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ABSTRACT

A Quantitative Exploration of the Opportunistic Approach to Disinflation*

This Paper explores the quantitative implications of an approach to monetary policy that gained prominence in the United States during the 1990s. Proponents of this approach recommend that, when inflation is moderate but still above the long-run objective, the central bank should not move immediately to fight inflation, but rather wait for exogenous circumstances — such as favourable supply shocks and unforeseen recessions — to deliver the desired reduction in inflation. While waiting for such circumstances the central bank should counteract any incipient increases in inflation. This approach has come to be known as 'the opportunistic approach to disinflation'. The implied policy rule is non-linear and path-dependent. This Paper compares the behaviour of inflation and output under opportunistic and conventional linear policy. Using stochastic simulations of a small-scale rational expectations model, we study the cost and time required to achieve a given disinflation, as well as the stochastic steady-state distributions of inflation and output under opportunistic versus linear policy rules.

JEL Classification: E31, E52, E58 and E61
Keywords: disinflation, inflation targeting, interest rates, monetary policy and policy rules

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1 Introduction

The conventional view regarding the appropriate conduct of monetary policy implies that the central bank should balance the objective of achieving and maintaining low inflation against the objective of stabilizing real activity around its sustainable level, and that the marginal tradeoff between the two objectives should be roughly linear. Such an approach to monetary policy is consistent with a loss function that penalizes squared deviations of inflation from the central bank's long-run target and squared deviations of output from its natural level; this type of loss function has been studied extensively (see for example the studies in Taylor(1999)). Furthermore, this loss function coincides with a quadratic approximation of the welfare of the representative household in a simple New-Keynesian model as discussed by Rotemberg and Woodford (1997) and Goodfriend and King (1997).

This paper contrasts the conventional linear approach to monetary policy with an alternative approach that has become known as the "opportunistic approach to disinflation." Proponents of this approach argue that when inflation is moderate but still above the long-run objective, the central bank should abstain from policy actions directed at fighting inflation and instead wait for exogenous circumstances—such as favorable supply shocks and unforeseen recessions—to deliver the desired reduction in inflation.[1] While waiting for such circumstances the central bank should focus on stabilizing output and employment and if necessary take action to avoid incipient increases in inflation. Once disinflation has occured due to exogenous events, the central bank should consolidate the gains and stay ready to counteract the return of inflation to past levels.[2]

[1] Arguments in favor of the opportunistic approach to monetary policy have been presented by former policymakers, including the former president of the Philadelphia Federal Reserve Bank, Edward Boehne, the former Vice-Chair of the Board of Governors, Alan Blinder and former Governor Lawrence Meyer. This approach has never been adopted as an official strategy of the Federal Open Market Committee (FOMC), but the Committee members have discussed their views regarding it at FOMC meetings. (See, in particular, the discussions at the December 1995, July 1996 and July 1997 meetings. Transcripts of these meetings are in the public domain.) See also Orphanides and Wilcox (2002) for additional references to policy discussions on this issue.

[2] See Kohn (1996) for a discussion of the U.S. disinflation experience since 1979 along these lines. These features of the opportunistic approach also led observers during the mid-1990s to remark that the U.S. economy was "one recession away" from price stability (e.g. Meyer 1996, Blinder, 1997).

Recently, Orphanides and Wilcox (2002) have developed a theoretical foundation for the opportunistic approach to monetary policy. Using a simple two-equation model with adaptive expectations, they show that the opportunistic approach is optimal under a loss function that penalizes squared deviations of inflation from a *history-dependent intermediate target* and *absolute* deviations of output from its natural level.[3] Balancing squared deviations of inflation against absolute deviations of output on the margin motivates the non-linear interest rate response to inflation implied by the opportunistic approach to disinflation. The history-dependent intermediate target introduces a path-dependence of interest rate responses to inflation. Orphanides and Wilcox derive optimal interest rate rules under the opportunistic and the conventional loss functions. In their model, the optimal linear policy is of the same form as Taylor's (1993a) rule.

In this paper we study the quantitative implications of opportunistic versus conventional policy in an empirical model of the U.S. economy with rational expectations and nominal rigidities due to staggered wage contracts. First, we compute benchmark opportunistic and linear policy rules by optimizing the coefficients of the rules provided by Orphanides and Wilcox to our more realistic macroeconomic model. In doing so we utilize the opportunistic and quadratic loss functions. Then, we proceed to evaluate the performance of these benchmark rules in a stochastic setting. We show that the opportunistic "wait and see" approach to disinflation that relies on favorable exogenous circumstances effectively achieves disinflation over time at a lower cost in terms of output losses than the conventional approach. Furthermore, we present evidence regarding the output and inflation distributions that will obtain over time if the central bank pursues an opportunistic policy rather than a linear Taylor-style rule.

