International Finance 5:2, 2002: pp. 193–211

Monetary Policy, Price Stability and Output Gap Stabilization*

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Abstract

Using a standard New-Keynesian model, this paper examines three reasons why monetary policy should primarily focus on price stability rather than the stabilization of output around potential, even if there appears to be an exploitable trade-off between the volatility of inflation and that of the output gap. First, we discuss the well-known time-inconsistency problem associated with active output gap stabilization. Increasing the relative weight on inflation stabilization improves the equilibrium outcome. Second, we analyse some of the problems associated with the substantial uncertainty that surrounds estimates of potential output. We argue that focusing on price stability is a robust monetary policy strategy in the face of such uncertainty. Finally, we consider the case where private agents are trying to estimate the inflation generating process using an 'ad hoc', but reasonable learning rule. By emphasizing a single goal the central bank facilitates the process of learning, thereby stablizing both inflation and the output gap.

*This paper was prepared for the conference on Stabilizing the Economy: What Roles for Monetary and Fiscal Policy?, organized by Adam Posen and Benn Steil on 11 July 2002 at the Council on Foreign Relations in New York. We are grateful to Olivier Blanchard, Mark Gertler, Athanasios Orphanides, Adam Posen, Olaf Sleijpen, Lars Svensson, Juan Luis Vega, three anonymous referees and especially Oreste Tristani for helpful comments and suggestions. The views expressed are solely our own and do not necessarily reflect those of the European Central Bank.

> The man of system … is often so enamoured with the supposed beauty of his own ideal plan of government, that he cannot suffer the smallest deviation from any part of it. He goes on to establish it completely in all its parts without any regard either to the great interests, or to the strong prejudices which may oppose it. He seems to imagine that he can arrange the different members of a great society with as much ease as the hand arranges the different pieces upon a chessboard. He does not consider that the pieces upon the chessboard have no other principle of motion besides which the hand impresses upon them; but that, in the great chessboard of human society, every single piece has a motion principle of its own, altogether different from what the legislature might choose to impress upon it. If those two principles coincide and act in the same direction, the game of human society will go on easily and harmoniously, and is very likely to be happy and successful. If they are opposite or different, the game will go on miserably, and the society must be at all times in the highest degree of disorder.
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> Adam Smith, *The Theory of Moral Sentiments*, Liberty Fund, 1984, pp. 233–4

I. Introduction

In this paper, we examine reasons why monetary policy should primarily focus on price stability rather than the stabilization of output around potential (the output gap), even if there appears to be an exploitable trade-off between the volatility of inflation and the volatility of the output gap. Our starting point is the recent analysis of optimal monetary policy in small-scale dynamic general equilibrium models (Goodfriend and King 1997), in which price and output gap stability are complementary goals in the face of a wide range of supply and demand shocks. In such a world, a focus on price stability (rather than output gap stabilization) is a natural choice because it has two important advantages. First, it provides the necessary nominal anchor to the economy and, thereby, reduces errors in inflation expectations that may otherwise give rise to a trade-off and destabilize the economy. Second, as the central bank's inflation objective is precise and measurable, it makes the central bank accountable; this would not be the case if the stabilization of the output gap which depends on unobservable potential output was used as the main performance criterion. However, most of the literature on optimal monetary policy (Taylor 1979, 1999) assumes that monetary authorities do face an exploitable trade-off between the volatility of inflation and the volatility of the output gap. This trade-off arises from the fact that the economy is affected by cost-push shocks that have a direct impact on inflation while leaving the output gap unchanged.

In this paper, our aim is to show that, even if there is such a trade-off, there are intrinsic difficulties associated with having the monetary authority stabilize output (and the output gap) in response to such shocks. These difficulties have to do with the endogeneity of private agents' expectations (see quotation from Adam Smith at the beginning). This endogeneity is, in turn, closely linked with the importance that central bankers attribute to credibility.

Using a common framework – as in Clarida et al. (1999) and Woodford (2002) – we review three arguments for why central banks should primarily focus on price stability in such a context. In Section II, we discuss the well-known time-inconsistency problem associated with active output gap stabilization. Following Clarida et al. (1999), we show that assigning monetary policy to a central bank that predominantly focuses on price stability can alleviate this problem. By doing so, we are looking at issues relating to optimal preferences for central banks, in the spirit of Rogoff (1985). Section III then analyses some of the problems associated with the substantial uncertainty that surrounds estimates of potential output (the appropriate target for output). Following Smets and Wouters (2002), we argue that focusing on price stability is a robust monetary policy strategy in the face of such uncertainty. Finally, in Section IV, we investigate the implications of the fact that the private sector is learning about the inflation process when forming its inflation expectations. Following the ideas of Orphanides and Williams (2002), we argue that also in this case, putting too much weight on output gap stabilization in the central bank's mandate is counterproductive in the sense that it risks unhinging inflation expectations and, thereby, causing costly output gap fluctuations necessary to restore price stability. The concluding Section V presents the thrust of our main arguments, which can be summarized as follows: even in the presence of so-called cost-push shocks, a central bank predominantly focusing on price stability will contribute to the stability of the output gap. The reason is that by emphasizing the single goal of price stability, the central bank anchors inflation expectations and, thereby, reduces an important source of instability in the economy that, otherwise, may give rise to an output gap inflation variability trade-off. The end result is an improved overall macroeconomic performance.

