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THE INFLATION BIAS REVISITED: THEORY AND SOME INTERNATIONAL EVIDENCE

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The Kydland–Prescott, Barro–Gordon inflation bias result hinges on policymakers aiming at employment above potential. This has been questioned by academics and policymakers on the ground of realism. We show that even if policymakers target the normal level of employment, a bias arises if they are uncertain about economic conditions and are more sensitive to employment below than above normal. This view implies a positive association between inflation and the variance of output shocks. Cross-sectional empirical evidence from OECD economies supports this implication. We also discuss the consequences for the transparency of monetary policy and for central bank reform.

1 Introduction

The twentieth century has been characterized by positive inflation rates in most countries during most time periods. The by now standard explanation for this bias is based on a two-way interaction between policymakers and a rational public within the context of the expectations-augmented Phillips curve (Kydland and Prescott, 1977; Barro and Gordon, 1983). It is based on the notion that monetary policymakers care about both price stability and employment and that their preferred level of employment is higher than the natural level. This is due to either tax distortions (Barro and Gordon, 1983) or the existence of unions that create excessive unemployment by maintaining the real wage above its market clearing level (Cukierman, 1992, Ch. 3). Under discretion policymakers try to create inflation surprises in order to push employment above its natural level towards the higher desired level. But individuals understand the temptation of policymakers and correctly forecast inflation, neutralizing any effect of inflation on employment. As a

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consequence employment remains at its natural level but monetary policy is subject to a suboptimal inflation bias. This is the well-known dynamic inconsistency of monetary policy under discretion.

Some students of monetary policy as well as real life policymakers have recently expressed doubts about the realism of this theory of the inflation bias. McCallum (1995) argues that since they understand the futility of trying to systematically stimulate output by means of inflation surprises central banks normally refrain from such attempts even under discretion.

Moreover, after a period of service as Vice Chairman of the Federal Reserve Blinder (1998) argued that policymakers at the Fed do not try to systematically maintain employment above the natural level. As a matter of fact he personally felt duty bound to pick monetary policy so as to hit the natural rate when in office (Blinder, 1998, p. 43). In his view even if some policymakers were trying to aim above the natural level of employment one could easily dispose of the consequent inflation bias by directing them to aim at the natural level. Blinder takes the reduction of inflation in the USA during the early 1980s as evidence in favour of the view that it is possible to tame the inflation bias even under discretion. Those doubts cannot be easily dismissed particularly when they come from an economist like Blinder who combines practical monetary policy experience with a solid understanding of formal models. Yet the standard explanation for the existence of an inflation bias has a considerable appeal because of both its simplicity and the persistence and universality of inflation during the second half of the twentieth century.

The fact that such doubts have been raised only recently rather than a few years after the publication of the Kydland–Prescott and Barro–Gordon articles may not be accidental. Central banks today are substantially more independent than they were ten years ago (Cukierman, 1998).[1] When monetary policymaking is dominated by political authorities whose electoral concerns breed short horizons and a strong concern for employment and economic activity, the standard inflation bias story seems reasonably realistic. But when, as is currently the case, many central banks have instrument independence and are legally directed to focus solely or mainly on price stability it is more likely that they will recognize the suboptimality of trying to maintain employment and output above their natural levels.[2] Should we conclude that in the current era of enhanced central bank autonomy the inflation bias is a shadow of the past? We believe the answer is not necessar-

[1]For example, Arthur Burns, who was Chairman of the Fed during the 1970s, was more receptive to the wishes of the political establishment than his successors. This might have partly been a matter of different personalities but the general recent trend towards more central bank autonomy and more focus on price stability no doubt played a role.

[2]Many new central bank laws grant the bank instrument but not goal independence. The distinction between those two kinds of independence was first drawn by Debelle and Fischer (1994) and Fischer (1995).

ily. Although the bias producing mechanism may be different when central banks have instrument independence some bias is likely to be present nonetheless.

More precisely, we demonstrate that when the central bank is also expected to engage in stabilization of employment and output, some uncertainty about the future state of the economy and asymmetric concerns about positive and negative output gaps combine to create an inflation bias. *This result obtains in spite of the fact that the central bank's desired level of economic activity is equal to potential output or normal employment.* In countries such as the USA, in which the central bank is directed by law to also maintain a reasonably high level of economic activity, this uncertainty-induced bias is likely to represent (in our view) a particularly realistic scenario. But even in the euro area in which the law does not explicitly saddle the European Central Bank (ECB) with the task of stabilization policy, decision-makers at the ECB are not totally indifferent to the real state of the economy.[3]

Conventional wisdom among policymakers and students of monetary policy is that monetary policymaking institutions should be devised so as to enable them to partially offset the effects of non-monetary policy induced shocks on output while reducing the Kydland–Prescott inflation bias. In particular, Rogoff (1985) proposes to improve the consequent 'credibility–flexibility' tradeoff by appointing a central banker who is more conservative than society. Persson and Tabellini (1993) and Walsh (1995) suggest optimal incentive contracts for central bankers and Svensson (1997a) shows that, in some cases, such optimal contracts can be implemented by means of a simple inflation target. The basic premise of this literature is that, in the absence of a Kydland–Prescott, Barro–Gordon (KPBG) bias, the use of monetary policy to stabilize shocks to the natural level of employment is socially beneficial.[4] We show that this approach may lead to an inflation bias even if policymakers are content with the potential level of employment so that the KPBG inflation bias is non-existent. It is therefore a warning against the dangers inherent in saddling the central bank with the task of stabilizing shocks to the natural level of employment.[5]

Milton Friedman and others have stressed that monetary policy operates with 'long and variable lags'. As practical central bankers well know,

[3]The Bundesbank who conducted monetary policy in Germany until the end of 1998 also was not required by law to engage in stabilization policy. In spite of this, Clarida and Gertler (1997) produce evidence suggesting that, while its rhetoric was different from that of the Fed, the Bundesbank did engage in some stabilization of output.

[4]This premise transcends the recent literature on 'strategic monetary policy' as illustrated for example by the earlier work of Fischer (1977) and Taylor (1993).

[5]Friedman (1968) who originally coined the term 'natural level of employment' defines it as that level of employment that would be generated by the general equilibrium of the economy in the absence of inflationary surprises. We are using this term in the same sense.

current monetary policy decisions are therefore made on the basis of forecasts about the state of the economy rather than on the basis of its actual state.[6] The inflation bias mechanism presented here is based on two presumptions: first, when current policies are chosen policymakers are uncertain about the real state of the economy at the time the planned policy is expected to impact the economy and, second, they possess a precautionary demand for expansions in the sense that they are more concerned about downward deviations of employment from its normal level than about upward deviations. As a result monetary policy is chosen so as to make the probability of erring on the side of tightness smaller than the probability of erring on the side of ease.[7] Consequently planned monetary expansion and inflation are positive on average. Since they understand this tendency of the central bank rational individuals expect positive inflation. This pushes policymakers to be even more accommodating and creates a, somewhat higher, permanent inflation bias. As in the standard model this bias is suboptimal. Although policymakers prefer to err on the side of expansion in order to reduce the probability of the costlier downward deviations of employment from its normal level the positive expected inflation neutralizes the effect of this policy on the distribution of employment and output.