Clearly, the opportunistic approach to disinflation is of quantitative relevance as an explanatory hypothesis regarding the past disinflation experience of the United States. It

[3]They also indicate potential microeconomic foundations for the absolute value of the output gap in the loss function. Using the fact that for much of the workforce employment is an all-or-nothing decision they illustrate that the concentration of unemployment provides a basis for treating small deviations of output from potential as imposing first-order costs on the policymaker in contrast to small deviations of inflation from target.

is also of potential importance for other countries that are in the process of disinflation. Finally, if U.S. monetary policymakers pursue an opportunistic conduct of policy in the current low-inflation environment, the stochastic steady-state distributions that we derive will be useful for evaluating current and future risks to inflation and output in the United States.

The remainder of this paper proceeds as follows. In section 2 we formally present the non-quadratic opportunistic loss function and the implied nonlinear, time-dependent interest rate rule. Section 3 describes the macroeconometric model that we use as a laboratory for our comparisons. In section 4 we present the derivation of our benchmark opportunistic and linear interest rate rules, we evaluate the disinflation performance of those rules and we compare stochastic steady-state distributions of output and inflation. Section 5 concludes. Further information on model solution techniques is given in the appendix of the paper.

2 The opportunistic approach to disinflation

The conventional quadratic loss function in per-period terms corresponds to:

$$L_C = (1-\gamma)(\pi-\pi^*)^2 + \gamma y^2, \qquad 0 < \gamma < 1 \tag{1}$$

It implies that the central bank cares exclusively about squared deviations of inflation, π, from its long-run target π^*, and about squared deviations, y_t^2, of output from potential. The parameter γ indicates the relative importance attached to output versus inflation stabilization. The key property of the quadratic loss function that we will focus on is that it implies a steady, deliberate pursuit of inflation stabilization whenever inflation is away from the central bank's long-run target. The reason is simply that the marginal tradeoff between inflation and output implied by a quadratic loss function is linear. As Orphanides and Wilcox (2002) show, the optimal interest rate rule in their simple two-equation model consisting of a linear Phillips curve and a linear aggregate demand equation takes the same form as Taylor's (1993a) rule:

$$i = r^* + \pi + \kappa_1(\pi - \pi^*) + \kappa_2 y \tag{2}$$

Here, i denotes the nominal federal funds rate (the monetary authority's policy instrument), r^* is the equilibrium short-term real interest rate (i.e. the short-term real interest rate consistent with output being at potential) and κ_1 and κ_2 are parameters governing the interest rate response to inflation and the output gap.[4] Equation (2) reflects the conventional view that both the inflation gap and the output gap should always have a non-zero marginal influence on the policy instrument.

In contrast to the conventional policymaker, whose objectives are well represented by the standard quadratic loss function, an opportunistic policymaker can be described by the following non-quadratic loss function:

$$L_O = (1-\gamma)(\pi - \tilde{\pi})^2 + \gamma|y| \quad (3)$$
$$\text{where } \tilde{\pi} = (1-\lambda)\pi^* + \lambda\pi^h$$

This loss function contains two important new elements, which combine to generate *path-dependence* and *non-linearity* in interest-rate setting.

First, the opportunistic loss function penalizes squared deviations of inflation from an intermediate target, $\tilde{\pi}$, which corresponds to the average of the long-run target π^* and inherited inflation π^h with a weight λ (we use h to denote "history"). We will comment further on the interpretation of inherited inflation shortly. The time-dependence of the intermediate target implies that as inflation moves down and towards the policymaker's ultimate objective, the opportunistic policymaker will actively defend the lowered inflation rate against regress to levels that were deemed acceptable in the past.

Secondly, the absolute value of the output gap $|y|$ imparts a nonlinearity to the marginal inflation-output tradeoff considered by the opportunistic policymaker. It implies that the marginal loss from a small output gap is of much greater importance to the central bank than the marginal loss due to a small deviation of inflation from its intermediate target. Thus, for some range of inflation deviations from the intermediate inflation target, output stabilization is the primary concern to the opportunistic policymaker. Larger deviations of

[4]Taylor's original values for the parameters were equal to 0.5, but the optimal values will be model-dependent. Taylor's values for r^* and π^* were 2 percent respectively.

inflation from the intermediate target, however, cause the policymaker to focus to inflation stabilization.

Orphanides and Wilcox (2002) show that, in their simple model, the optimal opportunistic interest rate rule takes the following form:

$$i_t = r^* + \pi + f(\pi - \tilde{\pi}) + \kappa_3 y \tag{4}$$

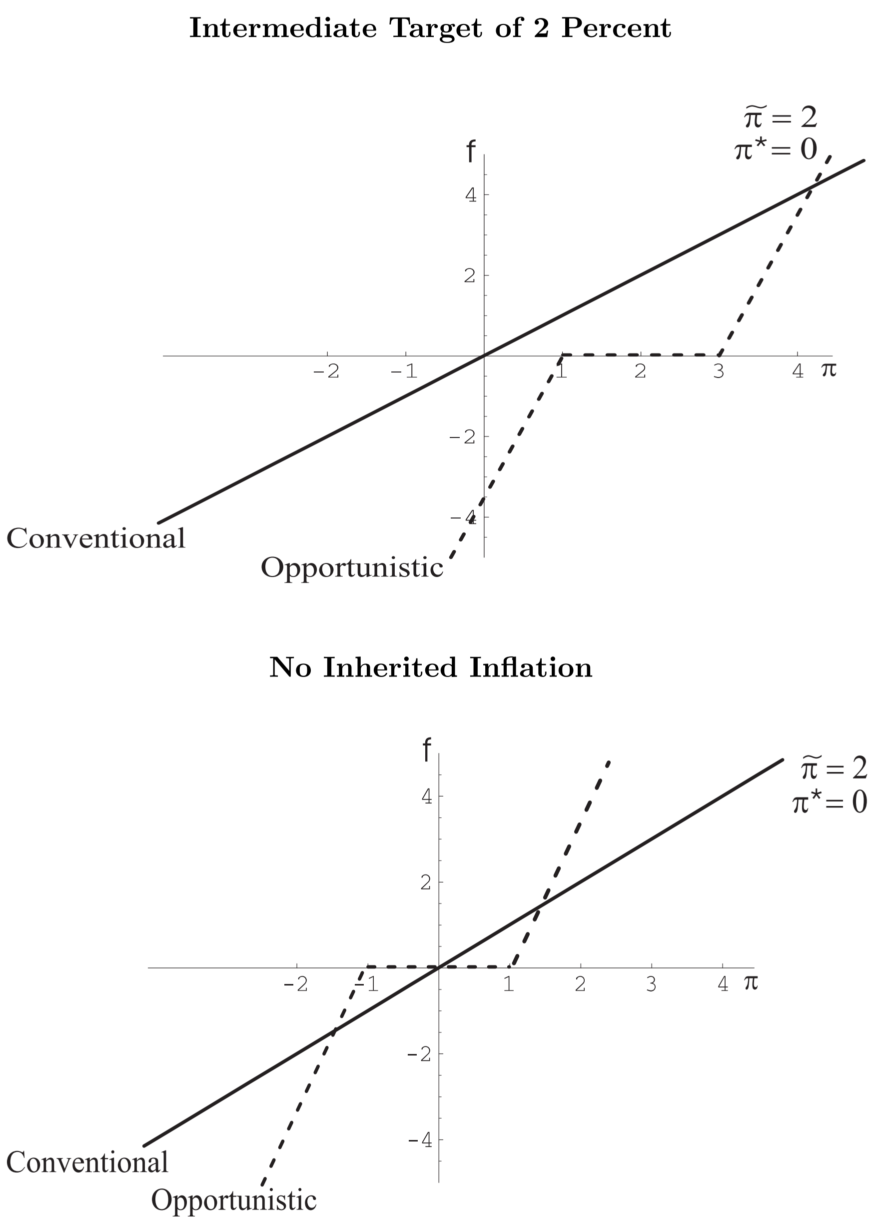
where $\tilde{\pi}_t$ as defined in equation (3), and

$$f(\pi - \tilde{\pi}) = \begin{cases} \kappa_4(\pi - \tilde{\pi} - \kappa_5) & \text{if } \pi - \tilde{\pi} > \kappa_5 \\ 0 & \text{if } \kappa_5 \geq \pi - \tilde{\pi} \geq -\kappa_5 \\ \kappa_4(\pi - \tilde{\pi} + \kappa_5) & \text{if } \pi - \tilde{\pi} < -\kappa_5 \end{cases}$$

The key characteristic of this rule is the nonlinear function f that depends on the parameters κ_4 and κ_5 and determines the nonlinearity of the policy response to inflation deviations from the intermediate target. **Figure 1** contrasts the inflation response implied by the opportunistic rule (dashed line) with the conventional linear inflation response (solid line).

The top panel in the figure shows the opportunistic inflation response with an intermediate inflation target of two percent and a long-run target of zero. The inflation response is characterized by a zone of inaction of plus or minus one percentage point around the intermediate target (i.e. $\kappa_5 = 1$.) As a result, the policymaker focuses exclusively on stabilizing output and abstains from anti-inflation action so long as the inflation rate is between 1 percent and 3 percent. However, if exogenous circumstances bring the inflation rate down, the zone of inaction shifts and the policymaker will move actively to avoid a return of inflation to the higher rates of the past. This change is apparent from the lower panel that compares the opportunistic and conventional responses when the inherited inflation rate is zero. In this case, the intermediate target equals the long-run target and the zone of inaction extends from -1 to $+1$ percent. If an inflationary shock were to push inflation again up to 3 percent, the policymaker would now counteract the incipient increase in inflation. Thus, the inflation response under the opportunistic rule is nonlinear and path-dependent. Henceforth we will refer to the zone of inaction also as the zone of opportunism.