II. Cost-push Shocks, Time-inconsistency and Rogoff's Conservative Central Banker

In this section, we briefly discuss the well-known time-inconsistency problem associated with active output gap stabilization in the face of cost-push shocks.[1]

[1]The analysis here partially follows Clarida et al. (1999), which should be consulted for a more thorough discussion of the time-consistency problem in the context of the model used in this paper.

The economy is given by the New Keynesian Phillips curve

$$\pi_t = \beta E_t \pi_{t+1} + \kappa(y_t - \bar{y}_t) + u_t = \beta E_t \pi_{t+1} + \kappa z_t + u_t \tag{1}$$

where y_t denotes real output, $\bar{y}_t$ the potential output level which coincides with the central bank's target level of output, z_t the output gap, π_t the inflation rate, E_t the expectation operator based on information available at time t and u_t a cost-push shock variable that affects inflation, but does not affect the target level of output. In other words, supply shocks do not affect inflation for an unchanged output gap, while cost-push shocks do. For simplicity, we will assume that β, the discount factor, equals 1 in the rest of the paper. We will also assume that the cost-push shock variable follows an AR(1) process:

$$u_t = \rho u_{t-1} + v_t \tag{2}$$

where v_t is a white noise stochastic process with variance σ_v^2. The stochastic process driving potential output can be more general, but does not need to be specified for our analysis.

As shown by Woodford (2002), (1) can be derived from the linearized version of a micro-founded model in which monopolistically competitive firms set their prices in a staggered way according to a Calvo (1983) scheme. In such a model, one can show that potential output will be driven by technology and preference shocks, whereas the cost-push shock may result from a time-varying mark-up in the goods or labour market or time-varying taxes on revenues in goods and labour markets.

Woodford (2002) also shows that, in such a model, a welfare-maximizing central bank would like to stabilize a weighted average of deviations of inflation from the central bank's inflation target and output around its potential level. This objective function can be captured by the quadratic loss function

$$E_t \sum_{i=0}^{\infty} \beta^i ((\pi_{t+i} - \bar{\pi})^2 + \lambda (z_{t+i})^2) \tag{3}$$

where the weight λ on output gap stabilization is determined by the underlying parameters of the model.[2] $\bar{\pi}$ is the central bank's inflation target. For simplicity, we will assume that the central bank can control output and, thus, the output gap. In a more realistic model, the central bank would control output and inflation through the short-term interest rate. However, this simplification does not affect our main results.

Putting (1) and (3) together, it is clear that the only difference between the potential output (or supply) shocks and the cost-push shocks is that the

[2]In the rest of this paper, we will ignore this dependence.

former affect the central bank's target level of output, whereas the latter do not. The underlying (micro-founded) reason for the loss function (3) is that while it is optimal for a welfare-maximizing central bank to accommodate shocks to supply that arise from changes in technology or preferences, it is not optimal to allow inefficient variations in output, for example, driven by temporary changes in taxes, mark-ups or the bargaining power of unions.

In this context, it is trivial to see that the supply shocks do not create a trade-off between output gap and inflation stabilization. Stabilizing the output gap in response to such shocks will also stabilize inflation. Put differently, stabilizing inflation will also keep output close to potential. This is an example of the complementarity result briefly discussed in Section I. In contrast, the cost-push shock will give rise to a trade-off between inflation and output gap stabilization, if the output gap is defined as in (1). However, under an alternative definition of the output gap, there would be no trade-off. Define the natural level of output as:[3]

$$y_t^n = \bar{y}_t - \frac{1}{\kappa} u_t \tag{4}$$

Now define the alternative measure of the output gap as

$$z_t^n = y_t - y_t^n = y_t - \bar{y}_t + \left(\frac{1}{\kappa}\right) u_t = z_t + \left(\frac{1}{\kappa}\right) u_t$$

The last term on the right-hand side may now be interpreted simply as a supply shock. Using this definition of the output gap in (3), it is again trivial to show there will be no trade-off between inflation and output gap stabilization.

