Measuring the Time-Inconsistency of US Monetary Policy

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Abstract

This paper offers an alternative explanation for the behavior of postwar US inflation by measuring a novel source of monetary policy time-inconsistency due to Cukierman (2002). In the presence of asymmetric preferences, the monetary authorities end up generating a systematic inflation bias through the private sector expectations of a larger policy response in recessions than in booms. Reduced-form estimates of US monetary policy rules indicate that while the inflation target declines from the pre- to the post-Volcker regime, the average inflation bias, which is about one percent before 1979, tends to disappear over the last two decades. This result can be rationalized in terms of the preference on output stabilization, which is found to be large and asymmetric in the former but not in the latter period.

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1 Introduction

The behavior of postwar US inflation is characterized by two major episodes. The first is an initial rise that extends from the 1960s through the early 1980s. The second is a subsequent fall that lasts from the early 1980s to the present day. The important change that underlies such a path can be exemplified by the average rates reported in the first column of Table 1. Inflation is measured as the annualized quarterly increase in the log GDP chain-type price index whereas the output gap is constructed as the log deviation of real GDP from the Congressional Budget Office potential output. The difference of the average inflation rates across the two sub-samples is above 2% and it is echoed by the decline in the volatility of the output gap displayed in the second column.

While a more favorable macroeconomic environment during the second period, a better policy management or a persistent error in the real-time measures of potential output are also likely to have played a role, an important strand of the literature has investigated whether the time-consistency problem can explain the behavior of US inflation.

In a stimulating contribution, Ireland (1999) shows that Barro and Gordon's (1983) model of time-consistent monetary policy imposes long-run restrictions on the time series properties of inflation and unemployment that are not rejected by the data. In the absence of a commitment technology, the monetary authorities face an incentive to surprise inflation in an effort to achieve a lower level of unemployment through an expectations-augmented Phillips curve. However, such an optimal plan is not time-consistent in the sense of Kydland and Prescott (1977), and private agents, who rationally understand such a temptation, adjust their decisions accordingly. In equilibrium, unemployment is still at its first-best level but the rate of inflation is inefficiently higher than it would otherwise be. This is the celebrated inflation bias result, according to which the higher the natural rate of unemployment the more severe the time-consistency problem of monetary policy is.

As Persson and Tabellini (1999) make clear, the central bankers' ambition of attaining a level of unemployment below the natural rate is crucial to generate the kind of inflation bias a la Barro and Gordon (1983), and both researchers and policy makers have challenged such an assumption on the ground of realism. McCallum (1997) argues that were this the case, the monetary authorities would learn by practicing the time-inconsistency of their actions and eventually would revise their objective. Describing his experience as vice-Chairman, Blinder (1998) claims that the Fed actually targets the natural rate of real activity, thereby suggesting that overambitious policy makers cannot be at the root of any kind of inflation bias. While this may rationalize the failure of the theory to account for the short-run inflation dynamics (see Ireland, 1999), it does not necessarily imply that the time-consistency problem has been unimportant in the recent history of US monetary policy.

In an intriguing article, Ruge-Murcia (2003) constructs a model of asymmetric central bank preferences that nests the Barro-Gordon model as a special case. When applied to the full postwar period, the hypothesis that the Fed targets a level of real activity different from the natural rate is rejected but the hypothesis that it weights more severely output contractions than output expansions is not. This suggests the existence of a novel *average inflation bias*, which according to Cukierman (2002) comes from the private sector expectations of a more vigorous policy response in recessions than in booms.

More specifically, the average inflation bias is a function of both the preferences of the central bank and the volatility of the output gap. To the extent that a significant policy regime shift has occurred at the beginning of the 1980s after the appointment of Paul Volcker as Fed Chairman, it is likely that the degree of asymmetry and therefore the degree of time-inconsistency has also changed during the last four decades. Hence, rather than focusing on the full postwar period like Ireland (1999) and Ruge-Murcia (2003), we study the sub-samples that are typically associated with a shift in the conduct of US monetary policy according to the reasoning that the time-inconsistency problem and the relative inflation bias are better interpreted as regime-specific. The difference in the sub-sample volatility of the output gap shown in the second column of Table 1 also seems consistent with this view.