Unlike the KPBG bias, the bias-producing mechanism in this paper implies that countries with more volatile shocks to output should have, on average, higher rates of inflation. We test this implication of the theory using cross-sectional data on a sample of 22 OECD countries between 1970 and 2000. The evidence supports the existence of a positive relationship between average inflation and the variance of output growth over this sample. The theory also implies that this relation should be weaker when the effective conservativeness, or independence, of central banks is higher. To test this implication of the theory the sample period is split into two subperiods: 1971–85 and 1986–2000. Since both legal and actual central bank independence are higher in the second than in the first subperiod the theory implies that the relation between inflation and the variance of shocks to output should be

[6]This is probably the main reason for the extensive forecast effort made by the research departments of the Fed and of the newly formed ECB. Uncertainty about the upcoming state of the economy complicates the task of the central bank in trying to achieve employment as well as inflation objectives. The effects of this uncertainty for the operation of inflation targets is examined by Svensson (1997b).

[7]This assumption is obviously realistic for the political establishment. In a world in which the central bank is supposed to be, at least partly, accountable to elected officials this asymmetry is likely to permeate, perhaps to a lesser extent, the objectives of the central bank. Although central banks today are substantially more independent than ten years ago they are nonetheless expected by many to pay attention to the wishes of political authorities. Stiglitz (1998, p. 19), for example, expresses the view that, since monetary policy is a key determinant of macroeconomic performance, removing it from the control of democratically elected officials should at least raise some questions.

weaker in the second subperiod.[8] The evidence supports this implication as well. Those results in conjunction with a recent burgeoning empirical literature discussed in the concluding section suggest that, especially for the years of high inflation, the view of the inflation bias stemming from this paper may be a serious contender to the standard view.

The paper is organized as follows. Using an expectations-augmented Phillips curve, Section 2 demonstrates that in the presence of a precautionary demand for expansions and uncertainty about the state of the economy there is an inflation bias even if policymakers target the potential level of output. As a benchmark the section also shows that the bias vanishes in the absence of a precautionary demand for expansions. Section 3 derives the main testable implication of the theory and tests it empirically using cross-sectional data from 22 developed economies. Section 4 discusses some implications for the transparency of monetary policymaking institutions and for central bank reform. This is followed by concluding remarks.

2 The Model

2.1 Basic Structure

The supply side of the economy is represented by an expectations-augmented Phillips curve

$$Y = Y_n + \alpha(\pi - \pi^e) \tag{1}$$

where Y and Y_n are the actual and the natural levels of output, π and π^e are actual and expected inflation, and α is a positive parameter that characterizes the effect of unanticipated inflation on employment. The natural level of output is subject to stochastic fluctuations and is given by

$$Y_n = Y_p + \varepsilon \tag{2}$$

where Y_p is potential output and $\varepsilon = Y_n - Y_p$ is the output gap in the absence of inflation surprises. For simplicity, ε is specified as a zero-mean stochastic shock to the natural level of output with variance σ^2. Staiger *et al.* (1997) present evidence suggesting that the natural level of employment in the USA is subject to substantial uncertainty.[9] Inflation is determined both by the

[8]Evidence in Cukierman (1998) and the discussion in Chapter 19 of Cukierman (1992) imply that the effective level of central bank conservativeness was substantially higher in the second subperiod.

[9]Y, Y_n and Y_p can also be interpreted as the *rates of growth* of the actual, natural and potential levels of output. All the results in this section go through with this reinterpretation. For concreteness the discussion in the paper is in terms of potential output and the output gap. Obviously all the discussion can also be cast in terms of employment or unemployment by mapping potential and actual output into normal and actual employment respectively. The qualitative results are identical.

choice of monetary policy and by the realization of the shock ε and is given by the following equation:

$$\pi = m - \gamma\varepsilon \tag{3}$$

where m is the rate of inflation planned by the central bank (as well as the policy instrument) and γ is a positive parameter that determines the effect of shocks to employment on inflation.[10] Equation (3) states that, given planned inflation, actual inflation is lower the larger is the supply shock to the economy. Provided there is no instrument uncertainty, this formulation is consistent both with cases in which the policy instrument is the interest rate and with situations in which it is some nominal stock variable.[11] To reflect the fact that central banks normally possess some imperfect forecasting ability about future shocks the supply shock ε is decomposed as follows:

$$\varepsilon = \varepsilon_1 + \varepsilon_2 \tag{4}$$

where ε_2 is the forecast of ε at the time policy is chosen and ε_1 is a forecast error that is independent of the forecast. The components ε_1 and ε_2 have zero means, standard deviations σ_1 and σ_2 and distribution functions $G(\varepsilon_1)$, $F(\varepsilon_2)$ respectively. This decomposition of the shock reflects the well-established notion that central banks possess some ability to forecast the shock ε but that this ability is usually not perfect. Letting $\sigma_1^2 = \tau\sigma^2$ and $\sigma_2^2 = (1 - \tau)\sigma^2$ where $0 \leq \tau \leq 1$ the forecasting ability of the central bank is monotonically increasing in $1 - \tau$. In the extreme case $\tau = 0$ the forecasting ability of the central bank is perfect as in Rogoff (1985) and in much of the ensuing literature. In the other extreme case, $\tau = 1$ and the central bank has no ability to stabilize the economy since ε is totally unforecastable.[12]

Casual observations suggest that the political establishment is more sensitive to the costs of recessions than it is content with expansions. Since, in a democratic society, independent but accountable central banks are not totally insensitive to the wishes of the political establishment some of this asymmetry trickles down into the objective function of the central bank as well. This hypothesis is captured here by specifying the loss function of the central bank as

[10]The positive sign of γ is consistent with the notion that ε is a supply shock.

[11]In order to focus on the effects of uncertainty about the state of the economy, we abstract, for simplicity, from instrument uncertainty. The effects of relaxing this assumption are mentioned briefly in footnote 17.

[12]An alternative but equivalent interpretation is that ε_2 is a shock that is realized prior to policy choice and is therefore known with certainty at that time, while ε_1 is realized after the policy choice has been made and is therefore uncertain at that time. Gerlach (2000, 2003) studies a related model in which policy is set after shocks are observed.