Turning again to model (1) to (3), it is straightforward to show that the optimal time-consistent monetary policy will be given by a reaction function for the output gap:

$$z_t = -\frac{\kappa}{\kappa^2 + \lambda} (E_t \pi_{t+1} - \bar{\pi} + u_t) \tag{5}$$

which, given (1), can also be written in the more standard form as

$$z_t = -\frac{\kappa}{\lambda} (\pi_t - \bar{\pi}) = -\alpha (\pi_t - \bar{\pi}) \tag{6}$$

Combining (1) and (6), the output gap and inflation can be written as a function of the cost-push shock and the inflation target:

$$z_t = -\frac{\kappa}{\kappa^2 + \lambda(1 - \rho)} u_t \tag{7}$$

[3] In the micro-founded model underlying equation (1), the natural output level coincides with the output level that would prevail under flexible prices.

$$\pi_t = \bar{\pi} + \frac{\lambda}{\kappa^2 + \lambda(1-\rho)} u_t \tag{8}$$

From (7) and (8), it is again clear that the cost-push shocks create a trade-off between output gap and inflation stabilization. How much inflation volatility is allowed will depend on the weight on output gap stabilization in the central bank's loss function. If this weight is zero, then inflation will always be equal to target in this model, but output gap volatility will be relatively large. A positive weight will reduce output gap variability, but increase inflation volatility. Varying the weight on output gap stabilization gives rise to Taylor's famous inflation/output gap variability efficiency frontier, which is a crucial ingredient of much of the optimal policy literature; see, for example, Taylor (1999).

From (8), it is also clear that, as long as the cost-push shocks are stationary, there will be no systematic inflation bias. However, as shown by Clarida et al. (1999), the presence of a cost-push shock does imply that the optimal time-consistent policy suffers from a stabilization bias: inflation volatility will be too large compared with the case in which the central bank can commit to its future policy actions and can, thereby, affect inflation expectations. In response to a persistent positive cost-push shock, the central bank would like to promise to contract output in the future so as to stabilize current inflation expectations and inflation, but the private agents realize that, in the absence of a commitment device, the central bank has an incentive to renege on that promise, once inflation expectations have adjusted. As a result, inflation expectations and inflation are temporarily too high in response to such a shock.

One solution, originally proposed by Rogoff (1985) to solve the time-inconsistency problem is to delegate monetary policy to a central banker that puts less weight on output gap stabilization. In this simple set-up, the optimal degree of 'conservativeness' can be calculated analytically by minimizing the loss function (3) subject to (1), (2) and (6) with respect to the parameter α, which reflects the central bank's reaction coefficient to deviations of inflation from target and is a function of the central bank's weight on output gap stabilization (Clarida et al. 1999). Doing this, one can show that the optimal reaction coefficient in (6) is given by

$$\alpha^* = \frac{\kappa}{\lambda(1-\rho)} = \frac{\alpha}{1-\rho} \tag{9}$$

From (9), it is clear that as long as the cost-push shock is persistent, it is optimal to increase the output response to deviations of inflation from target. Equivalently, it is optimal to appoint a conservative central bank with a lower weight on output gap stabilization. How much lower depends on the degree of persistence of the cost-push shock. In the limit, if the shock has a unit root, the optimal mandate is to focus solely on inflation stabilization. As one can argue that many of the cost-push shocks that one typically has in mind – such as changes in the bargaining power of unions or changes in taxes – are likely to be very persistent, this analysis suggests that the dominant focus should be on price stability if central banks want to avoid excessive volatility in inflation and the output gap.

III. Potential Output Uncertainty and Output Gap Stabilization

The previous analysis was based on the assumption that both the central bank and the private sector observe the level of potential output. In practice, there is a considerable degree of uncertainty about the appropriate target level of output. In this section, we analyse how this uncertainty affects the central bank's optimal policy strategy and, in particular, the feasibility of stabilizing the output gap. The question of optimal monetary policy under output gap uncertainty has recently received quite a bit of attention. For example, Orphanides (2000, 2001a), analyses actual monetary policy making by the Federal Reserve and shows that once one takes into account the real-time estimates of potential output, there is very little evidence of a big structural break in US monetary policy making over the 1970s and 1980s. A Taylor-type rule seems to characterize policies quite well. What appears to be different in the 1970s versus the 1980s is the degree of activism, i.e. the relative weight that is put on output gap versus inflation stabilization. Orphanides argues that the unobserved shocks to potential output together with the larger degree of activism in the 1970s is the dominant explanation for the big run-up in inflation in the 1970s. Orphanides (2001b) shows that, indeed, a policy that does not take into account the destabilization of the economy that results from mismeasurement of potential output can lead to an inefficient outcome. Using recent results by Svensson and Woodford (2000), Ehrmann and Smets (2002) show that society will, indeed, appoint a more conservative central banker when there is considerable uncertainty about potential output, even if the central bank applies optimal filtering techniques. Other recent references include Rudebusch (2002) and Leitemo and Lønning (2002).

