \alpha_r \kappa_q - \beta_r \alpha_q \kappa_q}{1 + \kappa_y^2 + \kappa_q^2} u_{\pi,t} \right], \tag{21}$$

where

$$\begin{aligned} \hat{\gamma} \equiv {} & \frac{\gamma}{(1+\kappa_y^2+\kappa_q^2)(\alpha_r \beta_b - \alpha_b \beta_r)} [\alpha_q^2 \beta_r^2 \kappa_y^2 + \alpha_q^2 \beta_r^2 + 2\alpha_q \kappa_q \beta_r^2 \kappa_y + \kappa_q^2 \beta_r^2 \\ & + 2\alpha_q \alpha_r \beta_r + 2\alpha_q \alpha_r \beta_r \kappa_y^2 + 2\kappa_q \alpha_r \beta_r \kappa_y + \alpha_r^2 \kappa_y^2 + \alpha_r^2 + \beta_r^2]. \end{aligned}$$

By comparing (21) with (11) we see that adjustment costs result in a more attenuated response to the shocks, but the signs remain the same. The solution for the optimal monetary policy under coordination becomes somewhat more complicated, and is given by

$$r_t = \frac{1}{(\alpha_r\beta_b - \alpha_b\beta_r) + \hat{\gamma}} \left[(\beta_b + \omega_y\gamma)u_{y,t} - (\alpha_b - \omega_q\gamma)u_{q,t} + \frac{(\beta_b\kappa_y - \alpha_b\kappa_q - \beta_b\alpha_q\kappa_q) + \omega_\pi\gamma}{1 + \kappa_y^2 + \kappa_q^2} u_{\pi,t} \right], \tag{22}$$

where

$$\begin{aligned}
\omega_y &= \frac{\alpha_r + \alpha_r\kappa_y^2 + \alpha_q\beta_r + \kappa_q\beta_r\kappa_y + \alpha_q\beta_r\kappa_y^2}{(\alpha_r\beta_b - \alpha_b\beta_r)(1 + \kappa_y^2 + \kappa_q^2)}, \\
\omega_q &= \frac{\beta_r + \alpha_q^2\beta_r + \kappa_q^2\beta_r + \alpha_q\alpha_r + \alpha_q^2\beta_r\kappa_y^2 + \kappa_q\alpha_r\kappa_y + \alpha_q\alpha_r\kappa_y^2 + 2\alpha_q\kappa_q\beta_r\kappa_y}{(\alpha_r\beta_b - \alpha_b\beta_r)(1 + \kappa_y^2 + \kappa_q^2)}, \\
\omega_\pi &= \frac{\kappa_q\beta_r + \alpha_r\kappa_y + \alpha_q\beta_r\kappa_y}{\alpha_r\beta_b - \alpha_b\beta_r}.
\end{aligned}$$

We see that whether the interest rate should be raised or lowered as a response to a financial shock, $u_{q,t}$, depends on the magnitude of the adjustment costs of using the macroprudential instrument. If it is sufficiently costly to use b_t, it is optimal to support macroprudential policy with monetary policy instead of "counteracting" it by an opposite response. The relationship between the adjustment costs γ and the optimal response of b_t and r_t to a financial shock is illustrated in Figure 1.[5]

We see that that **when the degree of adjustment costs, measured by γ, becomes sufficiently high, the two instruments go from being strategic substitutes to becoming strategic complements**, and should move in the same direction as a response to shocks.

2.3.1 Uncertainty about the effects of policy

So far I have assumed that the effects of the two policy instruments on the target variables are known by certainty. Although this is by far the most common assumption in the literature, it is obviously not the case in practice. The implications of such multiplicative uncertainty for optimal policy are well known in the literature from the seminal paper by Brainard (1967). Given that the uncertainty can be specified by a given distribution with known mean and variance, the optimal policy with uncertain effects is characterized by caution, i.e. that the policymaker adjusts the the instrument less than it would have if he were certain about the effects. Uncertain policy effects also have implications for the optimal policy mix, which I will illustrate below.

[5] The choice of parameter values does not affect the qualitative properties, and we set $\kappa_y = 0.2, \kappa_q = 0.1, \alpha_r = 0.5, \alpha_b = 0.15, \alpha_q = 0.2,\ \beta_r = 0.3, \beta_b = 0.6$.