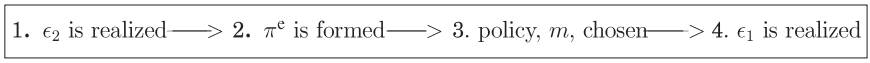

FIG. 1 The Sequence of Events

$$L = \frac{A}{2}\left(Y_p - Y\right)^2 + \frac{\pi^2}{2} \qquad \text{when } Y_p - Y > 0$$
$$L = \frac{\pi^2}{2} \qquad \text{when } Y_p - Y \le 0 \tag{5}$$

Equations (5) state that the central bank dislikes inflation as well as negative output gaps. But, given inflation, the central bank has no interest in deliberately creating positive output gaps. This specification is consistent with, and is partly motivated by, the observation of a Fed insider that 'In most situations the central bank will take far more political heat when it tightens preemptively to avoid higher inflation than when it eases preemptively to avoid higher unemployment' (Blinder, 1998, pp. 19, 20). In a recent survey on political economy and macroeconomic policy, Persson and Tabellini (1999) also posit a politically motivated asymmetric objective function (Section 3). Following recent expression of doubt about the realism of the assumption that the employment target of policymakers is above its potential level, equation (5) also builds in the presumption that the target level of employment is equal to its normal or potential level.[13] Hence there is no KPBG bias. Note that equation (5) is a positive description of central bank objectives rather than a social welfare function.

The sequence of events and the structure of information are as follows. First, the forecastable part of the real shock to employment, ε_2, is realized. Second, expectations π^e are formed and embedded into nominal contracts. In the third stage the central bank picks the value of its instrument, m. Finally the unforecastable part of the real shock to employment, ε_1, is realized and determines, along with monetary policy, employment and inflation. This sequence is illustrated in Fig. 1. A crucial element is that, when it chooses the setting of its instrument, the central bank is uncertain about the magnitude of the unforecastable part of the real shock to employment. This is also true for the public when they form their expectation.

The shock ε affects employment directly, as well as by creating, given monetary policy, unanticipated inflation in a direction that is opposite to the sign of the shock. From equations (1)–(3) the combined marginal impact of the shock on employment is

$$q \equiv 1 - \alpha\gamma \tag{6}$$

[13]Such doubts have been voiced also by McCallum (1995) and Vickers (1998).

We assume that the direct effect of the shock on employment dominates its indirect effect via unexpected inflation so that q is positive.[14]

2.2 Equilibrium

Using equations (1)–(3) in equation (5) the objective function of the central bank may be rewritten as

$$\begin{aligned} L &= \frac{A}{2}\left[q\varepsilon + \alpha\left(m - \pi^{e}\right)\right]^{2} + \frac{1}{2}\left(m - \gamma\varepsilon\right)^{2} \qquad \text{for } \varepsilon < \frac{\alpha}{q}\left(\pi^{e} - m\right) \\ L &= \frac{1}{2}\left(m - \gamma\varepsilon\right)^{2} \qquad \text{for } \varepsilon \geq \frac{\alpha}{q}\left(\pi^{e} - m\right) \end{aligned} \tag{7}$$

We proceed now to characterize the (subgame perfect) equilibrium of this game, as usual, by starting from the third stage.[15] At this stage the central bank takes the realization of ε_2 and of expectations as given and chooses the planned rate of inflation m so as to minimize the expected value of its loss function. From equation (7) this expected value is

$$\frac{A}{2}\int_{-\infty}^{b\left[\pi^{e}(\varepsilon_2) - m\right] - \varepsilon_2} \left\{q(\varepsilon_1 + \varepsilon_2) + \alpha\left[m - \pi^{e}(\varepsilon_2)\right]\right\}^{2} \mathrm{d}G(\varepsilon_1) + \frac{1}{2}E\left[m - \gamma(\varepsilon_1 + \varepsilon_2)\right]^{2} \tag{8}$$

where the expected value operator E is taken over the distribution of ε_1, $\pi^{e}(\varepsilon_2)$ is expected inflation given the realization of ε_2 and

$$b \equiv \alpha/q \tag{9}$$

Minimization of equation (8) with respect to m yields the following behavioural rule for the monetary authority:

$$\begin{aligned} m(\varepsilon_2) = \frac{1}{1 + \alpha^{2} A G(\varepsilon_{1u})} \Bigg\{ & \alpha^{2} A G(\varepsilon_{1u})\pi^{e} - \alpha A q \int_{-\infty}^{\varepsilon_{1u}} \varepsilon_1 \mathrm{d}G(\varepsilon_1) \\ & - \left[\alpha A q G(\varepsilon_{1u}) - \gamma\right]\varepsilon_2 \Bigg\} \end{aligned} \tag{10}$$

where $\varepsilon_{1u} \equiv b[\pi^{e}(\varepsilon_2) - m] - \varepsilon_2$. $G(\varepsilon_{1u})$ is the probability that ε_1 is smaller than the threshold ε_{1u} whose value depends on the realization of ε_2 and on the difference between expected inflation and the rate planned by the monetary authority.

We turn next to expectation formation which occurs in the second stage of the game. Like the central bank, individuals know the realization of ε_2 but

[14]Note that the assumption that q is positive covers the particular case $\gamma = 0$ since, in this case, $q = 1 > 0$. Thus all the results that follow for a positive q also apply to the case $\gamma = 0$.
[15]Since only 'nature' moves in the last stage the last strategic stage is the third one.

do not know the realization of ε_1. However, they know the stochastic structure of ε_1 as well as the structure of the economy and are familiar with the reaction function of the central bank, and use this information to calculate the rational expectation of inflation. Substituting equation (10) into equation (3), taking the expected value over the distribution of ε_1, given the observation on the shock ε_2, this rational expectation is

$$\begin{aligned}\pi^e(\varepsilon_2) &\equiv E_{\varepsilon_1}[m(\varepsilon_2)-\gamma(\varepsilon_2+\varepsilon_1)]\\ &= \frac{1}{1+\alpha^2 AG(\varepsilon_{1u})}\Big\{\alpha^2 AG(\varepsilon_{1u})\pi^e(\varepsilon_2)\\ &\quad -\alpha Aq\int_{-\infty}^{\varepsilon_{1u}}\varepsilon_1 \mathrm{d}G(\varepsilon_1)-[\alpha AqG(\varepsilon_{1u})-\gamma]\varepsilon_2\Big\}\end{aligned} \tag{11}$$

Rearranging equation (11) and noting (since $\pi^e(\varepsilon_2) - m(\varepsilon_2) = -\gamma\varepsilon_2$) that $\varepsilon_{1u} = -\varepsilon_2/q$, the explicit solution for $\pi^e(\varepsilon_2)$ is

$$\begin{aligned}\pi^e(\varepsilon_2) &= -\alpha Aq\int_{-\infty}^{-\varepsilon_2/q}\varepsilon_1 \mathrm{d}G(\varepsilon_1)-\alpha AG\left(-\frac{\varepsilon_2}{q}\right)\varepsilon_2\\ &= -\alpha AG\left(-\frac{\varepsilon_2}{q}\right)\left[qE\left(\varepsilon_1|\varepsilon_1<-\frac{\varepsilon_2}{q}\right)+\varepsilon_2\right]\end{aligned} \tag{12}$$