In this section, we follow the analysis of Smets and Wouters (2002) by analysing robust monetary policy when the central bank does not know the source of unexpected inflation developments (supply or cost-push shocks) in the framework discussed above. In practice, both types of shocks are likely to drive inflation developments. It is, however, very difficult to distinguish between the two types. As is clear from (1), if the central bank only observes inflation and output, there is a fundamental identification problem. In reality, one may argue that central banks have additional information about the source of inflation developments. For example, oil price developments are a typical driving force of inflation. However, even in that case, it is a non-trivial and very uncertain exercise to figure out what the supply effects are of such oil price shocks. In the rest of this section, we therefore ask the question: If the central bank has no information about whether the inflation shock affects potential output, what is the best minimax strategy, i.e. what assumption regarding the source of the shock and the associated policy response minimizes the maximum opportunity loss. For this, we calculate and compare the losses of these policies when the alternative assumption is the true one. For simplicity, we assume in this section that the inflation target is zero.

As in the previous section, we assume that the central bank cannot commit to its future policy actions so that it takes inflation expectations as given. The optimal time-consistent policy is given by (7) and (8). If the shock is a supply shock, then the outcome for inflation and output is given by

$$y_t = -\frac{1}{\kappa} u_t = \bar{y}_t \tag{10}$$

$$\pi_t = 0 \tag{11}$$

In this case, the loss is minimized at zero:

$$L_{SS} = 0 + 0 \tag{12}$$

If the shock is a cost-push shock, then the outcome for inflation and output is given by

$$y_t = -\frac{\kappa}{\kappa^2 + \lambda(1-\rho)} u_t \tag{13}$$

$$\pi_t = \frac{\lambda}{\kappa^2 + \lambda(1-\rho)} u_t \tag{14}$$

In this case, the loss is given by

$$L_{CC} = \frac{1}{1-\rho^2}\left[\frac{\lambda^2}{q^2} + \lambda\frac{\kappa^2}{q^2}\right] \tag{15}$$

where

$$q = \kappa^2 + \lambda(1-\rho)$$

Next, we analyse what is the robust policy to follow when the central bank does not know which inflation shock affects the economy. We define a robust policy as that policy (or assumption about the source of the inflation shock) that minimizes the opportunity loss or regret in the case that the alternative assumption is the true one. Specifically, a robust policy minimizes the maximum loss, relative to the optimum, associated with a given policy. It is important to bear in mind that, under this definition, the likelihood of the alternative shocks plays no role whatsoever. Table 1 summarizes the results.

The upper right cell of Table 1 shows that if the central bank assumes that the inflation shock is a supply shock when it is in fact a cost-push shock, then it will still stabilize inflation, but it will create output gap volatility by contracting output to achieve those stable prices. On the other hand, if the central bank assumes the shock is cost-push, when in fact it is a supply shock, then it will create both unnecessary output and inflation volatility (compared to the optimal outcome).

Under what policy is the loss associated with a mistake minimized? This can be seen by comparing the entries in the lower row of Table 1. It is easy to see that the maximum loss of assuming the shock is a supply shock is always less than or equal to the maximum loss of assuming the shock is a cost-push shock.

The difference between the two opportunity losses is given by

$$(L_{CS} - L_{CC}) - (L_{SC} - L_{SS}) = -\frac{2\lambda^2 \rho}{\left(1-\rho^2\right)\left[\kappa^2 + \lambda(1-\rho)\right]^2} \qquad (16)$$

The gain (in a minimax sense) from assuming that the shock is a supply shock (rather than a cost-push shock) is an increasing function of the persistence of the shock and the weight on output gap stabilization. When the shock has no persistence ($\rho = 0$), the loss from making a mistake is equally great when assuming either a cost-push or a supply shock. However, as the persistence of the shocks increases assuming that the inflation shock is a supply shock becomes robust policy. The intuitive reason for this result is that assuming a shock is a supply shock will avoid negative effects on inflation expectations as inflation is expected to be stabilized even if, in reality, it is a cost-push shock. This is not the case when the opposite mistake is made. The negative impact on inflation expectations will be greater, the more persistent the inflation shocks are.

Another interesting finding is that the larger the weight on output gap stabilization, the higher the relative benefits of assuming all shocks are supply shocks. Again, the intuition is that the effect of making mistakes on inflation expectations is greater with a high weight on output gap stabilization and, thus, the cost of assuming that shocks are cost-push when they are, in fact, supply is much higher than that of making the reverse mistake.