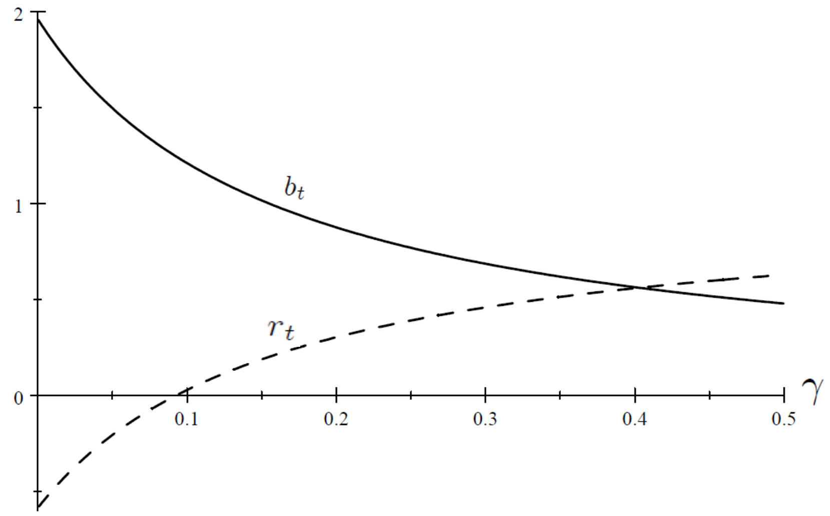

Figure 1: Optimal policy mix as a function of adjustment costs in b_t.

Consider first the case where there is uncertainty only about the effects of macroprudential policy. This is an interesting starting point, since policymakers have limited experience with macroprudential instruments, which makes the effects particularly uncertain. I will specify such uncertainty in the model above as

$$\begin{aligned} \alpha_b &= \bar{\alpha}_b(1+\varepsilon_{\alpha_b,t}), \\ \beta_b &= \bar{\beta}_b(1+\varepsilon_{\beta_b,t}), \end{aligned}$$

where $\varepsilon_{\alpha_b,t}$ and $\varepsilon_{\beta_b,t}$ are two independent white noise shocks, with variances $\sigma^2_{\alpha_b}$ and $\sigma^2_{\beta_b}$. The policymakers must set r_t and b_t before $\varepsilon_{\alpha_b,t}$ and $\varepsilon_{\beta_b,t}$ are realized, but know $\sigma^2_{\alpha_b}$ and $\sigma^2_{\beta_b}$ before policy is set. Thus, I consider so-called Bayesian uncertainty, as opposed to Knightian uncertainty, which I will briefly discuss in the end of this sub-section. With uncertain effects of macroprudential policy, the first-order condition (6) is replaced by

$$E_t\left[-(\alpha_q\kappa_y\beta_b+\beta_b\kappa_q+\kappa_y\alpha_b)\pi_t-(\alpha_b+\alpha_q\beta_b)y_t-\beta_b q_t\right]=0,$$

where $E_t\alpha_b=\bar{\alpha}_b$, $E_t\beta_b=\bar{\beta}_b$, $E_t(\alpha_b^2)=\bar{\alpha}_b^2(1+\sigma^2_{\alpha_b})$, $E_t(\beta_b^2)=\bar{\beta}_b^2(1+\sigma^2_{\beta_b})$. (Remember that $E_tu_{y,t}=u_{y,t}$, $E_tu_{\pi,t}=u_{\pi,t}$, and $E_tu_{q,t}=u_{q,t}$). Unfortunately, the analytical solution of the model under such uncertainty becomes too messy to be tractable, so I will illustrate the effects of uncertainty numerically using the same parameters values as above. In the