This paper contributes to the literature on optimal monetary policy by proposing a measure of the average inflation bias that arises in a model of asymmetric central bank preferences.

To this end, it is developed a novel identification strategy that allows to recover the relevant parameters in the central bank objective function and, most importantly, to translate them into a measure of time-inconsistency. The comparison between the commitment and the discretionary solutions shows how the observed inflation mean can be successfully decomposed into a target and a bias argument, a result that to our knowledge of the existing literature comes as new. Reduced-form estimates of US monetary policy rules indicate that a significant regime shift has occurred during the last forty years as measured by the change in the Fed policy preferences. In particular, while the inflation target declines from 3.42% to 1.96%, the average inflation bias, which is estimated at 1.01% before 1979, is found to disappear over the last two decades. The result can be rationalized in terms of the policy preference on output stabilization, which is found to be large and asymmetric in the pre- but not in the post-Volcker period.

The paper is organized as follows. Section 2 sets up the model and solves for the optimal monetary policy. Section 3 derives its reduced-form version and reports the estimates of both the feedback rule coefficients and the average inflation bias. Section 4 concludes.

2 The model

Following the literature, the private sector behavior is characterized by an expectations-augmented Phillips curve:

$$y_t = \theta\left(\pi_t - \pi_t^e\right) + u_t, \;\; \theta > 0 \tag{1}$$

where y_t is the output gap measured as the difference between actual and potential output, π_t denotes inflation and π_t^e stands for the inflation expectation in period $t-1$ on the inflation rate in period t. The supply disturbance, u_t, obeys a potentially autoregressive process:

$$u_t = \rho u_{t-1} + \varepsilon_t$$

where $\rho \in [0, 1)$ and ε_t is an i.i.d. shock with zero mean and variance σ_ε^2. The private sector has rational expectations

$$\pi_t^e = E_{t-1}\pi_t \tag{2}$$

with E_{t-1} being the expectation conditional upon the information available at time $t-1$.

Potential output is identified with the real GDP trend so that the mean of the output gap is normalized to zero. Moreover, y_t is also a random variable since it depends on u_t, and its variance, which is a positive function of both ρ and σ_ε^2, is denoted by σ^2.

As customary in the literature, the central bank is assumed to have full and direct control over inflation, which is chosen to minimize the following intertemporal criterion:

$$\underset{\{\pi_t\}}{Min} \;\; E_{t-1} \sum_{\tau=0}^{\infty} \delta^\tau L_{t+\tau} \tag{3}$$

where δ is the discount factor and L_t stands for the period loss function. The latter is specified in a linear-exponential form:

$$L_t = \frac{1}{2} \left(\pi_t - \pi^*\right)^2 + \lambda \left(\frac{\exp\left(\gamma y_t\right) - \gamma y_t - 1}{\gamma^2} \right) \tag{4}$$

where $\lambda > 0$ and γ represent the relative weight and the asymmetric preference on output stabilization, respectively. As in Ireland (1999), π^* is assumed stable enough to be approximated by a positive constant. Unlike in the Barro-Gordon model, the target level of output is not meant to overambitiously exceed potential. This is consistent with the empirical evidence reported by Ruge-Murcia (2003).

The objective function (4) tends to its minimum whenever both inflation and output gaps shrink and larger losses are associated with larger absolute values at an increasing rate. The linex specification, which has been originally proposed by Varian (1974) and Zellner (1986) in the context of Bayesian econometric analysis and introduced by Nobay and Peel (1998) in the optimal monetary policy literature, allows departures from the quadratic objective in that policy makers may treat differently output contractions and output expansions. Indeed, under an asymmetric loss function deviations of the same size but opposite sign yield different losses and a negative value of γ implies that negative gaps are weighted more severely than positive ones. To see this notice that whenever $y_t < 0$ the exponential component of the loss function dominates the linear component while the opposite is true for $y_t > 0$. The reasoning is reversed for positive values of γ.

The linex specification nests the quadratic form as a special case and by means of L'Hôpital's rule it can be shown that whenever γ tends to zero the central bank objective function (4) reduces to the conventional symmetric parametrization $L_t = \frac{1}{2}\left[(\pi_t - \pi^*)^2 + \lambda y_t^2\right]$. As argued by Ruge-Murcia (2003), this feature is attractive as it allows to test whether the relevant preference parameter is statistically different from zero.