Table 1: Losses under Alternative Assumptions

	Shock is a supply shock	Shock is a cost-push shock
CB assumes a supply shock	$L_{\text{SS}} = 0 + 0$	$L_{\text{CS}} = \frac{1}{1-\rho^2}\left[0 + \lambda \frac{1}{\kappa^2}\right]$
CB assumes a cost-push shock	$L_{\text{SC}} = \frac{1}{1-\rho^2}\left[\frac{\lambda^2}{q^2} + \lambda\left(\frac{q-\kappa^2}{\kappa q}\right)^2\right]$	$L_{\text{CC}} = \frac{1}{1-\rho^2}\left[\frac{\lambda^2}{q^2} + \lambda \frac{\kappa^2}{q^2}\right]$
Opportunity loss (or regret)	$L_{\text{SC}} - L_{\text{SS}} = \frac{1}{1-\rho^2}\frac{\lambda^2\left[\kappa^2 + \lambda(1-\rho)^2\right]}{\kappa^2 q^2}$	$L_{\text{CS}} - L_{\text{CC}} = \frac{1}{1-\rho^2}\left[\frac{\lambda^2\left[\kappa^2 + \lambda(1-\rho)^2\right]}{\kappa^2 q^2} - \frac{2\lambda^2\rho}{\left[\kappa^2 + \lambda(1-\rho)\right]^2}\right]$

IV. Private Sector Learning and Output Gap Stabilization

In Section III, we analysed the effects of the central bank's uncertainty about what type of shock is hitting the economy and argued that, when in doubt, the robust strategy is for the central bank to treat shocks to inflation as supply shocks. This can be implemented by mandating the central bank to focus solely on inflation stabilization. In this section, we discuss some of the implications of uncertainty on the part of the private agents in the economy and emphasize the importance of giving clear signals to anchor inflation expectations when these are formed through a learning process. There is a recent, but growing literature on how monetary policy should respond when the private sector is learning; see, for example, Evans and Honkapohja (2001). Following the analysis in Orphanides and Williams (2002), the main idea here is to see how the economy behaves under different weights on output gap stabilization when the private sector is using a simple constant gain least squares regression model to learn about the inflation process and form its expectations. The main finding is that, with perpetual learning, a large weight on output gap stabilization risks unhinging inflation expectations when a series of cost-push shocks in the same direction hits the economy.

Taking again as a starting point the model of (1) and (2) and assuming that the central bank implements the reaction function given by (5), the law of motion of inflation is given by

$$\pi_t = (1 - \gamma)\bar{\pi} + \gamma \tilde{E}_t \pi_{t+1} + \gamma u_t \tag{17}$$

where

$$\gamma = \frac{\lambda}{\kappa^2 + \lambda}$$

The tilde on the expectations operator denotes the fact that, in this section, expectations may not be fully rational. It is worth noting that the weight on output gap stabilization will determine to what extent the inflation process is anchored at the inflation target and to what extent it will be driven by inflation expectations itself. Thus, with zero weight on output gap stabilization ($\gamma = 0$), inflation will only depend on the inflation target. In contrast, with very little weight on inflation stabilization, there is a lot of scope for inflation expectations to move the actual inflation process.

As shown in (8), under rational expectations, the equilibrium solution for inflation is given by

$$\pi_t^{\mathrm{RE}} = \bar{\pi} + \frac{\gamma}{1 - \gamma\rho} u_t \tag{18}$$

Alternatively, the equilibrium solution for inflation under rational expectations can be written as an AR(1) process:

$$\pi_t^{\mathrm{RE}} = (1-\rho)\bar{\pi} + \rho\pi_{t-1}^{\mathrm{RE}} + \frac{\gamma}{1-\gamma\rho}\nu_t \tag{19}$$

It is therefore not unreasonable to assume that, as is common practice in the learning literature, private agents use an estimated first-order autoregressive process for inflation when forming their inflation expectations:[4]

$$\pi_t = c_{0,t} + c_{1,t}\pi_{t-1} + \omega_t \tag{20}$$

According to this regression model, expected future inflation is given by

$$\tilde{E}_t\pi_{t+1} = c_{0,t}(1 + c_{1,t}) + c_{1,t}^2\pi_{t-1} \tag{21}$$

where we have assumed that agents do not observe contemporaneous inflation to avoid the simultaneity problem which would arise from the fact that agents use current inflation to update their estimates and form their expectations which, in turn, affect current inflation leading to a revision in their updated parameter estimates, and so on.

Under least squares learning, the private agents update the parameters of the perceived law of motion (20) according to

$$c_t = c_{t-1} + \phi R_t^{-1} X_{t-1}(\pi_{t-1} - X'_{t-1}c_{t-1}) \tag{22}$$

$$R_t = R_{t-1} + \phi(X_{t-1}X'_{t-1} - \mathrm{R}_{t-1}) \tag{23}$$

where

$$X_t = [1 \quad \pi_{t-1}] \quad \text{and} \quad c_t = [c_{0,t} \quad c_{1,t}]$$

and φ is a small positive constant Kalman gain, which is directly linked to the data sample, l, over which the regression is estimated: $\varphi = 2/l$.