2.3 An Uncertainty-induced Inflation Bias

Given the realization of ε_2, $G(\varepsilon_2/q)$ is the probability of a recession. More precisely it is the probability that the realization of the employment shock ε is lower than the mean of this shock which is zero. $E(\varepsilon_1|\varepsilon_1 < -\varepsilon_2/q)$ is the expected value of ε_1 conditioned on the economy being in a recession (ε negative). Since the unconditional expected value of ε_1 is zero, $E(\varepsilon_1|\varepsilon_1 < -\varepsilon_2/q)$ is negative for all finite values of ε_2. Hence the expression on the right-hand side of equation (12) is positive for all $\varepsilon_2 \leq 0$ as well as for some positive values of ε_2 provided they are not too large. This intuitive argument suggests that, in spite of the fact that the target level of output is equal to potential output, there is an inflation tendency in the economy. Moreover, since the central bank does not possess any information advantage monetary policy has no impact on employment and output so that, when it is positive, this tendency is an unnecessary bias. Obviously, there will be sufficiently large values of ε_2 for which the bias will be deflationary. But if the distribution of ε_2 around its zero mean is symmetric and unimodal the likelihood of such realizations of ε_2 is smaller than that of realizations that lead to positive inflation. This can be demonstrated more precisely by calculating the expected value of $\pi^e(\varepsilon_2)$ over the distribution of ε_2. Using equation (12) this expected value is

$$E_{\varepsilon_2}\pi^e(\varepsilon_2) = -\alpha A\left[q\int_{-\infty}^{\infty} G\left(-\frac{\varepsilon_2}{q}\right)E\left(\varepsilon_1|\varepsilon_1 < -\frac{\varepsilon_2}{q}\right)\mathrm{d}F(\varepsilon_2) + \int_{-\infty}^{\infty} G\left(-\frac{\varepsilon_2}{q}\right)\varepsilon_2\mathrm{d}F(\varepsilon_2)\right] \tag{13}$$

This expression characterizes overall average inflation. Since $E(\varepsilon_1 | \varepsilon_1 < -\varepsilon_2/q) \leq 0$ for all values of ε_2 and is strictly negative for finite values of ε_2, the first expression in square brackets is negative. If the distribution of ε_1 is unimodal and symmetric around its zero mean (and median), the second integral in square brackets is also negative. The reason is that negative values of ε_2 uniformly get higher weights than positive values (the weights of negative values of ε_2 are larger than one-half and the weights of positive values are smaller than one-half). Thus a sufficient, but not necessary, condition for a positive overall inflation bias is that the distribution of the part of the shock that is known to the central bank (ε_2) is symmetric.

Intuitively the bias arises because the central bank does not have perfect information about the state of the economy in conjunction with the fact that it is more sensitive to policy errors in which monetary policy is too tight than to policy errors in which policy is overly expansionary. This in turn is a direct consequence of the fact that policymakers pay a political price that increases with unemployment when unemployment is above a certain threshold but their political benefits do not increase to the same extent when unemployment decreases below that threshold. Both conditions appear to be satisfied in reality. The upshot is that an inflation bias arises even when policymakers are content with achieving the potential level of output.

As in the case of the KPBG hypothesis, the bias is an increasing function of the slope of the short-run Phillips curve (α) as well of the relative importance attributed by policymakers to employment (A). Hence, as in Rogoff (1985), the more conservative is the central bank (the lower A), the lower is the bias. A novel element is that, given those parameters, the bias is positively related to the probability of a recession, and to its expected depth. For a given ε_2 the probability of a recession is given by $G(-\varepsilon_2/q)$. Given there is a recession, the expected depth of the recession is positively related to $E(\varepsilon_1 | \varepsilon_1 < -\varepsilon_2/q)$. The first integral in square brackets on the right-hand side of equation (13) is therefore a convolution of terms that characterize the probability of a recession with terms that characterize its expected depth for alternative realizations of ε_2. Hence, other things the same, economies that are more recession prone and subject to larger expected recessions suffer from a higher inflation bias. The intuition underlying this result is as follows. Due to their asymmetric attitude to recessions and to expansions, policymakers tend to relax monetary policies more when the likelihood, and the expected magnitude, of a recession is higher. Since the public is aware of that, it adjusts

its inflation expectation accordingly and neutralizes in the process any effects of monetary policy on employment and output. Thus, employment remains at its natural level but the bias is higher due to the stronger incentive of policymakers to inflate.[16]

2.4 Symmetric Preferences as a Benchmark

This section highlights the origin of the bias in the absence of a KPBG type bias by showing that when the objective function is symmetric uncertainty alone does not produce excessive inflation. Symmetric preferences imply that the first branch of the loss function in equation (5) holds for the entire range of values of the output gap. That is, the central bank dislikes any given negative output gap to the same extent that it dislikes a positive output gap of the same size. For this case the reaction function of the central bank in equation (10) is replaced by

$$m(\varepsilon_2) = \frac{1}{1+\alpha^2 A}\left[\alpha^2 A \pi^e(\varepsilon_2) - (\alpha A q - \gamma)\varepsilon_2\right]$$

Rationality of expectations implies that $\pi^e(\varepsilon_2) = m(\varepsilon_2) - \gamma\varepsilon_2$. Combining this with the central bank reaction function yields

$$\pi^e(\varepsilon_2) = -\alpha A \varepsilon_2$$

Thus, given ε_2, expected inflation is positive or negative depending on whether a recession or an expansion is anticipated (i.e. on whether ε_2 is negative or positive). However, the overall inflation bias

$$E_{\varepsilon_2}\pi^e(\varepsilon_2) = -\alpha A E_{\varepsilon_2}\varepsilon_2$$

is zero since $E_{\varepsilon_2}\varepsilon_2 = 0$. The lesson from this section is that in the presence of uncertainty about the future state of the economy asymmetric central bank objectives (or a precautionary demand for expansions) are essential for the bias-producing mechanism of this paper.[17]

[16]Preliminary evidence reported in Gerlach (2000) indicates that during the 1960s and 1970s interest rate policy in the USA responded more strongly to recessions than to expansions.

[17]For simplicity we have assumed that there is no instrument uncertainty. Had there been additive instrument uncertainty in the model, its effect on the inflationary bias in the presence of a precautionary demand for expansions would be qualitatively similar to that of uncertainty about the state of the economy. This is demonstrated by Jordan (2001, Ch. 4) for a uniform distribution of the monetary control error. Cukierman (2000b, Section 3.2) shows that this conclusion carries over to any distribution of instrument uncertainty and any combination of this uncertainty with uncertainty about the state of the economy as long as both types of uncertainties are additive.