The intuition for having an asymmetric loss function with respect to the output gap comes from the labor market asymmetry over the business cycle between the extensive and the intensive margin. Indeed, whenever output is at its potential level the economy experiences full employment and production can only be expanded along the intensive margin, namely by increasing the number of worked hours per employee. By contrast, during recessions also the extensive margin becomes available and production can be lowered through a reduction of both the number of workers and the number of worked hours per employee. This introduces a natural asymmetry in the cost of business fluctuations that policy makers are likely to suffer. A simple microfoundation for an asymmetric objective function in the output gap can be found in Geraats (1999).

2.1 Commitment

This subsection solves for the optimal monetary policy under commitment. Because no endogenous state variable enters the model, the intertemporal policy problem reduces to a sequence of static optimization problems. Accordingly, the monetary authorities, who can manipulate inflation expectations, choose both planned inflation, π_t, and expected inflation, π_t^e, to minimize the asymmetric loss function (4) subject to the augmented Phillips curve (1) and to the additional constraint (2) imposed by the rational expectations hypothesis. The corresponding first order conditions are, respectively:

$$
\begin{aligned}
(\pi_t - \pi^*) + E_{t-1}\left\{\frac{\lambda\theta}{\gamma}\left[\exp\left(\gamma y_t\right) - 1\right] - \mu\right\} &= 0 \qquad (5)\\
-E_{t-1}\left\{\frac{\lambda\theta}{\gamma}\left[\exp\left(\gamma y_t\right) - 1\right]\right\} + \mu &= 0
\end{aligned}
$$

with μ being the Lagrange multiplier associated to the rational expectation constraint. Combining the optimality conditions to eliminate μ, and taking expectations of the resulting expression produce

$$E(\pi_t) = \pi^* \tag{6}$$

where we have used the law of iterated expectations to get rid of E_{t-1}. Equation (6) states that the planned inflation rate equals on average the socially desirable inflation rate and therefore it is independent of the output gap.

2.2 Discretion

If commitment is infeasible, the monetary authorities choose the inflation rate π_t at the beginning of the period after the private agents have formed their expectations but before the realization of the real shock u_t. Accordingly, the discretionary solution reads

$$(\pi_t - \pi^*) + E_{t-1}\left\{\frac{\lambda\theta}{\gamma}\left[\exp(\gamma y_t) - 1\right]\right\} = 0 \tag{7}$$

It is instructive at this point to compare the solution obtained under asymmetric preferences with the solution obtained under the standard quadratic case. Whenever γ tends to zero, it is possible to show using L'Hôpital's rule that the optimal monetary policy becomes

$$(\pi_t - \pi^*) = -\lambda\theta E_{t-1}(y_t) \tag{8}$$

This implies that under quadratic preferences there exists a one to one mapping between the inflation bias and the output gap conditional mean. Moreover, in the face of white noise supply disturbances (i.e. $\rho = 0$) the inflation bias is zero reflecting the notion of potential output targeting.

Turning back to equation (7), we notice that if the output gap is a zero mean, normally distributed process, then $\exp(\gamma y_t)$ is distributed log normal with mean $\exp\left(\frac{\gamma^2}{2}\sigma^2\right)$. It follows that by taking expectations of (7) and rearranging terms, it is possible to write the optimality condition as:

$$1 - \frac{\gamma}{\lambda\theta}E(\pi_t - \pi^*) = \exp\left(\frac{\gamma^2}{2}\sigma^2\right) \tag{9}$$

To compute the *average inflation bias*, we use a simple transformation of the model that confronts directly the time-inconsistency of monetary policy. This amounts to take logs of both side of (9) and gives the following expression:

$$E(\pi_t) \simeq \pi^* - \frac{\lambda\theta\gamma}{2}\sigma^2 \tag{10}$$

A comparison between the expected rates under commitment (6) and under discretion (10) illustrates the source of a novel *average inflation bias*. The time-inconsistency of monetary policy arises here because policy preferences are asymmetric rather than because the desired level of output is above potential like in the Barro-Gordon model. As the private sector correctly anticipates the monetary authorities' incentive to respond more aggressively to output contractions than to output expansions (i.e. $\gamma < 0$), the inflation rate exceeds the first-best solution attainable under commitment. Hence, policy makers end up generating a systematic boost in inflation expectations, which is higher the larger and the more asymmetric the policy preference on output stabilization is.