We can now analyse the behaviour of the economy under constant gain least squares learning by simulating (17), (21), (22) and (23) for a particular

[4]An important difference with most of the analysis in Evans and Honkapohja (2001) is that agents do not use the minimum-state-variable (MSV) equation (18) to form their expectations. If they did, it turns out that recursive least squares learning is e-stable, which under the assumptions of the model is always satisfied ($\beta\gamma < 1$). We also found that, in this case, constant-gain learning is very stable for reasonable estimation windows. Our assumption in (20) is a small and reasonable deviation from the MSV case, but turns out to have quite important implications for the overall stability of the system as illustrated by the simulations.

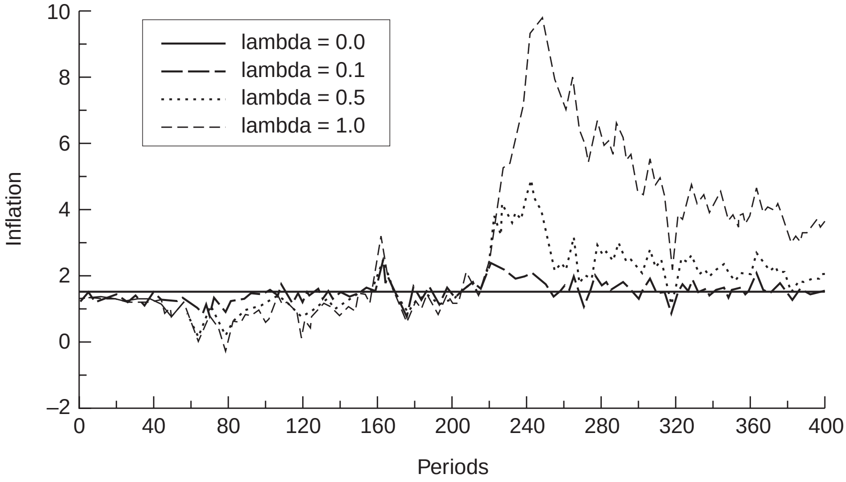

Figure 1: Inflation under constant gain learning with different weights on output gap stabilization

set of parameters under different assumptions regarding the weight on output gap stabilization. Figure 1 reports the evolution of inflation, the output gap and the agents' estimated persistence of the inflation process for a particular realization of the cost-push shock process. In this simulation, we have assumed the following parameters: $\bar{\pi} = 1.5$, $\kappa = 0.2$, $\rho = 0.5$, $\sigma_v^2 = 0.2$ and $\varphi = 0.05$ (implying an estimation window of 40 periods). As starting values for the estimated parameters in (20), we took the corresponding values of the rational expectations coefficients in (19). Figure 1 reports the outcomes for four different weights on output gap stabilization: 0.0, 0.1, 0.5 and 1.0, assuming the same realization of shocks. A number of observations are worth making. First, when the weight on output gap stabilization is zero, inflation is perfectly stabilized and agents continuously use the 'right' model to form their inflation expectations. However, output exhibits a relatively large short-term volatility reflecting the fact that it takes all the adjustment in response to the cost-push shocks. Second, as the weight on output gap stabilization increases, the short-term volatility in the output gap falls, but the inflation process becomes more volatile. However, in contrast to the findings under rational expectations, also the persistence of the inflation and output gap process increases substantially. This reflects similar findings in Orphanides and Williams (2002). The average estimated degree of inflation persistence over the sample of 400 periods (as captured by the estimated autoregressive coefficient c_{1t}) increases from 0.47 for a very small weight of 0.01 to 0.60, 0.73 and 0.80 for a weight on output gap stabilization of 0.1, 0.5 and 1.0 respectively. Moreover, the bottom panel of Figure 1 shows that the estimated degree of persistence is quite variable over time depending on the particular realization of the cost-push shocks.

Finally, a run of subsequent positive cost-push shocks around period 220 sets inflation off on an inflationary spiral, which is clearly more pronounced, the more weight the central bank puts on output gap stabilization. With a high weight on output gap stabilization, this episode is characterized by an estimated inflation persistence close to a unit root, suggesting that inflation expectations lose their nominal anchor. It is also noteworthy that this inflationary spiral is accompanied by a very persistent negative output gap and, therefore, can be characterized as a stagflationary episode similar to that experienced in the 1970s. While, eventually, the central bank's desire to stabilize inflation leads to a reversal of the inflationary spiral, the disinflation process is taking much longer than the inflationary phase. It is also worth noting that although such episodes do not appear in the particular simulation of Figures 1–3, deflationary spirals can also occur.

The large and persistent deviations of both inflation and the output gap from target when the central bank puts a lot of weight on output gap stabilization, also suggest that, in this case, it may be beneficial to mandate the central bank to focus predominantly on price stability. To check this, we increased the simulation sample to 10,000 periods and calculated the average loss using equal weights on inflation and output gap stabilization when the central bank has a reduced weight on output gap stabilization.