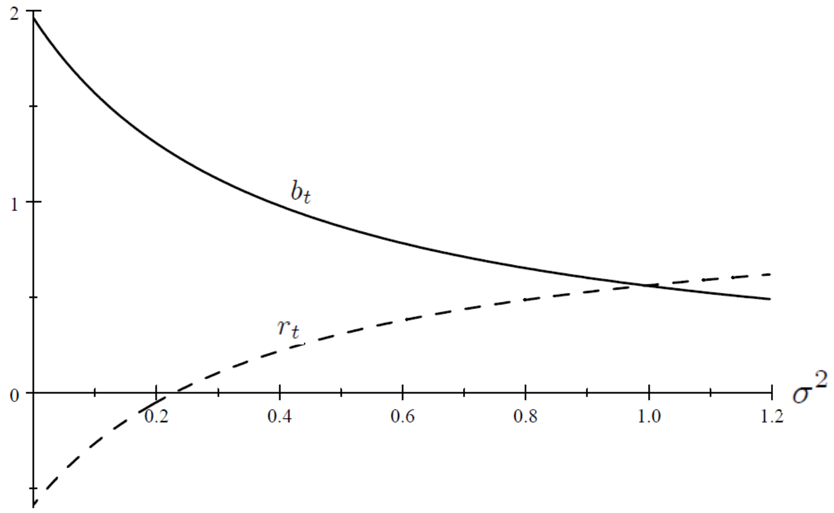

Figure 2: Optimal policy mix as a function of uncertainty about about the effects of b_t.

illustration, I assume that the effects of b_t on y_t and q_t are equally uncertain, i.e. $\sigma^2_{\alpha_b} = \sigma^2_{\beta_b} = \sigma^2$. The results are illustrated in Figure 2. We see that the uncertainty gives rise to a more attenuated response of the macroprudential instrument to the shock. However, as uncertainty increases, the attenuation in b_t must be counter-acted by using the interest rate more actively to support macroprudential policy. For sufficiently high degree of uncertainty, the optimal interest rate response becomes positive, as opposed to being negative when uncrtainty is low. Then, the interest rate should not be used in opposite direction to counter-act the negative effect of the macroprudential response on output and inflation, but should instead be used to support the macroprudential response to the financial shock. Whether the two instruments should be moved in the same or opposite direction thus depends on the degree of uncertainty about the effects of the macroprudential instrument.

If also the effects of monetary policy are uncertain, the same qualitative results hold. In Figure 3 I have assumed that the uncertainty about the effects of b_t and r_t are proportional, i.e.

$$\begin{aligned} \alpha_r &= \bar{\alpha}_r(1 + \varepsilon_{\alpha_r,t}), \\ \beta_r &= \bar{\beta}_r(1 + \varepsilon_{\beta_r,t}), \end{aligned}$$

where the shocks are independent, but, for the sake of illustrating it in

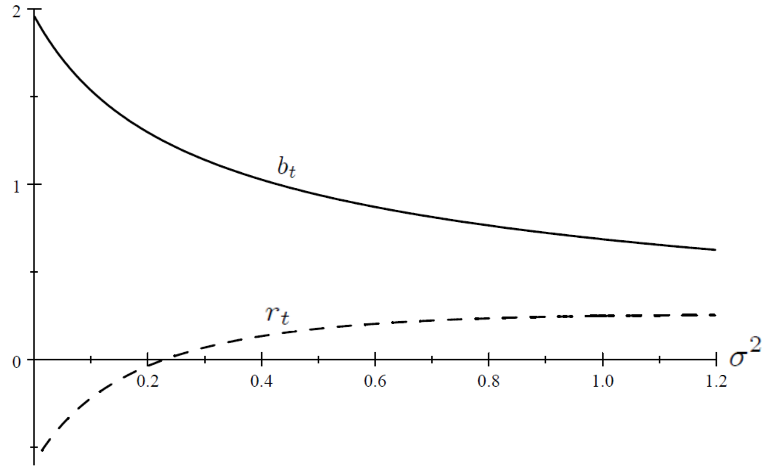

Figure 3: Optimal policy mix as a function of uncertainty about the effects of r_t and b_t.The the degree of uncertainty of r_t and b_t is assumed proportional.

one figure, the shocks have the same variance, i.e., $E_t(\varepsilon^2_{\alpha_r,t}) = E_t(\varepsilon^2_{\beta_r,t}) = E_t(\varepsilon^2_{\alpha_b,t}) = E_t(\varepsilon^2_{\beta_b,t}) = \sigma^2$. We see that the attenuation result now also applies to the optimal use of the interest rate. When there is uncertainty about the effects of both instruments, the optimal response in b_t tends to be somewhat less attenuated compared with the case where there is only uncertainty about the effects of b_t. The reason is that b_t to some degree counteracts the more attenuated response in r_t.