Possible improvements to the discretionary solution would require the appointment of either a more conservative central banker, who is one endowed with a lower relative weight λ in the spirit of Rogoff (1985) and/or a lower inflation target than society, or a more symmetric policy maker, who is one endowed with a smaller absolute value of γ. Lastly, the average inflation bias is proportional to the variance of the output gap as the marginal benefit of an inflation surprise in (7) is convex in the output gap. When γ goes to zero as it does in equation (8), such a marginal benefit becomes linear and the *average* inflation bias disappears together with the precautionary motive.

3 The evidence

This section investigates the empirical merits of the asymmetric preference model to account for the behavior of postwar US inflation. The analysis spans the period 1960:1-2002:3 and it is conducted on quarterly, seasonally adjusted data that have been obtained in February 2003 from the web site of the Federal Reserve Bank of St. Louis. Inflation is measured as the annualized change in the log GDP chain-weighted price index, whereas the output gap is constructed as the difference between the log real GDP and the log real potential output provided by the Congressional Budget Office.

To make our results comparable with those reported by Ruge-Murcia (2003), we first consider the whole sample. Then, we use our identification strategy to estimate the asymmetric preference and to obtain a measure of the inflation bias for both the pre- and the post-Volcker regimes. We also address the issue of sub-sample stability by re-estimating the model over Greenspan's tenure, which begins in the third quarter of 1987. Indeed, equation (10) makes it clear that the inflation bias is a function of policy makers' preferences and therefore it can only be interpreted as regime-specific. To the extent that a significant break has occurred in the conduct of US monetary policy during the last forty years, our identification scheme provides a sharper evaluation of the model by measuring the time-inconsistency across the two eras.

3.1 Preliminary analysis

As a way to provide a preliminary evidence before turning to the estimates of the nonlinear optimal monetary policy (7), we evaluate the performance of the symmetric quadratic paradigm upon the behavior of the inflation bias that this specification predicts. According to equation (8), the conditional mean of the output gap is informative about the difference between the realized inflation and the inflation target. In particular, in the face of i.i.d. supply shocks the conditional mean and therefore the inflation bias should be zero reflecting the notion of quadratic preferences and potential output targeting.

Figure 1 displays the kernel estimates of the output gap conditional mean (with the sign switched) over the full sample using the Nadaraya-Watson estimator, a second order Gaussian kernel and the likelihood cross validation procedure to obtain a value for the fixed bandwidth parameter. The results are unaffected by using the least squares cross validation criterion and an higher-order kernel. Before proceeding however it is important to stress what we are not doing in this exercise. In particular, we are not using the output gap as the dependent variable while estimating the optimality condition (8). Rather, we are computing from the bivariate time-series model for inflation and output the conditional mean of the output gap, which according to the model of quadratic preferences and potential output targeting is the measure of the inflation bias at each point in time.

A number of interesting results emerge from Figure 1. First, the third quarter of 1982 appears to witness the beginning of a new era as represented by the intersection between the lower bound of the 95% confidence interval and the zero line. This is consistent with the conventional wisdom that a regime-switch in the conduct of US monetary policy has occurred at the beginning of the 1980s, especially with the end of the so-called 'Volcker experiment' of non-borrowed reserves targeting that Bernanke and Mihov (1998) date in 1982:3. Moreover, the measure of the inflation bias is not statistically significant only during the last two decades, implying that the model of quadratic preferences and potential output targeting is rejected by the data over the earlier regime. Although part of the difference may be due to a change in the persistence of the supply shocks, during the first half of the sample the output gap conditional mean and hence the inflation bias appears to be *on average* statistically different from zero. This finding proves inconsistent with a quadratic preference model and therefore calls for an extension of the theory.