Figure 1: Opportunistic and Conventional Policy Responses to Inflation



3 An empirical model of the U.S. economy with rational expectations and nominal rigidities

The small open-economy model that we use as a laboratory for comparing the opportunistic and conventional approaches incorporates forward-looking behavior by economic agents in labor markets, financial markets and goods markets.[5] Expectations of endogenous variables are formed rationally, and fully reflect the choice of monetary policy rule, and monetary policy has no long-run real effects. Monetary policy, however, still has temporary real effects due to the presence of staggered wage contracts which induce nominal rigidity. The policy instrument—that is, the nominal short-term interest rate—is set alternatively according to the linear and opportunistic policy rules presented in the preceding section. We will return to the exact specification and parameterization of those rules in the next section. Due to the nominal rigidity, monetary policy affects the real interest rate and the real exchange rate, and these factors in turn affect the various components of aggregate demand. Deviations of aggregate demand from potential output then have consequences for wage and price setting.

The model equations are summarized in **Table 1**. First, the long-term nominal rate, l_t, is related to expected future short-term rates via the term structure relationship in equation (5).[6] Then, the long-term real interest rate, r_t, is determined according to the Fisher equation (6), where p_t refers to the price level. The real exchange rate, s_t, depends on the differential between domestic and foreign real interest rates, consistent with uncovered interest rate parity (7). The tilde ' ˜ ' refers to foreign variables.

Aggregate demand is broken down into its major components: consumption, fixed investment, inventory investment, total government purchases and net exports, as indicated by equation (8). We scale each demand component by the level of potential output as estimated by the Congressional Budget Office (2002), and denote the result with lower-case letters. Normalized consumption, c_t, is modeled in equation (9) as a function of its own lagged value, permanent income and the expected long-term real interest rate. The lagged dependent variable is motivated by the possibility of habit persistence. Permanent income,

[5] Earlier versions of this model were used in Orphanides and Wieland (1998) and Levin, Wieland and Williams (1999, 2003). The model specification is broadly similar to the U.S. block of the multi-country model in Taylor (1993b).

[6] Rather than estimating the term structure explicitly, we rely on the accumulated forecasts of the short rate over the following 8 quarters which, under the expectations hypothesis, will coincide with the long rate forecast for this horizon. In defining the long rate in terms of the expectations hypothesis we deliberately avoid the added complexities that would be associated with modeling term and risk premia. Since our specification is invariant to the presence of a constant premium, we set it equal to zero for expositional simplicity.

Table 1: Model Equations

Interest and Exchange Rates		
Long-Term Nominal Rate	$l_t = \mathrm{E}_t \left[\frac{1}{8} \sum_{j=1}^{8} i_{t+j-1} \right]$	(5)
Long-Term Real Rate	$r_t = l_t - 4\,\mathrm{E}_t \left[\frac{1}{8} (p_{t+8} - p_t) \right]$	(6)
Real Exchange Rate	$s_t = \mathrm{E}_t [s_{t+1}] + 0.25\ (i_t - 4\,\mathrm{E}_t [p_{t+1} - p_t])$ $- 0.25\ (\tilde{i}_t - 4\,\mathrm{E}_t [\tilde{p}_{t+1} - \tilde{p}_t])$	(7)
Aggregate Demand Components		
Aggregate Demand	$y_t = c_t + f_t + n_t + e_t + g_t - 1$	(8)
Consumption	$c_t = \alpha_1\, c_{t-1} + \alpha_2\, \bar{y}_t + \alpha_3\, r_t + \epsilon_{c,t},$ where $\bar{y}_t = \frac{(1-.9)}{1-(.9)^9} \sum_{i=0}^{8} (.9)^i y_{t+i}$	(9)
Fixed Investment	$f_t = \sum_{i=1}^{2} \beta_i\, f_{t-i} + \beta_3\, \bar{y}_t + \epsilon_{f,t}$	(10)
Inventory Investment	$n_t = \sum_{i=1}^{3} \rho_i\, n_{t-i} + \sum_{i=1}^{3} \rho_{3+i}\, y_{t-i-1} + \epsilon_{n,t}$	(11)
Net Exports	$e_t = \delta_1 e_{t-1} + \delta_2 y_t + \delta_3 y_t^* + \delta_4 s_t + \epsilon_{e,t}$	(12)
Government Spending	$g_t = \chi_1 g_{t-1} + \epsilon_{g,t}$	(13)
Prices and Wages		
Price Level	$p_t = \sum_{i=0}^{3} \omega_i\, x_{t-i},$ where $\omega_i = .25 + (1.5 - i)\,\theta_1,\ \theta_1 \in (0, 1/6]$	(14)
Contract Wage	$x_t = \mathrm{E}_t \left[\sum_{i=0}^{3} \omega_i\, p_{t+i} + \theta_2 \sum_{i=0}^{3} \omega_i\, y_{t+i} \right] + \epsilon_{x,t},$ where $v_t = \sum_{i=0}^{3} \omega_i\, (x_{t-i} - p_{t-i})$	(15)

Notes: l: long-term nominal interest rate; i : short-term nominal interest rate; r: ex-ante long-term real interest rate; p: aggregate price level; s: real exchange rate; y: output gap; c: consumption; f: fixed investment; n: inventory investment; e: net exports; g: government spending; $\bar{y}$: permanent income; $\epsilon_{(\cdot)}$: random white-noise shocks; x: nominal contract wage; v: real contract wage index; a '*' indicates foreign variables.