Although the analytical solution is too complicated in this case, a highly simplified model could illustrate the mechanisms at play. Assume that there are only two target variables, x_1 and x_2, and that the (semi-reduced form) relationship between the targets and the instruments are

$$x_1 = -\tilde{\varphi}_r r - \tilde{\varphi}_b b + u_1, \quad (23)$$
$$x_2 = -\tilde{\theta}_r r - \tilde{\theta}_b b + u_2, \quad (24)$$

where

$$\begin{aligned}
\tilde{\varphi}_r &= \varphi_r + \varepsilon_{\varphi_r}, \quad E\varepsilon_{\varphi_r} = 0, \ E\varepsilon^2_{\varphi_r} = \sigma^2_{\varphi_r} \\
\tilde{\varphi}_b &= \varphi_b + \varepsilon_{\varphi_b}, \quad E\varepsilon_{\varphi_b} = 0, \ E\varepsilon^2_{\varphi_b} = \sigma^2_{\varphi_b} \\
\tilde{\theta}_r &= \theta_r + \varepsilon_{\theta_r}, \quad E\varepsilon_{\theta_r} = 0 \quad E\varepsilon^2_{\theta_r} = \sigma^2_{\theta_r}, \\
\tilde{\theta}_b &= \theta_b + \varepsilon_{\theta_b}, \quad E\varepsilon_{\theta_b} = 0 \quad E\varepsilon^2_{\theta_b} = \sigma^2_{\theta_b}.
\end{aligned}$$

After minimizing $E[x_1^2 + x_2^2]$ we find the optimal solutions for r and b as

$$r = \frac{\left[\theta_b(\theta_b\varphi_r - \varphi_b\theta_r) + \sigma^2_{\theta_b}\theta_b^2\varphi_r + \sigma^2_{\varphi_b}\varphi_b^2\varphi_r\right] u_1 + \left[\varphi_b(\varphi_b\theta_r - \theta_b\varphi) + \sigma^2_{\theta_b}\theta_b^2\theta_r + \sigma^2_{\varphi_b}\varphi_b^2\theta_r\right] u_2}{(\theta_b\varphi_r - \varphi_b\theta_r)^2 + \tilde{\sigma}}, \tag{25}$$

$$b = \frac{\left[\theta_r(\theta_r\varphi_b - \varphi_r\theta_b) + \sigma^2_{\theta_r}\theta_r^2\varphi_b + \sigma^2_{\varphi_r}\varphi_r^2\varphi_b\right] u_1 + \left[\varphi_r(\varphi_r\theta_b - \theta_r\varphi) + \sigma^2_{\theta_r}\theta_r^2\theta_b + \sigma^2_{\varphi_r}\varphi_r^2\theta_b\right] u_2}{(\theta_b\varphi_r - \varphi_b\theta_r)^2 + \tilde{\sigma}}, \tag{26}$$

where

$$\begin{aligned}\tilde{\sigma} \equiv\ & \theta_b^2\theta_r^2\sigma^2_{\theta_b} + \theta_b^2\varphi_r^2\sigma^2_{\theta_b} + \theta_b^2\theta_r^2\sigma^2_{\theta_r} + \varphi_b^2\theta_r^2\sigma^2_{\varphi_b} + \varphi_b^2\theta_r^2\sigma^2_{\theta_r} + \varphi_b^2\varphi_r^2\sigma^2_{\varphi_b} + \theta_b^2\varphi_r^2\sigma^2_{\varphi_r} + \varphi_b^2\varphi_r^2\sigma^2_{\varphi_r} \\ & + \theta_b^2\theta_r^2\sigma^2_{\theta_b}\sigma^2_{\theta_r} + \theta_b^2\varphi_r^2\sigma^2_{\theta_b}\sigma^2_{\varphi_r} + \varphi_b^2\theta_r^2\sigma^2_{\varphi_b}\sigma^2_{\theta_r} + \varphi_b^2\varphi_r^2\sigma^2_{\varphi_b}\sigma^2_{\varphi_r}.\end{aligned}$$

In the case of full certainty, the solutions for r and b collapse to

$$r = \frac{\theta_b u_1 - \varphi_b u_2}{\theta_b\varphi_r - \varphi_b\theta_r}, \tag{27}$$

$$b = -\frac{\theta_r u_1 - \varphi_r u_2}{\theta_b\varphi_r - \varphi_b\theta_r}, \tag{28}$$

where we see directly that the responses of r and b to a given shock should have opposite signs, as in the more general model I considered earlier. For example, assuming that r has a comparative advantage in stabilizing x_1, so that the denominator is positive, a positive u_2 shock should imply an increase in b and a decrease in r. However, we see from (25) that with (Bayesian) uncertainty about the effects, the sign for the r response is ambiguous, and it becomes positive as the degree of uncertainty becomes sufficiently large.