3.2 The reduced-form

The parameter γ and the exponential function in (7) govern the asymmetric response of the policy rate to positive and negative deviations of output from potential. Our task is to estimate a nonlinear reaction function in order to evaluate whether the asymmetric preference is significantly different from zero. This amounts to test linearity against a nonlinear specification, which is complicated by the fact that it is not possible to recover all structural parameters of the model from the reduced-form estimates. To overcome the issue and identify both γ and the inflation bias, we take a simple transformation of the model. This involves the linearization of the exponential terms in (7) by means of a first-order Taylor series expansion, and produces:

$$(\pi_t - \pi^*) + \lambda\theta E_{t-1}(y_t) + \frac{\lambda\theta\gamma}{2} E_{t-1}\left(y_t^2\right) + e_t = 0 \tag{11}$$

with e_t being the remainder of the approximation.

This condition relates the inflation rate to the expected values of the level and the squared of the output gap conditional upon the information available at time $t-1$. We solve equation (11) for π_t and prior to estimation we replace expected output gaps with actual values. The empirical version of the feedback rule is given by:

$$\pi_t = \pi^* + \alpha y_t + \beta y_t^2 + v_t \tag{12}$$

which is linear in the coefficients

$$\alpha = -\lambda\theta \quad \text{and} \quad \beta = -\frac{\lambda\theta\gamma}{2}$$

and whose error term is defined as

$$v_t \equiv -\left\{\alpha\left(y_t - E_{t-1}y_t\right) + \beta\left[y_t^2 - E_{t-1}\left(y_t^2\right)\right] + e_t\right\}$$

Under the null of quadratic preferences, the term in curly brackets is a linear combination of forecast errors and therefore v_t is orthogonal to any variable in the information set available at time $t-1$.

Equation (12) reveals that by assuming an optimizing central bank behavior the reaction function parameters can only be interpreted as convolutions of the coefficients representing policy makers' preferences and those describing the structure of the economy. Nevertheless, the reduced-form parameters allow now to recover both the asymmetric preferences, $\gamma = 2\beta/\alpha$, and the average inflation bias that results from the difference between equations (6) and (10), namely $\beta\sigma^2$.

3.3 Empirical results

To the extent that the penalty associated to an output contraction is larger than the penalty associated to an output expansion of the same magnitude, the model predicts $\gamma < 0$, $\alpha < 0$ (since λ, $\theta > 0$), and $\beta > 0$. When coupled with the expectations-augmented Phillips curve (1), this implies that the central bank faces an incentive to surprise inflation in an effort to hedge against the occurrence of an economic downturn. Put it differently, the asymmetric preference on output generates a precautionary demand for expansions as the model predicts a positive relation between average inflation and the variance of the output gap.

The orthogonality conditions implied by the rational expectation hypothesis makes the Generalized Method of Moments (GMM) a natural candidate to estimate equation (12). This has also the advantage that no arbitrary restrictions need to be imposed on the information set that private agents use to form expectations. To control for possible heteroskedasticity and serial correlation in the error terms we use the optimal weighting scheme in Hansen (1982) with a four lag Newey-West estimate of the covariance matrix. Three lags of inflation, output gap and squared output gap are used as instruments corresponding to a set of 7 overidentifying restrictions that can be tested for. The choice of a relatively small number of instruments is meant to minimize the potential small sample bias that may arise when too many overidentifying restrictions are imposed. We also check the robustness of our results to changes in the instrument set. In particular, we re-estimate the model using five lags of inflation and two lags of output gap and squared output gap. The F-test applied to the first stage regressions, which Staiger and Stock (1997) argue to be important in evaluating the relevance of the instruments, always rejects the null of weak correlation between the endogenous regressors and the variables in the instrument sets.

Table 2 reports the estimates of the feedback rule (12) for the whole sample. Each row corresponds to a different set of instruments. The parameter on the output gap, α, is not statistically different from zero whereas the parameter on the squared output gap, β, is significant and positive. The estimates of the slope coefficients as well as the estimates of the inflation target are robust to the instrument selection and the hypothesis of valid overidentifying restrictions is never rejected. These results are similar to those reported by Ruge-Murcia (2003) and Surico (2002) as they confirm the presence of asymmetric preference using a different method of estimation and a different measure of real activity.