3 A Test of the New Inflation Bias Hypothesis

3.1 A Testable Implication

The preceding section has shown that there is an inflation bias even if the target and the potential levels of output (and of employment) are equal provided policymakers have a precautionary demand for expansions. This section provides a cross-sectional empirical test of the mechanism responsible for the inflation bias under such circumstances. In order to discriminate between the KPBG inflation bias story and the one presented here the test is based on an implication of the new theory that is not shared with the KPBG theory. In particular, provided the distributions of the components ε_1 and ε_2 of the supply shock are normal, the new inflation bias theory implies that there should be a positive relation between average inflation in a country and the variance of shocks to output. More precisely, it is shown in the Appendix that, when ε_1 and ε_2 possess normal distributions, equation (13) assumes the form

$$E_{\varepsilon_2}\pi^e(\varepsilon_2) = \alpha A\left(\frac{q^2\tau + 1 - \tau}{2\pi}\right)^{1/2}\sigma \qquad 0 < \tau \leq 1 \tag{14}$$

The key implication of this equation is that the average rate of inflation depends positively on the variance of the supply shock. Intuitively, the larger σ is, the more likely it is that large contractionary shocks will occur. As a consequence the interaction between the precautionary demand of policymakers for expansions and uncertainty about supply shocks induces a stronger inflation reaction when the variability of shocks is higher. Since the public is familiar with this tendency of policymakers, inflation expectations are therefore also positively related to σ.

The new inflation bias mechanism implies that the slope parameter in a regression of average inflation on the standard deviation of the supply shock should be positive. By contrast, the traditional KPBG hypothesis does not imply that such a relation should exist. It is therefore possible to perform a first pass test of the new mechanism by examining whether there is such a relation in the data. It also follows from equation (14) that this implication should hold only if the central bank is not too conservative (A is not too small). In fact the theory predicts that, when central banks are highly independent and concerned mainly with inflation, so that A is small, the positive relation between inflation and the variance of shocks to output should weaken and may even disappear. The next section provides cross-sectional evidence that supports these implications.

3.2 Empirical Implementation of the Test

We think of the theory as relevant for explaining average inflation rates over an extended time period, say a decade, in highly developed economies. To test

it we use annual data spanning the period 1971–2000 for a sample of 22 OECD countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the UK and the USA.[18] Ideally, to test the theory one would need an estimate of the standard deviation of the supply shock, i.e. the disturbance to the Phillips curve equation. For simplicity, we use the standard deviation of the growth rate of real GDP as a proxy for σ. The rationale for using this proxy is that, in the absence of anticyclical policy, the variability in the rate of growth of real GDP and the variance of shocks to GDP are positively and strongly related. Although stabilization policy may weaken this relation it is unlikely that it destroys it for at least two reasons. First, due to imperfect knowledge about the economy, stabilization policy is only partially successful. Second, since policymakers are also concerned about inflation, the stabilization of shocks to output is partial even in the absence of uncertainty.

3.2.1 Regression Results. For each country i we calculate the average inflation rate $\overline{\pi}_i$ using the GDP deflator and the standard deviation of real GDP growth, $\hat{\sigma}_i$. Since inflation rates declined substantially between the 1970s and the 1990s, we also compute $\hat{\sigma}_i$ and $\overline{\pi}_i$ for the subperiods 1971–85 and 1986–2000.

The empirical work is based on fitting the regression

$$\overline{\pi}_i = \phi_0 + \phi_1 \hat{\sigma}_i + \eta_i \tag{15}$$

where η_i is a residual.[19] Before turning to the formal econometric work, it is useful to explore the relationship between the variables more informally. Figures 2–4 contain scatterplots of $\overline{\pi}_i$ versus $\hat{\sigma}_i$ for the full sample period and the two subperiods. Several observations are of interest. First, the graphs reveal that there is a clear positive relationship between the two variables in the full sample and the pre-1986 subsample, but not for the post-1985 sample. The fact that the relationships in the two subsamples differ is clear from the fact that, while the mean of $\hat{\sigma}_i$ is roughly the same in the two subsamples, the mean of $\overline{\pi}_i$ falls sharply.[20] Second, the scatterplots for the full sample and

[18]The source of the data is the July 2002 IFS CD-Rom.

[19]Since we use $\hat{\sigma}_i$ rather than σ_i in fitting (15), the estimates are subject to an errors-in-variables problem. This will bias the estimate of ϕ_1 towards zero and make it more difficult to reject the null hypothesis that $\phi_1 = 0$ (see, for instance, Greene, 1997, p. 437). This suggests that if the null hypothesis is rejected the relation between inflation and the variance of GDP growth is likely to be strong.

[20]The average standard deviation of output growth in the first sample is 2.50 (with a standard deviation of 0.61) while in the second subsample it is 1.97 (0.72). For inflation the mean falls from 10.68 (6.06) to 4.29 (3.15).