$\bar{y}_t$, is modeled as the annuity value of expected income in the current and next eight periods. Fixed investment, f_t, depends on two lags of itself and permanent income as a proxy for expected future sales, (equation (10)), while inventory investment, n_t, instead is (nearly) of the accelerator type (equation (11)). Net exports, e_t, depend on the level of income at home and abroad, and on the real exchange rate. Finally, government spending, g_t, follows a simple autoregressive process with a near-unit root (equation (13)).

As to the short-run supply side of the model, we follow Fuhrer and Moore (1995a,b) rather than Taylor (1980) in modeling staggered wages and prices. Fuhrer and Moore (1995a,b) assume that workers and firms set the real wage in the first period of each new contract with an eye toward the real wage agreed upon in contracts signed in the recent past and expected to be signed in the near future.[7] As Fuhrer and Moore show, models specified in this manner exhibit a greater and hence more realistic degree of inflation persistence than do models in which workers and firms care about relative wages in nominal terms. Equation (14) indicates that the price level is related to the weighted average of wages on contracts that are currently in effect assuming a constant markup. Equation (15) specifies that the real wage under contracts signed in the current period, $x_t - p_t$, is set in reference to a centered moving average of initial-period real wages established under contracts signed as many as three quarters earlier as well as contracts to be signed as many as three quarters ahead. Furthermore, the negotiated real wage is assumed to depend also on expected excess-demand conditions. Once contracts are signed, they remain in force for up to four quarters.

In the deterministic steady state of this model output is at potential, the long-term real interest rate and the real exchange rate equal to their equilibrium values, and the steady-state shares of the demand components are constant. The steady-state value of inflation is determined exclusively by the inflation target in the policy rule, because the wage-price block does not impose any restriction on the steady-state inflation rate.

[7] By contrast, Taylor (1980) assumed that workers and firms set the *nominal* wage in the first period of each new contract with an eye toward the *nominal* wage settlements of recently signed and soon-to-be signed contracts.

Table 2: Parameter Estimates

Consumption[a]:	α_1	α_2	α_3			
	0.636 (0.046)	0.297 (0.040)	-0.075 (0.015)			
Fixed Investment[a]:	β_1	β_2	β_3			
	1.394 (0.041)	-0.458 (0.042)	0.046 (0.010)			
Inventory Investment[a]:	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6
	0.388 (0.057)	0.022 (0.040)	0.138 (0.073)	0.332 (0.052)	-0.118 (0.079)	-0.165 (0.040)
Net Exports[a]:	δ_1	δ_2	δ_3	δ_4		
	0.910 (0.043)	-0.026 (0.020)	0.054 (0.012)	-0.006 (0.002)		
Government Spending[a]:	χ_1					
	0.959 (0.015)					
Fuhrer-Moore Contracts[b]:	θ_1	θ_2				
	0.0803	0.0055				

Notes: [a] Instrumental variables estimates. Standard errors in parentheses. [b] Estimates from Fuhrer (1997).

The model allows for inflation and output persistence. While the presence of these lags is not explicitly derived from optimizing behavior of representative agents, they are consistent with the presence of habit persistence in consumption, adjustment costs in investment, and overlapping wage contracts. The advantage of such a model is that it can fit empirical inflation and output dynamics for the U.S. economy up to a set of white-noise structural shocks.[8]

The parameter estimates of the model are reported in **Table 2**. We have estimated the demand side equations on an equation-by-equation basis using the Generalized Method of Moments applied to quarterly data from 1980 to 2000. As to the supply side, we have used the estimates obtained by Fuhrer (1997). The individual equations fit the data well. In addition we have evaluated the fit of the model imposing the cross-equation restrictions due to rational, model-consistent expectations and found that it forecasts within-sample movements of inflation and output quite well. Thus, the model captures the degree of persistence in output and inflation that is observed in the data. The historical series of structural shocks, which we compute based on model-consistent expectations, do not exhibit serial correlation.