Figure 4 presents the results for different estimation windows. First, it is clear that, for reasonable estimation windows, the optimal weight on output gap stabilization is very low. For $\varphi = 0.05$ (an estimation window of 40 periods), the optimal weight for the central bank is 0.15 compared to society's weight

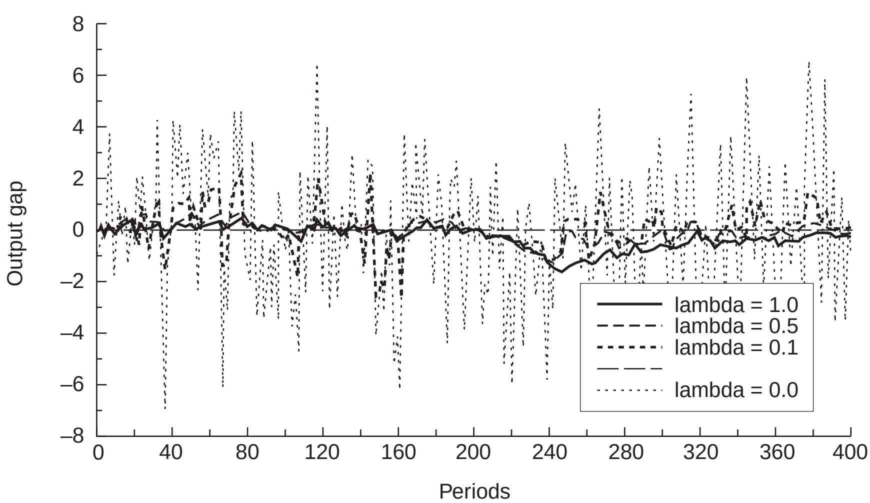

Figure 2: Output gap under constant gain learning with different weights on output gap stabilization

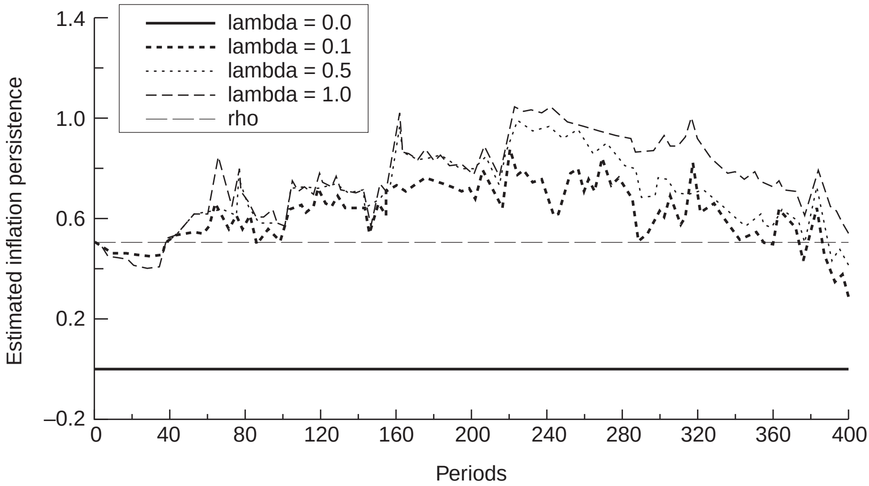

Figure 3: Estimated inflation persistence under constant gain learning with different weights on output gap stabilization

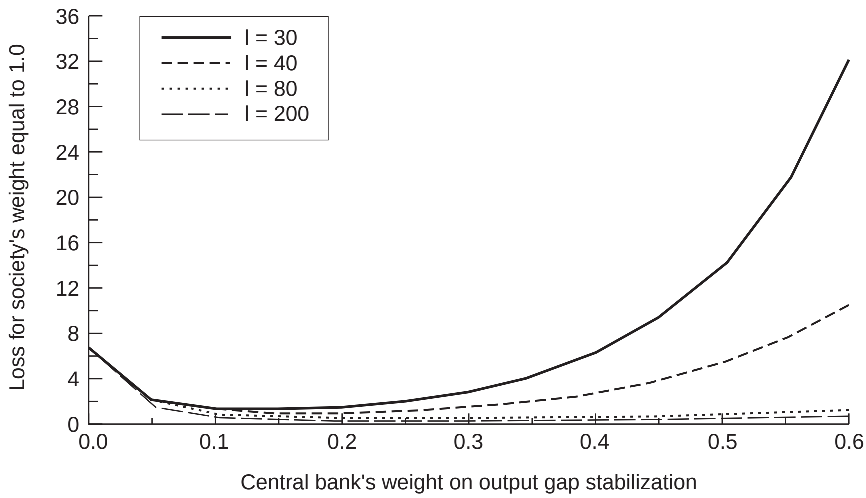

Figure 4: Optimal weight on output gap stabilization for different estimation windows

of 1. An important finding is that, in contrast to the time-inconsistency argument of Section II, both inflation and output gap variability are substantially reduced by focusing predominantly on inflation stabilization. The intuitive reason is that a focus on price stability anchors inflation expectations and reduces the risk that following a series of cost-push shocks in the same direction an inflationary spiral arises. Once they arise, such spirals are also very costly in terms of output gap stabilization as the central bank is trying to re-establish price stability. Second, as the private agents use more information (i.e. the estimation window lengthens), the optimal weight on output gap stabilization increases.