When the realization of the parameters on the policy instruments are not known, but where it is not meaningful to treat the parameters as random variables with known statistical moments, the policymaker faces Knightian uncertainty. The common approach to such uncertainty is the minimax principle: the policymaker aims to minimize the maximum loss that can occur given the possible values the parameter can take. As shown by Onatski (2000), if there is no uncertainty about the *sign* of the effect of the instrument, the policymaker should set the instrument based on the assumption that the parameter takes the midpoint of the feasible range. Thus, the policy response is equivalent to the case with full certainty. If the range of possible values for the parameter includes values of both signs, so that the policymaker is not certain about the sign of the policy effect, then it is optimal to respond more cautiously to the shock. Thus, the same 'attenuation principle' as under Bayesian uncertainty prevails.

Ajello *et al.* (2016) consider both Bayesian and Knightian uncertainty within a model with stochastic financial crises. When there is uncertainty about how the policy instruments affect current output and inflation, they confirm the attenuation result of Brainard (1967). They show, however, that the result can be turned around if there is uncertainty about other parameters in the model, such as uncertainty about how financial conditions affect the probability of a crisis.

To conclude, whether monetary policy and macroeconomic policy should be substitutes or complements depends on the costs of using the instruments and how certain the policymaker is about the effect of the instruments on the target variables. If the costs of using the instruments are low and there is not substantial uncertainty about the effects, the two policy instruments should be substitutes, so that they should be used in opposite directions. If the costs are high and/or the uncertainty is substantial, one should use the instruments as complements in stabilizing the target variables. One could argue that there are non-significant costs and uncertainty related to in particular macroprudential tools. This suggests that monetary policy should complement macroprudential policy, i.e. monetary policy should "lean against the wind".

3 LAW and the time-inconsistency problem

In the above model, I have shown that if financial stability enters as a separate term in the loss function, it might under some assumptions be beneficial to use monetary policy (along with macroprudential policy) to dampen fluctuations in relevant financial variables. Even if the net gain might be positive, the costs of LAW are higher variability in inflation and output. Leaning might, however, have additional costs if the monetary authorities face a time-inconsistency problem. The time-inconsistency problem of LAW can be modelled equivalently to the traditional time-inconsistency problem of leaning against output (or employment) instability, as analyzed by Kydland and Prescott (1977) and Barro and Gordon (1985), except that the policy bias may have the opposite sign as in the earlier literature. Such a time-inconsistency problem can occur if there is a financial imperfection in steady state or if the costs of financial cycles are asymmetric.

Smets (2014) considered the time-inconsistency problem within a Barro-Gordon model when there were two steady state distortions: a too low steady state output and a too high steady state debt level. The former implies an incentive to conduct an expansionary policy and creates a positive inflation bias, while the latter gives rise to a negative inflation bias. I shall abstract from the policy maker's incentive to bring output above its potential, since there is a widespread view that independent central banks do not aim for a positive output gap. As Alan Blinder (1998) put it: "Of course that would be inflationary. That's why we don't do it." The incentive to try to reduce debt and asset prices, in the form of LAW, seems more present among policy makers.

I shall below first consider a steady-state distortion, as in Smets (2014), but within the model presented above, and show how the policy bias depends on the various monetary policy channels. Then, I shall consider the case where there is no financial distortion in (deterministic) steady state, but where the cost of asset prices are asymmetric, i.e. high asset prices are considered more costly than low asset prices.

3.1 Distorted steady state

A distorted steady state in this context might come from excessive risk taking among financial institutions or households due to e.g. pecuniar externalities, moral hazard (due to anticipated government bailouts) or perverse remuneration schemes for financial agents. To account for this, replace the loss function (4) with

$$L_t = \pi_t^2 + \lambda_y y_t^2 + \lambda_q (q_t - q^*)^2, \tag{29}$$

where $q^* < 0$. This assumption implies that the desired level of the financial variable (e.g. the debt to income ratio or real house prices) is lower than its equilibrium value (which is normalised to zero). The first-order conditon for optimal monetary policy under discretion now becomes

$$-(\kappa_y \alpha_r + \alpha_q \beta_r \kappa_y + \beta_r \kappa_q)\pi_t - (\alpha_r + \alpha_q \beta_r) y_t - \beta_r (q_t - q^*) = 0. \tag{30}$$