4 Quantitative implications of the opportunistic approach to disinflation

Calibrating benchmark policy rules

Before proceeding to study disinflations under the opportunistic and conventional linear policy rules presented in section 2, we need to calibrate the parameters of those rules so as to obtain two benchmark specifications for comparison. We choose parameter values that are optimal in a well-defined sense within our model under the conventional quadratic and opportunistic loss functions discussed by Orphanides and Wilcox (2002). To be sure, any parameterization obtained in their simple backward-looking model would not be fully optimal in the larger empirical model with a much greater number of state variables that we consider in this paper. In particular, policy rules that are fully optimal in our model would respond to all the observable state variables. However, recent research on robust monetary policy rules in a variety of models (including an earlier version of this model) suggests that

[8] An alternative approach, followed by Rotemberg and Woodford (1997) and others, is to estimate a model based on optimizing behavior by representative agents but introduce serially correlated shocks in order to achieve empirical fit. See Estrella and Fuhrer (2000) for a critique of that approach. Under either modeling approach, the degree of output and inflation persistence is important for the analysis of monetary policy.

optimized simple rules that respond to a few key variables tend to be substantially more robust to model uncertainty than complicated fully optimal rules that are fine-tuned to a specific model (cf. the studies in Taylor (1999), in particular Levin, Wieland and Williams (1999), and Levin, Wieland and Williams (2003).[9] For this reason, we focus on the rules in section 2, which contain only two state variables, namely inflation and the output gap, and optimize their response parameters $(\kappa_1, \kappa_2, \kappa_3, \kappa_4)$ with respect to the quadratic and opportunistic loss functions.

In deriving the optimized linear Taylor-style rule we use the methodology described in Levin, Wieland and Williams (1999). This methodology is applicable to linear models of the economy combined with a conventional quadratic loss function. It involves searching for the values of the two response coefficients κ_1 and κ_2 in equation (2) that minimize the quadratic loss function (1) for a given value of the preference parameter γ, while keeping interest volatility the same as under Taylor's original rule with response coefficients of 0.5.[10] For a preference weight γ of 0.5 on output versus inflation variability we find that the optimal response coefficients on inflation and the output gap in a Taylor-style rule are $\kappa_1 = 0.73$ and $\kappa_2 = 0.42$ respectively.[11] In the following we will use this rule as our benchmark policy for conventional disinflations.[12]

Unfortunately, these methods do not apply in non-linear models and cannot be used to optimize the parameters of the opportunistic rule. Instead, to obtain a benchmark

[9] The earlier version of our model is listed as the MSR model in these studies.

[10] We compute the unique stationary rational expectations solution of the linear model using the Anderson and Moore (1985) implementation of the Blanchard and Kahn (1980) method, modified to take advantage of sparse matrix functions. Unconditional moments of output and inflation are computed using the doubling algorithm described in Hansen and Sargent (1997), also modified to take advantage of sparse matrix functions. Following the recent literature on monetary policy rules, cf. Taylor (1999), we compare unconditional losses rather than the discounted sum of per-period losses. Thus, in the quadratic case, the loss function can be re-written in terms of the unconditional variances of output and inflation, $(1-\gamma)\mathrm{Var}(\pi - \pi^*) + \gamma \mathrm{Var}(y)$. In the opportunistic case, the reference points are the unconditional variance of inflation deviations from the intermediate target and the mean absolute deviation of output from potential.

[11] For alternative values of γ between 0 and 1 the inflation and output response coefficients vary from 0.6 to 0.9 and 0.1 to 0.5 respectively.

[12] Note also that we have operationalized this rule for use with quarterly data by assuming that the policymaker reacts to the lagged output gap (y_{t-1}) and the lagged four-quarter inflation rate $(\pi_{t-1} \equiv p_{t-1} - p_{t-5}$, where p denotes the log of the price level). We implement the benchmark opportunistic rule in the same manner. In all our simulations, we also set $\pi^* = 0$ and abstract from issues relating to the zero bound on nominal interest rates (cf. Orphanides and Wieland (1998)).

opportunistic rule. we apply a computationally more intensive and cumbersome approach. The opportunistic rule defined by equation (5) has four key parameters. These include the response coefficient on the output gap, κ_3, the slope coefficient on the inflation deviation from the intermediate inflation target outside the zone of inaction, κ_4, the width of the same zone of inaction, κ_5, and the weight on inherited inflation versus the long-run inflation target, λ.[13] In the following we will keep the width of the zone of inaction fixed at 2% centered on the intermediate inflation target (i.e. $\kappa_5 = 1$) and we will consider a weight on inherited inflation of $\lambda = 1/2$.[14] Inherited inflation will be defined as the lagged two-year moving average of the quarterly inflation rate. We then proceed to consider a grid of possible values for the response coefficients on output and inflation, κ_3 and κ_4. For any given choice of coefficients we run 1000 stochastic simulations, each 100 periods in length, using the solution algorithm for nonlinear rational expectations models discussed in the appendix. Initial conditions are set to the deterministic steady state. We then compute the value of the opportunistic loss function based on those observations and select those response coefficients that minimize the opportunistic loss. With regard to the grid of possible values of κ_3 and κ_4, we start from the coefficients of the original Taylor rule (0.5 each) and increase both successively in steps of 0.5. Intuitively, a good opportunistic rule should be fairly aggressive on inflation outside the zone of inaction and it should imply a proactive response to output deviations from target. Based on this grid search we select response coefficients for the opportunistic rule of $\kappa_3 = 1.5$ and $\kappa_4 = 2$.[15]