Table 3 reports the estimates for the pre- and post-Volcker regimes. We remove from the second sub-sample the period 1979:3-1982:3 when the temporary switch in the Fed operating procedure documented by Bernanke and Mihov (1998) appears to be responsible for the failure to gain control over inflation. The sample selection is also consistent with the nonparametric evidence reported in the preliminary analysis.

The first two rows of Table 3 refer to the pre-Volcker era and show large negative values for the level of the output gap besides to positive and significant parameters for its squared.

The point estimates of the inflation target range from 3.42% to 3.69% while the asymmetric preference parameter is negative and statistically significant. These results sharply contrast with the post-1979 values that are displayed in the middle rows and the bottom rows of Table 3. Indeed, not only the inflation target statistically declines to values around 2%, but also the impact of the output gap level on inflation appears to be weaker, although still significant. To the extent that the structure of the economy has remained stable during the last forty years, a smaller value of α can only be rationalized by a decline in λ, which corresponds to a more conservative monetary policy stance. Nevertheless, the most dramatic difference between the two regimes emerges on the squared output gap, which loses any explanatory power for both set of instruments as well as for both post-1979 samples. This translates into values of the policy parameter γ that are not statistically different from zero.

Turning to the measure of the asymmetric preference induced time-inconsistency, Table 4 reports the estimates of the average inflation bias. According to equation (10), this is a convolution of the structural parameters of the model and the variance of the output gap. Given the decline in the latter reported in the second column of Table 1, we would expect also the inflation bias to decline moving from the pre- to the post-Volcker period. This seems consistent with the change in the volatility of the supply shocks documented by Hamilton (1996) between the 1970s and the 1980s.

The first column of Table 4 shows the measure of the average inflation bias implied by the reduced-form estimates of Table 3. The first block reports the pre-Volcker values whose point estimates range from 1.01% in the baseline case to 1.36% for the alternative instrument set. By contrast, the inflation bias is found to be not statistically different from zero over the post-1979 era, reflecting the fact that US monetary policy can be characterized by a nonlinear feedback rule during the former but not during the latter period. Empirical support for this form of regime shift can also be found in the cross-country evidence reported by Cukierman and Gerlach (2002).

Lastly, while the realized inflation mean over the pre-1979 sample falls in the range of estimates implied by the sum of the inflation target and the inflation bias, its post-Volcker counterparts appear to be higher than the model predicts. This suggests that while the theory can effectively decompose the observed inflation mean into a measure of the target and a measure of the bias over the pre-1979 regime, it needs to be extended to account more fully for the gap that appears in the data over the last two decades.

4 Concluding remarks

This paper develops a method to measure the time-inconsistency of monetary policy when the preferences of the central bank are asymmetric. As demonstrated by Cukierman (2002), if policy makers are more concerned about output contractions than output expansions, an inflation bias can emerge *on average* even though the level of output is targeted at potential. In addition, both casual observations and formal empirical analyses challenge the predictions of the Barro-Gordon model by arguing that the Fed's desired level of output does not exceed the natural rate (see Blinder, 1998, and Ruge-Murcia, 2003).

Using a model of asymmetric preferences and potential output targeting, it is shown how the observed inflation mean can be successfully decomposed into a target and a bias argument. When applied to postwar US data, our identification method indicates that the target is 3.42% and the bias 1.01% during the pre-1979 policy regime. By contrast, over the last two decades the inflation target declines to 1.96% while the average inflation bias tends to disappear. This result can be rationalized by the fact that the policy preference on output stabilization is found to be large and asymmetric before but not after the appointment of Paul Volcker as Fed Chairman. Although other factors such as a better policy making and more favorable supply shocks are also likely to have played a role, this paper provides empirical support and quantitative measures of a new, additional explanation for the behavior of US inflation during the postwar period.

While suggestive, the results reported in this paper are based on a simple model, and specifying a richer structure of the economy is likely to produce also a state-contingent bias as well as a stabilization bias. However, as shown by Svensson (1997) and Cukierman (2002), the average inflation bias is then larger than it would be with a conventional expectations-augmented Phillips curve. This suggests not only that our estimates are better interpreted as a lower bound but also that a richer specification of the private agents' behavior may account for the gap between the model-based and the average inflation realized over the last two decades. Given our limited knowledge of the channel(s) through which the time-consistency problem affects policy outcomes, measuring and disentangling the inflation bias remains a challenging topic for future research.