Taking the expectations of (30) and solving for $E\pi_t$ gives (since $Ey_t = Eq_t = 0$)

$$E\pi_t = \frac{\beta_r q^*}{\kappa_y \alpha_r + \alpha_q \beta_r \kappa_y + \beta_r \kappa_q}. \tag{31}$$

From (31) we see that $q^* < 0$ gives rise to a negative inflation bias, or *deflation bias,* i.e., $E\pi_t < 0$, or more precisely, since π_t is measured as deviation from the inflation target, a **bias towards too low inflation relative to the target**. Monetary policy cannot remove the financial imperfection, but the central bank is able to affect the financial variable in the short run. In a situation where $\pi_t = 0$, $y_t = 0$ and $q_t = 0$, the central bank has an incentive to increase the interest rate to reduce the financial imbalance. Rational agents recognize the central bank's incentive, and the Nash equilibrium is characterized by sufficiently low inflation to offset the central bank's incentive to increase the interest rate.

The deflation bias is larger the more effective monetary policy is in stabilizing asset prices relative to stabilizing inflation. This is seen from (31), where β_r is the effect asset prices by a change in the interest rate, and the denominator represents the total effect on inflation, as the sum of three transmission channels of the interest rate to inflation.

If the economy is characterized by a steady state distortion of this kind, the appropriate policy tool is macroprudential policy because macroprudential instruments (capital requirements, loan-to-value requirements, etc) are likely to have permanent effects and thus affect the steady state. However, it might be politically difficult to adopt regulations that remove the steady state distortions completely, and it is tempting to use monetary policy to dampen financial imbalances. Monetary policy may still have a role in dampening the financial cycles, i.e. there is a role for LAW.[6] However, the costs of LAW become higher because of the time-inconsistency problem stemming from the financial distortion in steady state. The more effective the permanent part of macroprudential policy is, the less costly it is to "lean against the wind" in monetary policy.

3.2 Asymmetric costs

A bias towards too low inflation may occur even if there is no distortion in steady state. This could be the case if the costs of fluctuations in financial variables are asymmetric. One extreme version of this is that the cost is quadratic if the financial variable is above a given threshold, but where the cost is zero if it is below this level. This case is considered by Disyatat (2010), but in a backward-looking model, which by construction does not lead to any discretionary bias. Within the traditional time-inconsistency literature, Cukierman and Gerlach (2003) considered this type of preferences and showed that this asymmetry would give an inflation bias even if $y^* = 0$. In the following, I shall assume that $q^* = 0$, i.e. that the central bank does not aim to stabilize the financial variable around a level that is inconsistent with the long-run equilibrium level. I will, however, assume a less extreme asymmetry than Cukierman and Gerlach (2003) and Disyatat (2010), and instead consider a preference function where the central bank prefers that the financial variable is as stable as possible around the equilibrium level, but is more concerned about high levels of q_t than about low levels. Specifically, I shall assume that the central bank's preferences over asset prices are characterized by the *linex* function $f(a_t) = (\exp(\eta a_t) - \eta a_t - 1)/\eta^2$, where η is a positive constant.[7] In the traditional Barro-Gordon framework, Nobay and Peel (2003) considered linex preferences over inflation, and Ruge-Murcia (2004) considered linex preferences over unemployment. The linex function is illustrated in figure 1.

[6] This assumes that the financial cycles are not longer than the horizon where monetary policy can affect the financal variables.

[7] If $\eta < 0$, the central bank is more concerned about low asset prices than about high asset prices. If $\eta \to 0$, the linex function converges to a quadratic function.