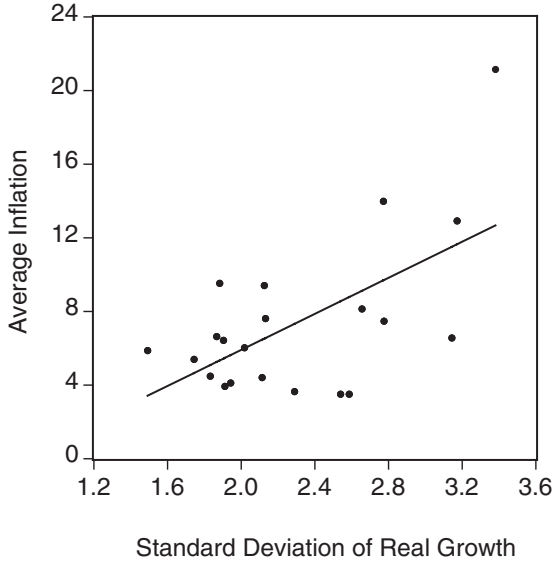

FIG. 2 Average Inflation and Standard Deviation of Real GDP Growth, 1971–2000

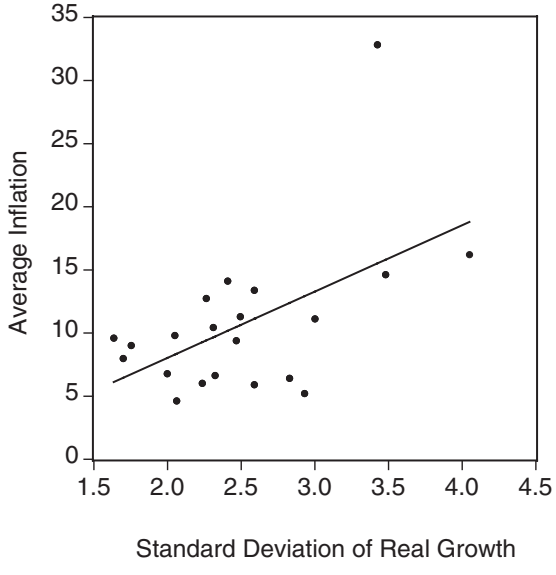

FIG. 3 Average Inflation and Standard Deviation of Real GDP Growth, 1971–85

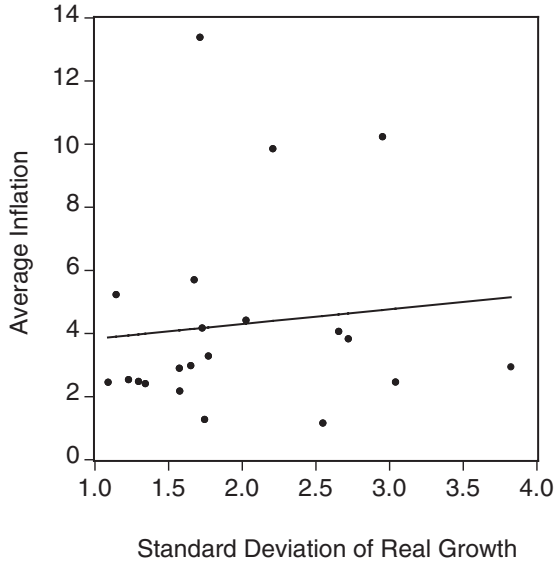

FIG. 4 Average Inflation and Standard Deviation of Real GDP Growth, 1986–2000

the first subsample indicate that there is one observation, Iceland, in the upper-right-hand corner of the plots.[21] Since it appears plausible that the results may be sensitive to this observation, we reestimate (15) and include a dummy for Iceland:

$$\bar{\pi}_i = \phi_0 + \phi_1 \hat{\sigma}_i + \phi_2 \text{Dummy} + \eta_i \tag{16}$$

Table 1, part (A), presents the results of ordinary least squares estimates of (15), using the estimates of $\bar{\pi}_i$ and $\hat{\sigma}_i$ from the full sample and the two subsamples. Table 1, part (B), contains estimates of (16). Given that heteroscedasticity is likely in cross-sectional regressions, we provide the p value for a White test of the null hypothesis that the residuals are homoscedastic, and also provide heteroscedasticity-consistent p values for the estimated parameters in square brackets.

Several aspects of the results are of interest. First, ϕ_1 is positive and significant, at least at the 10 per cent confidence level, in regressions for the full sample and for the first subsample irrespectively of whether or not a dummy for Iceland is included.[22] This finding provides support for the basic implica-

[21]It should be noted that the very high inflation rates experienced in Iceland before the early 1990s were due precisely to the tendency of the central bank to accommodate contractionary disturbances (Andersen and Guðmundsson, 1998). See also the discussion in Gerlach (1999).

[22]The fact that ϕ_1 is less significant in the full sample than in the first subsample is not surprising given that the results suggest that a structural break has occurred.

Table 1

Sample	ϕ_0	ϕ_1	ϕ_2
(A) $\bar{\pi}_i = \phi_0 + \phi_1\hat{\sigma}_i + \eta_i$			
1971–2000	–3.97	4.89	
	(26.7%)	(0.4%)	
	[38.1%]	[3.1%]	
$\overline{R^2}$ = 0.32, *p* value White = 0.2%			
1971–1985	–2.53	5.21	
	(60.9%)	(1.2%)	
	[64.1%]	[4.4%]	
$\overline{R^2}$ = 0.24, *p* value White = 25.7%			
1986–2000	3.28	0.47	
	(12.3%)	(63.4%)	
	[6.0%]	[57.7%]	
$\overline{R^2}$ = –0.04, *p* value White = 69.4%			
(B) $\bar{\pi}_i = \phi_0 + \phi_1\hat{\sigma}_i + \phi_2\text{Dummy} + \eta_i$			
1971–2000	0.73	2.61	11.58
	(81.2%)	(6.2%)	(0.2%)
	[81.4%]	[9.4%]	[0.0%]
$\overline{R^2}$ = 0.58, *p* value White = 17.6%			
1971–1985	2.82	2.70	20.8
	(35.2%)	(3.3%)	(0.0%)
	[26.2%]	[1.5%]	[0.0%]
$\overline{R^2}$ = 0.74, *p* value White = 27.0%			
1986–2000	4.17	–0.13	6.45
	(4.5%)	(89.4%)	(5.5%)
	[0.5%]	[80.3%]	[0.0%]
$\overline{R^2}$ = 0.10, *p* value White = 84.2%			

Notes: *p* values from ordinary least squares standard errors appear in parentheses and from White standard errors in square brackets. *p* value White denotes the *p* value from a White test of the hypothesis of homoscedasticity.

tion of the model discussed above. Second, the estimate of ϕ_1 in the first subsample is larger than that for the full period and highly significant. Third, ϕ_1 is not significantly different from zero in the second subsample. The last two findings are consistent with the view that the new bias was important in the first part of the period when central bank independence was low and A high. But when, due to substantial increases in central bank independence during the second half of the period, A declined, the positive relationship between average inflation and the variance of shocks to output weakened substantially.[23]

Before proceeding, we note that New Keynesian models of the type developed and tested empirically by Ball *et al*. (1988) also suggest a rela-

[23]The worldwide increase in central bank independence during the 1990s is discussed in Cukierman (1998).

tionship between average inflation and the variance of supply shocks.[24] In this case, however, the assumption of menu costs implies that the slope of the short-run Phillips curve should be steeper when average inflation is higher and, as a consequence, the variance of output should be negatively related to average inflation. Using the variance of the rate of growth in real output as a proxy for output variability and controlling for the variability of nominal output growth, Ball *et al*. (1988, pp. 56–57) find empirical support for this implication.

While there is some similarity between the two approaches, there are also several important differences. First, our approach implies a positive, while New Keynesian literature implies a negative, relationship between inflation and the variance of real output growth. Second, in contrast to our hypothesis, the New Keynesian model suggests that the variability of nominal output growth should be controlled for. Third, Ball *et al*. (1988) focus on the behaviour of the private sector while we emphasize the behaviour of policymakers. Fourth, in their framework causality runs from inflation to output variability while in ours it runs in the opposite direction. Combining or discriminating between those two approaches is a potentially interesting issue that we leave for future research.

4 Implications for Transparency and for Central Bank Reform

4.1 Implications for Transparency

In comparison with past decades there is nowadays substantially more transparency about the main objective of monetary policy. In most contemporary central banks the main legal objective of monetary policy is price stability and all other objectives are either non-existent (as is nearly the case in the charter of the ECB) or relegated to being (at least legally) a second priority (as is the case with the growth and employment objectives in the 1997 charter of the Bank of England). This is a substantial increase in transparency in comparison to the 1980s and previous decades during which most central bank charters featured several conflicting objectives with no clear specification of priorities.