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Table 1: Descriptive Statistics

Sample	*Inflation mean*	*Output gap standard deviation*
1960 – 2002	3.78	2.61
1960 – 1982	4.87	3.03
1983 - 2002	2.51	1.98

US quarterly data. Inflation is measured as changes in the GDP chain-type price index and output gap is obtained from the CBO.

Table 2: Reaction Function and Policy Preference Estimates

- full sample -

Instruments	p*	*a*	*b*	*p-values*
Sample 1960:1 2002:3				
(1)	2.34**	0.09	0.04**	*F-stat: .00/.00*
	(0.24)	(0.11)	(0.01)	*J(7): .13*
(2)	2.33**	0.10	0.04**	*F-stat: .00/.00*
	(0.24)	(0.12)	(0.02)	*J(7): .14*

Specification: $p_t = p^* + ay_t + by_t^2 + v_t$

Standard errors using a four lag Newey-West covariance matrix are reported in brackets. Inflation is measured as changes in the GDP chain-type price index and output gap is obtained from the CBO. The instrument set (1) includes a constant, three lags of inflation, output gap and squared output gap. The instrument set (2) includes a constant, five lags of inflation, and two lags of output gap and squared output gap. F-stat refers to the statistics of the hypothesis testing for weak instruments relative to output gap and squared output gap, respectively. J(*m*) refers to the statistics of Hansen's test for *m* overidentifying restrictions which is distributed as a $\chi^2(m)$ under the null hypothesis of valid overidentifying restrictions. The superscript ** and * denote the rejection of the null hypothesis that the true coefficient is zero at the 5 percent and 10 percent significance levels, respectively.

Table 3: Reaction Function and Policy Preference Estimates

- sub samples -

Instruments	*p**	*a*	*b*	*g*	*p-values*
Sample 1960:1-1979:2					
(1)	3.42**	-0.63**	0.14**	-0.46**	*F-stat: .00/.00*
	(0.58)	(0.19)	(0.06)	(0.15)	*J(7): .35*
(2)	3.69**	-0.84**	0.19**	-0.46**	*F-stat: .00/.00*
	(0.67)	(0.27)	(0.08)	(0.13)	*J(7): .37*
Sample 1982:4-2002:3					
(1)	1.96**	-0.18**	0.01	-0.07	*F-stat: .00/.00*
	(0.13)	(0.08)	(0.01)	(0.17)	*J(7): .51*
(2)	1.94**	-0.16*	0.01	-0.10	*F-stat: .00/.00*
	(0.14)	(0.09)	(0.02)	(0.24)	*J(7): .47*
Sample 1987:3-2002:3					
(1)	1.76**	-0.13**	0.04	-0.79	*F-stat: .00/.00*
	(0.19)	(0.06)	(0.04)	(0.83)	*J(7): .73*
(2)	1.96**	-0.17**	-0.01	-0.03	*F-stat: .00/.00*
	(0.18)	(0.08)	(0.04)	(0.49)	*J(7): .38*