A cross-comparison of the losses realized under the benchmark linear rule and the benchmark nonlinear rule selected in the manner described above is reported in **Table 3**. As can

[13]For the numerical analysis we use the following smooth continuously-differentiable approximation to the nonlinear function f in the opportunistic rule:

$$\begin{aligned} f(\pi - \tilde{\pi}) &\approx \kappa_3 g(\pi - \tilde{\pi}) \\ &= \kappa_3[0.05(\pi - \tilde{\pi}) + 0.475(-\kappa_5 + \pi - \tilde{\pi} + ((-\kappa_5 + \pi - \tilde{\pi})^2)^{0.51}) \\ &\quad + 0.475(\kappa_5 + \pi - \tilde{\pi} - ((\kappa_5 + \pi - \tilde{\pi})^2)^{0.51})] \end{aligned} \tag{5}$$

[14]We also conducted sensitivity analysis for the alternative value $\lambda = 1/3$.

[15]The opportunistic loss surface rises rapidly as these response coefficients become smaller but is essentially flat for response coefficients with larger values.

be seen from the table, the linear rule is preferred over the nonlinear rule under the conventional quadratic criterion while the nonlinear rule is preferred under the non-quadratic opportunistic criterion.

Table 3: Benchmark Rules and Alternative Losses

	Quadratic Loss ($\gamma = 0.5$)	Opportunistic Loss ($\lambda = 0.5, \gamma = 0.5$)
Linear Rule	.00054	.01329
Nonlinear Rule	.00060	.00715

Notes: Unconditional losses represent the weighted average of unconditional variances of inflation and output gaps in the quadratic case, and the weighted average of the unconditional variance of the inflation deviation from the intermediate target and the unconditional mean absolute deviation of output from potential in the opportunistic case.

Opportunistic versus deliberate disinflation in a stochastic economy

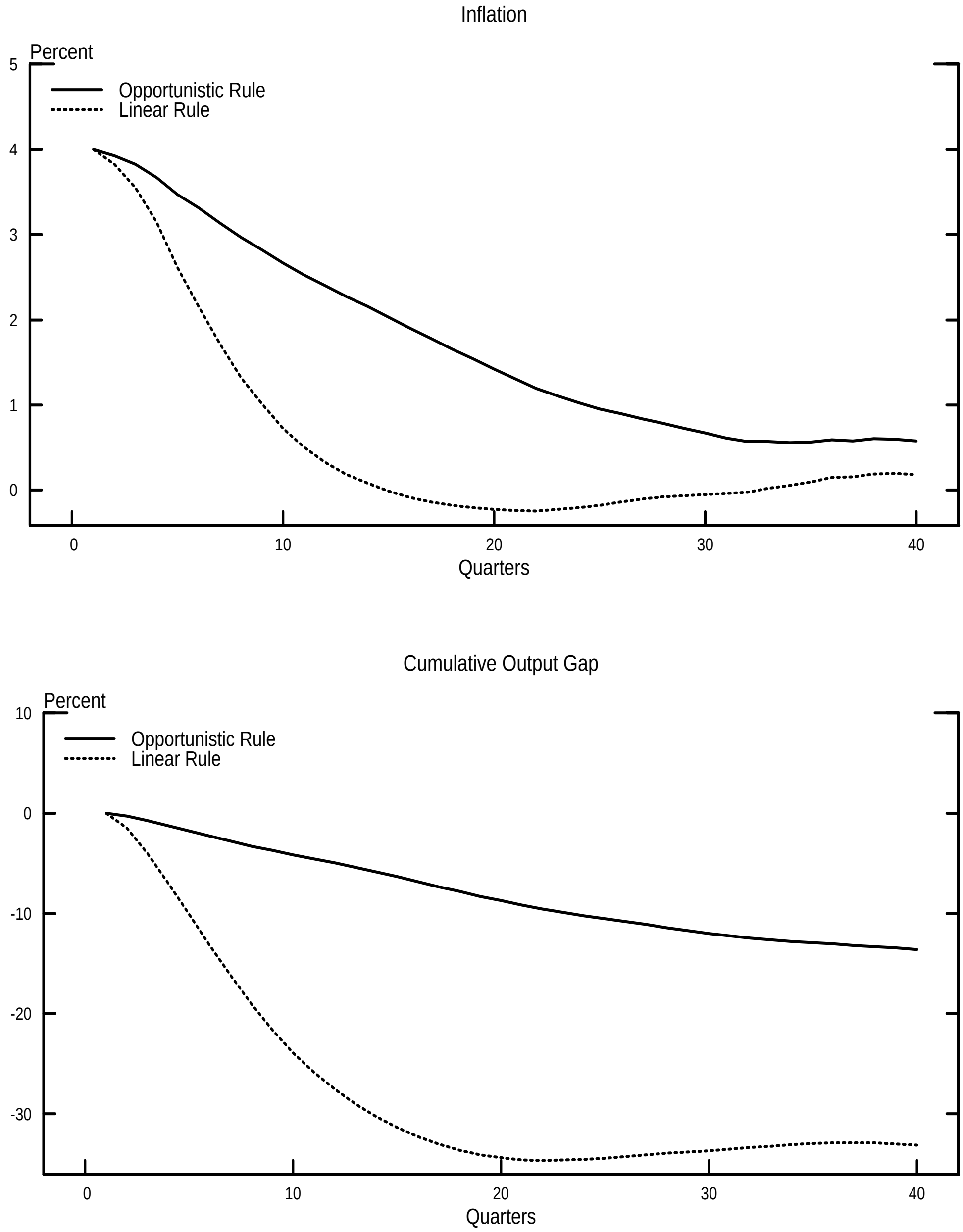
As is well known, linear models with additive shocks exhibit certainty-equivalence. Therefore, given an initial level of inflation (say 4 percent), it is straightforward to calculate the expected time until inflation is within some neighborhood of the long-run target if monetary policy is implemented according to the benchmark linear rule. In fact, the calculation can be done by setting all future shocks equal to their expected value of zero and simulating the model, i.e. by conducting what is typically referred to as a deterministic simulation. Averaging over many stochastic simulations would deliver the same result in terms of the expected path of endogenous variables. In contrast, the model under the opportunistic rule is not linear, so the expected path of disinflation differs from the path of disinflation in the absence of economic shocks.