In spite of these advances there is still substantial opaqueness about the output-gap segment of the loss function of modern central banks as well as about the relative importance attributed to stabilization of output versus stabilization of inflation (the parameter A). Following Svensson (1997b) we also refer to A as the 'flexibility parameter' since it determines the degree of flexibility in targeting inflation. There is little doubt that all central banks are

[24]We are grateful to an anonymous referee for pointing this out.

quite opaque about the flexibility parameter. This is admitted quite candidly by Vickers (1998) in a review of recent UK monetary policy. Vickers openly recognizes that the Monetary Policy Committee's remit is silent on the magnitude of this parameter. Furthermore, no central bank has ever come close to disclosing any minimal amount of information about the shape of its loss function for alternative levels of the output gap.[25]

Our inflation bias hypothesis implies that when $A = 0$ murkiness about the output-gap segment of the loss function does not matter for inflation. No matter what the shape of losses from non-zero output gaps is, there is no inflation bias in this case. But when A is positive, equation (13) implies that, the larger it is, the higher is the inflation bias even when policymakers aim at potential output. As a consequence, a flexible inflation targeter with a non-negligible flexibility parameter has good reason to try to appear to be less flexible than he really is.

This may have underlain the traditional historical public position of the Bundesbank, according to which it was not concerned about fluctuations in output, as well as a recent observation by Mervyn King from the Bank of England. King's argument is that it is difficult to distinguish, in practice, between strict and flexible inflation targeters since both raise interest rates when inflation and output are above target. We doubt that a strict inflation targeter would have made such a statement. As a matter of fact, flexible inflation targeters with asymmetric output-gap concerns have, in view of the new inflation bias result presented here, a credibility reason for *not* highlighting this fact. By contrast, simple monetary policy games with signalling imply that a strict inflation targeter would like to send messages that would make his identity clear to the public.[26] Such a 'type' is unlikely to claim that it is not possible to distinguish flexible from strict inflation targeters.

One consequence of these observations is that, even if they possess precautionary demands for expansions, central bankers are unlikely to openly admit that. This suggests that the main source of future information about possible asymmetries in the loss functions of central banks is likely to be empirical work which tries to infer whether central banks do or do not possess precautionary demands for expansions. The previous section offers one such attempt and its findings are consistent with the view that an uncertainty-induced inflation bias was present between 1971 and 1985. The concluding section features a brief description of other recent empirical work on this issue.

[25]A more detailed discussion of these issues and additional documentation appears in Cukierman (2002).

[26]This is in the spirit of formal models of monetary policy games with private information like Vickers (1986). Within the context of inflation targets, Cukierman (2000a) shows that a policymaker who is more seriously committed to low inflation has a stronger incentive to reveal his identity.

4.2 Implications for Central Bank Reform

The recent flurry of reform in central bank laws raised the issue of whether the only objective of the central bank should be price stability or whether the law should also require policymakers to take into consideration the state of the real economy. Since there are different views on this question among central bankers and academics, it is interesting to examine whether it is possible to rank these two alternative institutional arrangements from a welfare point of view. The equilibrium described in Section 2 corresponds to the case in which the law charges the central bank with the dual task of 'price stability' and a 'sufficiently high level of economic activity and employment' implying that the central bank is expected to also engage in anticyclical policy. In the case in which the bank is directed to achieve *only* price stability, the first term in equation (8) vanishes. Maximization of the remaining expression yields the policy rule

$$m(\varepsilon_2) = \gamma\varepsilon_2 \tag{17}$$

which implies that the average inflation bias is zero and that unexpected inflation is $-\gamma\varepsilon_1$. From equations (1) and (2) this implies that economic activity is given by

$$Y = Y_n - \alpha\gamma\varepsilon_1 \tag{18}$$

Note that it differs from the natural rate only because of the realization of the unforecastable part of the shock, and that, on average, output is at the natural level. Consider now the behaviour of output in the case in which the central bank is charged by law with the dual task of price stability and stabilization of employment as is the case for example in the USA. In this case $m(\varepsilon_2)$ is given by the reaction function in equation (10) and $\pi^e(\varepsilon_2) = m(\varepsilon_2) - \gamma\varepsilon_2$. Hence unexpected inflation is again $-\gamma\varepsilon_1$ so that economic activity is given again by equation (18). Thus, given the realization of the shock ε_1, economic activity is the same in the two cases but average inflation is higher in the case in which the central bank is also directed to choose its policy so as to maintain a 'reasonable' level of economic activity. Thus, in the presence of some uncertainty about the state of the economy in conjunction with a precautionary demand for expansions, the requirement that the central bank should partially offset recessions produces a suboptimal inflation bias even in the absence of a systematic divergence between potential and desired output.

This result would seem to imply that price stability should be the only legal objective of the central bank. But the matter is not as clear cut as may appear to be the case at first. For simplicity and focus we have assumed that, at each stage of the game, the information sets of the public and of the central bank are identical. This assumption rules out socially beneficial stabilization

policy.[27] But if at the time it sets monetary policy the central bank has more information about the state of the real economy than what the public had when they formed expectations, there is room for beneficial stabilization policy. The model could be extended to allow for the existence of beneficial stabilization policy by introducing some persistence in the employment shock and by allowing the monetary authority to have more (although not fully) precise information on its future value than the public had when it formed its expectation.[28]

In such an extended framework there will be a familiar (as in Rogoff (1985) and Lohmann (1992)) tradeoff between the credibility needed to reduce the inflation bias and the flexibility required to enable the central bank to engage in stabilization policy. Although the precise investigation of the extended framework is beyond the scope of this paper it is easy to see that leaving the door open for some stabilization of the real economy (by not totally excluding employment from the objectives of the central bank) may in this case be socially beneficial. The higher is the information advantage of the central bank in comparison to the extent to which it is uncertain about the future, the more likely it is that requiring some stabilization of output by the central bank will be beneficial.

5 Concluding Remarks

The standard KPBG inflation bias hypothesis has enriched our understanding of the possible reasons for persistent and widespread inflation under discretion. This conceptual framework heavily relies on the presumption that policymakers use monetary policy to raise employment above its normal level. This presumption has been questioned by policymakers as well as by some academics on the ground of realism.

Using a natural rate model this paper shows that the conjunction of forecasting uncertainty and asymmetric attitudes of the central bank to positive and to negative retrospective monetary policy errors implies that there is a bias even if the desired level of employment is identical to its normal level.[29] This bias arises because the central bank is more sensitive to policy errors

[27]Stabilization policy can be introduced into the model by adjusting the timing of moves in the model so that the public's inflationary expectations are formed prior to the realization of *both* components of the shock ε. The new inflation bias result carries over to this case as well but the algebra leading to a testable implication is more complicated.

[28]Note that this does not necessarily imply that the monetary authority is better informed about the state of the economy at the *same* point in time. All that it requires is that the central bank choose policy after some additional persistent information, that was not available at the time of expectation formation, is revealed.