Specification: $p_t = p^* + ay_t + by_t^2 + v_t$

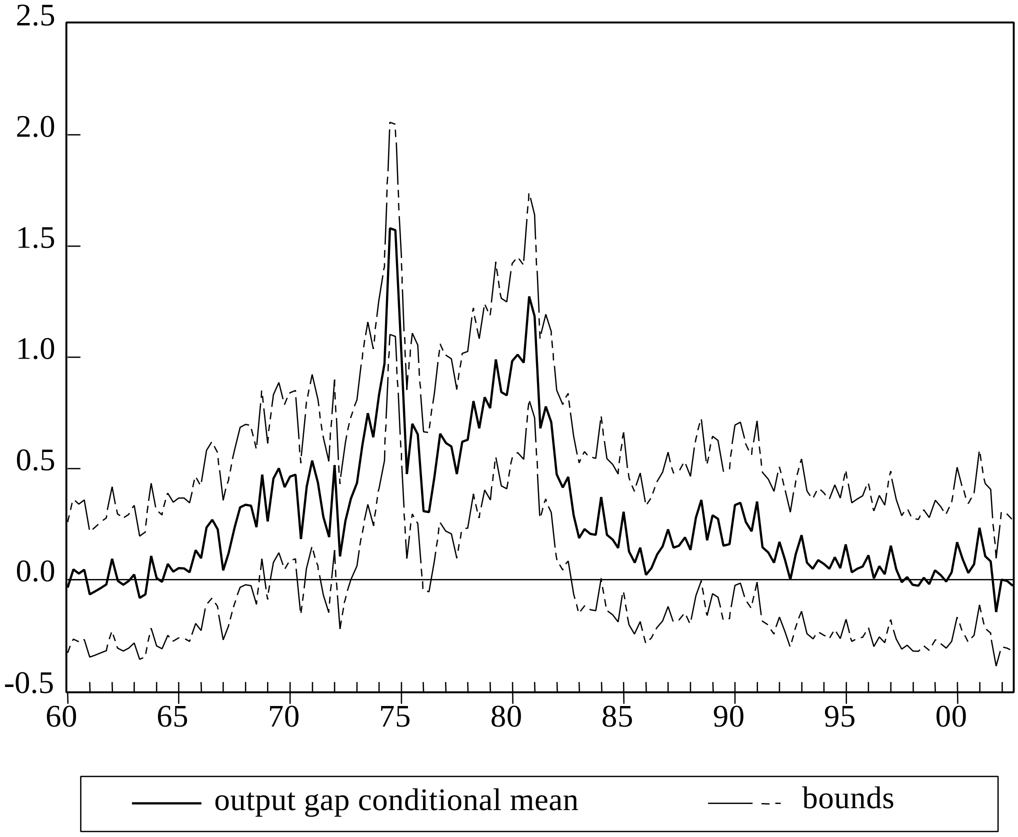
Standard errors using a four lag Newey-West covariance matrix are reported in brackets. Inflation is measured as changes in the GDP chain-type price index and output gap is obtained from the CBO. The instrument set (1) includes a constant, three lags of inflation, output gap and squared output gap. The instrument set (2) includes a constant, five lags of inflation, and two lags of output gap and squared output gap. F-stat refers to the statistics of the hypothesis testing for weak instruments relative to output gap and squared output gap, respectively. J(*m*) refers to the statistics of Hansen's test for *m* overidentifying restrictions which is distributed as a $\chi^2(m)$ under the null hypothesis of valid overidentifying restrictions. The superscript ** and * denote the rejection of the null hypothesis that the true coefficient is zero at the 5 percent and 10 percent significance levels, respectively.

Table 4: The Average Inflation Bias

Instruments	***Inflation Bias***	*Inflation Target*	*Inflation Bias + Inflation Target*	*Inflation Mean*
Sample 1960:1-1979:2				4.39
(1)	1.01**	3.42**	4.43**	
	(0.39)	(0.58)	(0.52)	
(2)	1.36**	3.69**	5.05**	
	(0.54)	(0.57)	(0.68)	
Sample 1982:4-2002:3				2.53
(1)	0.03	1.96**	1.99**	
	(0.06)	(0.13)	(0.14)	
(2)	0.04	1.94**	1.98**	
	(0.07)	(0.14)	(0.14)	
Sample 1987:3-2002:3				2.36
(1)	0.16	1.76**	1.92**	
	(0.11)	(0.19)	(0.12)	
(2)	-0.01	1.96**	1.95**	
	(0.13)	(0.18)	(0.13)	

Standard errors in parenthesis. The instrument set (1) includes a constant, three lags of inflation, output gap and squared output gap. The instrument set (2) includes a constant, five lags of inflation, and two lags of output gap and squared output gap. The superscript ** and * denote the rejection of the null hypothesis that the true coefficient is zero at the 5 percent and 10 percent significance levels, respectively. The inflation bias is computed as $b s^2$.

Figure 1: The Evolution of the Inflation Bias over Time



Sample: 1960:1 – 2002:3, US quarterly data. Inflation is measured as changes in the GDP chain-type price index and output gap is obtained from the CBO. The kernel estimates of the output gap conditional mean on inflation are obtained using the Nadaraya-Watson method, a second order Gaussian kernel and the likelihood cross validation procedure to get a value for the fixed bandwidth parameter. Dashed lines represent upper and lower bounds of the 95% confidence interval.