V. Conclusions

In this paper, we have challenged the widely held view that monetary authorities face an exploitable trade-off between stabilizing inflation and stabilizing the output gap. In our view, price stability and output gap stability should be seen as complements. This is a point of significant practical importance for the conduct of monetary policy.

In the context of a small-scale dynamic general equilibrium model with imperfect competition and nominal rigidities (labelled the New Neoclassical Synthesis (NNS) model), Goodfriend and King (2001) have argued rigorously that, in an environment where the central bank is fully credible and focuses on price stability only, monetary policy will be neutral in the sense of keeping output at its potential. Goodfriend and King (2001) interpret the difference between price and marginal cost – the mark-up – as analogous to a tax rate. This equivalence allows one to apply the principles from the optimal taxation literature. In this context, the case for price stability corresponds to the case for uniform taxation. The important results of Goodfriend and King (2001) are also in the spirit of the recent New Keynesian literature emphasizing the stabilization of output around its flexible price level, instead of stabilization of output *per se*; see, for example, Woodford (2002) and Gali (2000). In this class of models, there is no trade-off between price stability and the stability of the output gap. Price and output gap stability are complements.

Of course, both the uniform tax principle and the result on the complementarity of price and output gap stability only hold under very specific and stringent conditions that are unlikely to hold empirically. However, these results are likely to hold as good approximations under a much wider set of circumstances. For example, in the New Keynesian set-up, it is not clear that one would want monetary authorities to stabilize output around its flexible-price level if this output level is inefficiently low, for example because of monopolistic competition. However, from the analysis of the time-inconsistency problem by Kydland and Prescott (1977), Calvo (1978), and Barro and Gordon (1983a, 1983b), it is widely understood that the central bank's ability to push output above its natural rate can only be short-lived. After temporary effects working themselves through the economic system, the result would be counterproductive: no output gain and permanently higher inflation. In other words, the attempt to stabilize output above its potential would lead to an *inflation level bias*.

In micro-founded models with monopolistic competitive firms and staggered price setting (like the NNS or New Keynesian models discussed above), the simplest way to induce a trade-off between price stability and output gap stability is by allowing for cost-push shocks. Cost-push shocks could result from shocks to taxes, mark-ups or wages. The latter, in turn, could derive, for example, from changes in the bargaining power of unions. Now, in our view, cost-push shocks raise a number of issues. First, in the context of simple models, like the one used in the paper, the only difference between supply shocks and cost-push shocks is the way in which they enter the monetary authorities objective function. By convention, supply shocks affect potential output, while cost-push shocks do not. The trade-off is, therefore, created by the assumed form of the authorities' objective function and could easily be avoided by defining potential output as the flexible-price level of output. Second, it is an open empirical issue what is the role of changes in taxation, mark-ups and the bargaining power of unions to explain economic developments at business cycle frequency. For example, a permanent upward shift in unions' bargaining power would push up inflation and real wages. However, permanently higher real wages would, *ceteris paribus*, lead to permanently lower equilibrium output. If this permanent level shift is not allowed to affect the central bank's target level of output, it leads to an *inflation level bias* as described above.

In this paper, we have argued that, even allowing for cost-push shocks that create a trade-off between price stability and output gap stability, it is still a good idea for central banks to focus, first and foremost, on price stability. The reason for this is linked to the endogeneity of inflation expectations. The emphasis on price stability helps to anchor inflation expectations leading to superior outcomes in terms of overall macroeconomic stability.

We started by reviewing the well-known time-inconsistency problem. When the central bank is bound to follow time-consistent policies, output gap stabilization leads to a stabilization bias associated with inefficiently high inflation variability. Increasing the relative weight on inflation stabilization improves the resulting equilibrium. Second, we discussed a simple case where the central bank does not know whether it is facing a supply shock or a cost-push shock. These shocks are postulated to be observationally equivalent. For such a case, we show that a focus on price stability leads to robust policy. It minimizes the opportunity loss when a mistake is made. Finally, we considered the case where private agents are trying to estimate the inflation generating process using an '*ad hoc*', but reasonable learning rule. By emphasizing a single goal, the central bank facilitates the process of learning, thereby improving results in terms of both inflation stability and output gap stability. Interestingly, with sufficiently high weight on output gap stabilization, it is possible to obtain paths for inflation and the output gap characterized by the simultaneous occurrence of persistent high inflation and output below potential. This resembles the stagflation experience of the 1970s.

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