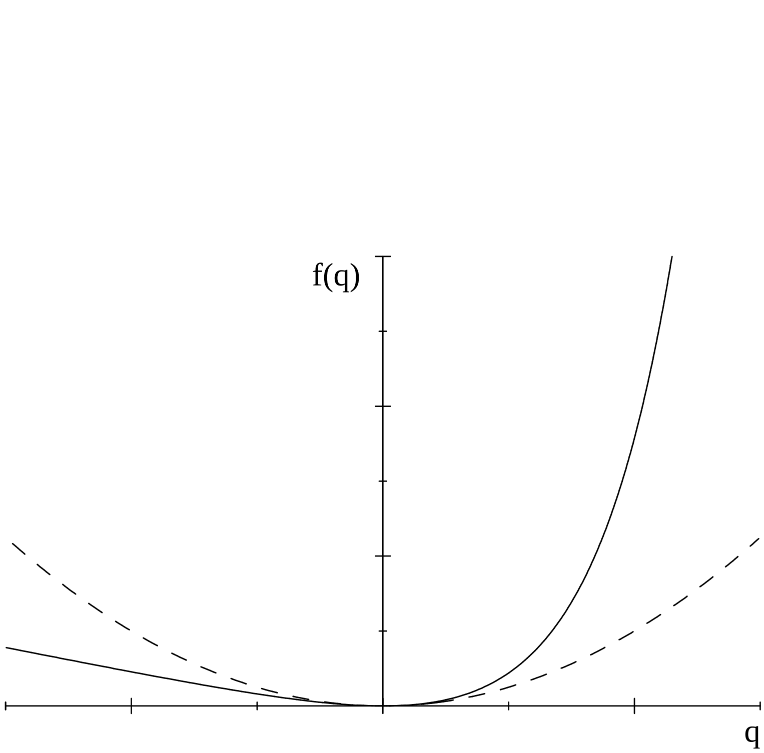

Figure 1. Example of linex preferences. $\eta = 2$ (solid line), $\eta \to 0$ (dashed line).

The loss function is thus

$$L_t = \frac{1}{2}\left(\pi_t^2 + \lambda y_t^2\right) + \frac{1}{\eta^2}(e^{\eta q_t} - \eta q_t - 1), \tag{32}$$

which implies the following first-order condition for minimum loss:

$$-(\kappa_y \alpha_r + \alpha_q \beta_r \kappa_y + \beta_r \kappa_q)\pi_t - (\alpha_r + \alpha_q \beta_r)y_t - \frac{\beta_r}{\eta}(e^{\eta a_t} - 1) = 0. \tag{33}$$

Taking the expectation through (33) yields

$$E\pi_t = -\frac{\beta_r}{\eta(\kappa_y \alpha_r + \alpha_q \beta_r \kappa_y + \beta_r \kappa_q)}(e^{\frac{\eta^2 \sigma_q^2}{2}} - 1), \tag{34}$$

where σ_q^2 denotes the conditional variance of q_t, and where I have followed Nobay and Peel (2003) and Ruge-Murcia (2004) in assuming that q_t is normally distributed, which implies that $E(e^{\eta q_t}) = e^{\frac{\eta^2 \sigma_q^2}{2}}$. We see from (34) that there is a 'deflation bias', i.e., $E\pi_t < 0$, if $\eta > 0$, i.e. when the central bank is more concerned about too high levels of q_t than corresponding low levels. Moreover, the bias is larger the more volatile the financial variable is (as measured by σ_q^2). Thus, even if the central bank does not aim to stabilize the financial variable below its fundamental equilibrium, conducting LAW in an asymmetric fashion gives rise to a similar deflation bias as in the case with quadratic preferences and and a steady state distortion. In this case, macroprudential policy aimed at dampening the financial cycle would reduce the deflation bias of LAW, as the bias depends on the variance of q_t.

4 Conclusions

The paper has analyzed various aspects of the interplay between monetary policy and macroprudential policy within a simple analytical framework. I have shown that coordination is necessary to implement the optimal policy mix if the financial variables also affect inflation beyond the effect through aggregate demand. Such direct effects depends on the financial variable, but credit spreads and asset prices could affect firms' price setting through marginal financing costs. Moreover, I have shown that whether the two types of policy instruments - monetary policy and macruprudential policy - should respond to a financial shock in the same or opposite direction depends on whether there are costs and/or uncertainty about the effect of the macroprudential instrument. When there is no uncertainy about its effect, or no costs associated with using it, macroprudential policy should be tightened in response to a positive financial shock, while the interest rate should be reduced, if macroprudential policy is relatively more efficient in stabilizing financial variables. But if the costs or uncertainty are sufficiently large, both instrument should be tightened. Separation of objectives between the two policy instruments are generally not optimal if there are costs of using macroeconomic tools or if there is uncertainty about their effects.

A possible pitfall in using monetary policy for financial stability purposes is that it may result in too low average inflation. This may occur under a discretionary policy if there is a steady-state financial distortion or if e.g. the policymakers are more concerned about higher asset price or credit growth/levels than their steady state values.

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