[29]Most of the literature on endogenous monetary policy abstracts from such a possibility by postulating quadratic loss functions. Cukierman (2002) argues that the quadratic form is postulated mostly for analytical convenience rather than because of its descriptive realism.

that lead to negative output gaps than to policy errors that lead to positive output gaps. Such precautionary demand for expansions leads to more expansionary monetary policies which (since they are anticipated by nominal contract setters) lead, in turn, to inflation expectations and to a modified form of the original KPBG bias.[30] But in the absence of asymmetries in the loss function of the central bank there is no precautionary demand for expansions and no bias.

The potential existence of a precautionary motive for expansionary monetary policy has two implications. The first is that there should be a positive relation between average inflation and the variance of output shocks. The second is that this association should be weaker the more effectively conservative are the central banks. The first implication is supported by cross-sectional evidence from a sample of 22 developed economies in the 30 years' period ending in 2000. To test the second implication the sample period has been divided into two subperiods. Since the effective levels of central bank independence, and therefore of conservativeness, are both higher in the second subperiod our theory predicts that the cross-sectional association between average inflation and the variance of shocks to output should be weaker in the second subperiod. This implication of the theory is also supported by the data.

Although the empirical work in the paper is simple, the results are sufficiently strong and clear cut to warrant the conclusion that, at least until 1985, the view that the central banks of (most if not all) developed economies possessed an inflation bias induced by precautionary demands for expansions cannot be easily dismissed.[31] Due to the substantial increase in central bank independence during the 1990s such a sweeping conclusion is less appropriate today. But this still leaves the door open for the possibility that individual central banks possess precautionary demands for expansions.[32]

There is time series evidence within individual countries that supports the existence of precautionary demands for expansions in some countries but not in others. Dolado *et al*. (2000) estimate interest rate reaction functions over time for a number of central banks (USA, Germany, Spain, France), allowing for different interest rate responses for positive and negative output

[30]Section V in Cukierman (2002) shows that a similar bias arises under similar circumstances with a New Keynesian transmission mechanism.

[31]Ruge-Murcia (2002) also presents cross-sectional evidence supporting the existence of a precautionary demand for expansions.

[32]At a broad level one may claim that the underlying cause for the bias here and in the standard KPBG inflation bias story is similar (see also Gerlach, 2003). KPBG assume that desired output is centred above the normal level while we replace this assumption by the (similar) assumption that policymakers are more averse to negative than to positive output gaps. Although such a characterization may have some merit it is important to keep in mind that uncertainty is essential for the bias-creating mechanism in our framework while it is not in the KPBG theory.

and inflation movements. They find evidence for asymmetric central bank attitudes to negative and to positive output gaps in the USA but not in the three other countries (see also Dolado *et al*., 2002a, 2002b). Using a natural rate model and a Linex function to allow for possible asymmetries in the loss function, Ruge-Murcia (2001) provides evidence supporting the view that the US and French central banks possessed precautionary demands for expansions but that the central banks of the UK and of Japan did not. Using a New Keynesian framework Cukierman and Muscatelli (2003) develop a procedure for the detection of a precautionary demand for expansions from interest rate reaction functions of the type used by Clarida *et al*. (2000). They find evidence supporting the existence of a precautionary motive for expansions during the second half of the 1980s and the 1990s in the USA but not in Germany, Japan and the UK.

For sceptics like McCallum (1995), who argue that the KPBG inflation bias hypothesis is not a good explanation of inflation even prior to Volcker's disinflation in the USA, this paper provides an alternative, more realistic, hypothesis that is supported by cross-sectional evidence from 22 developed economies. This raises the possibility that the new inflation bias hypothesis proposed here provides, for the period in which most of the developed economies suffered from relatively high inflation, a more believable alternative to the KPBG bias hypothesis. More definitive judgement on this issue must await further work. But the fact that, in the pre-1985 period, there was a strong positive relation between inflation and the variability of output growth—which is consistent with the new bias hypothesis but not with the KPBG hypothesis—raises the possibility that, for developed economies, the new bias hypothesis is a serious contender to the standard one.

Appendix: Derivation of Equation (14)

The first integral on the right-hand side of equation (13) can be rewritten as

$$\int_{-\infty}^{\infty} G\left(-\frac{\varepsilon_2}{q}\right) E\left(\varepsilon_1 \middle| \varepsilon_1 < -\frac{\varepsilon_2}{q}\right) \mathrm{d}F(\varepsilon_2) = \int_{-\infty}^{\infty} E_{\varepsilon_1} \varepsilon_1 I_{\{\varepsilon_1 < -\varepsilon_2/q\}} \mathrm{d}F(\varepsilon_2) = E\varepsilon_1 I_{\{\varepsilon_1 < -\varepsilon_2/q\}} \tag{19}$$

where

$$I_{\{\varepsilon_1 < -\varepsilon_2/q\}} \equiv \begin{cases} 1 & \text{if } \varepsilon_1 < -\varepsilon_2/q \\ 0 & \text{otherwise} \end{cases} \tag{20}$$

is the indicator function and the symbol E denotes an expected value over the distributions of both ε_1 and ε_2. The second integral on the right-hand side of equation (13) can be rewritten as

$$\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \varepsilon_2 I_{\{\varepsilon_1 < -\varepsilon_2/q\}} \mathrm{d}G(\varepsilon_1) \mathrm{d}F(\varepsilon_2) = E\varepsilon_2 I_{\{\varepsilon_1 < -\varepsilon_2/q\}} \tag{21}$$

Substituting equations (19) and (21) into equation (13) and rearranging

$$E_{\varepsilon_2}\pi^e(\varepsilon_2) = -\alpha A E(q\varepsilon_1 + \varepsilon_2) I_{\{\varepsilon_1 < -\varepsilon_2/q\}} \tag{22}$$

Letting $\hat{\varepsilon} \equiv q\varepsilon_1 + \varepsilon_2$, $\hat{\varepsilon}$ is distributed normally with a zero mean and variance $\hat{\sigma} = q^2\sigma_1^2 + \sigma_2^2$. It follows that $\hat{\varepsilon} = \hat{\sigma}z$ where z is a standard normal variate. Hence the expression in equation (22) can be rewritten as

$$E_{\varepsilon_2}\pi^e(\varepsilon_2) = -\alpha A E\hat{\varepsilon} I_{\{\hat{\varepsilon}<0\}} = -\alpha A \hat{\sigma} E z I_{\{z<0\}} = -\alpha A \hat{\sigma}[-\phi(0)] = \alpha A \hat{\sigma}\phi(0) \tag{23}$$

where $\phi(0)$ is the density of the standard normal distribution at the (zero) mean of this distribution. Using the relations $\phi(0) = 1/\sqrt{(2\pi)}$ and $\hat{\sigma}^2 = q^2\sigma_1^2 + \sigma_2^2 = q^2\tau\sigma^2 + (1 - \tau)\sigma^2$ in equation (23) and rearranging yields equation (14) in the text.

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