We compute the expected path of an opportunistic disinflation by conducting stochastic simulations of the nonlinear model. We initialize inflation at a rate of 4 percent and output at potential. As a result, the demand components are equal to their equilibrium shares and real interest and exchange rates equal their equilibrium values. We then conduct 1000 simulations of 100 periods in length, drawing shocks from the covariance matrix of our estimated shocks.

The top panel of **Figure 2** compares the expected path of disinflation under the benchmark linear and opportunistic rules. As shown, disinflation is expected to take place much more rapidly under the linear rule (dashed line) than under the opportunistic rule (solid line). The (four-quarter-moving average) of inflation essentially reaches the long-run target of zero percent after 10 quarters. This is no surprise, given that the conventional linear strategy takes deliberate steps to achieve disinflation by tightening policy and opening up an output gap. Some output gap is maintained until inflation is stabilized around the long-run target. As a result, the disinflation is accompanied by a steady increase in the cumulative output gap until the rate of inflation falls to zero as shown in the lower panel of **Figure 2**.

As discussed previously, the opportunistic "wait for favorable circumstances" approach to disinflation does not pursue disinflation in such an activist manner. Rather, it prescribes that the central bank focus almost exclusively on stabilizing the output gap as long as inflation is not too far away from an intermediate rather than the long-run target. With a long-term target of zero and an inherited inflation of 4 percent, the opportunistic policymaker's intermediate inflation target initially corresponds to 2 percent. Consequently, the zone of inaction, in which the opportunistic policymaker does not actively pursue a disinflation, extends up to an inflation rate of 3 percent. Thus, with inflation initially at 4 percent, even our opportunistic policymaker takes some small steps toward disinflation and tightens policy. As can be seen in the top panel of **Figure 2** the opportunistic approach is ultimately successful in reducing inflation both as a consequence of these initial deliberate policy actions and as a result of disinflationary shocks. However, because the policymaker disregards the rate of inflation as soon as it enters the zone of inaction, disinflation occurs more slowly than under the conventional approach. The rate of inflation is expected to decline below 1 percent only after 30 quarters. Over time, the opportunistic policymaker's intermediate target also drifts down, in expectation, and eventually it becomes equal to the long-run target.

Figure 2: Opportunistic versus Deliberate Disinflation
Expected Inflation and Cumulative Output Paths



Notes: The inflation rate is expressed in percentage terms. The cumulative output gap corresponds to the simple sum of past quarterly output gaps also expressed in percentage terms.

The benefit of the opportunistic approach to disinflation is apparent from the lower panel of **Figure 2**. The expected cumulative output gap remains substantially smaller and is only about 1/3 of the level reached under the linear rule after 40 quarters. Thus, opportunistic disinflation requires significantly smaller output losses to achieve a certain extent of disinflation. **Table 4** provides an alternative perspective on the time required to achieve

Table 4: Cumulative Frequency of Time To Disinflate from 4 Percent

Year	Percent of Simulations with Inflation first dropping below 2 percent by year shown		Frequency of Simulations with Inflation first dropping below 0 percent by year shown	
	Linear	Opportunistic	Linear	Opportunistic
1	0	0	0	0
2	0	0	0	0
3	43	18	32	3
4	65	40	62	22
5	78	51	76	37
6	86	59	84	48
7	92	67	90	57
8	95	72	93	63
9	96	76	94	69
10	97	79	95	73
20	100	95	100	94

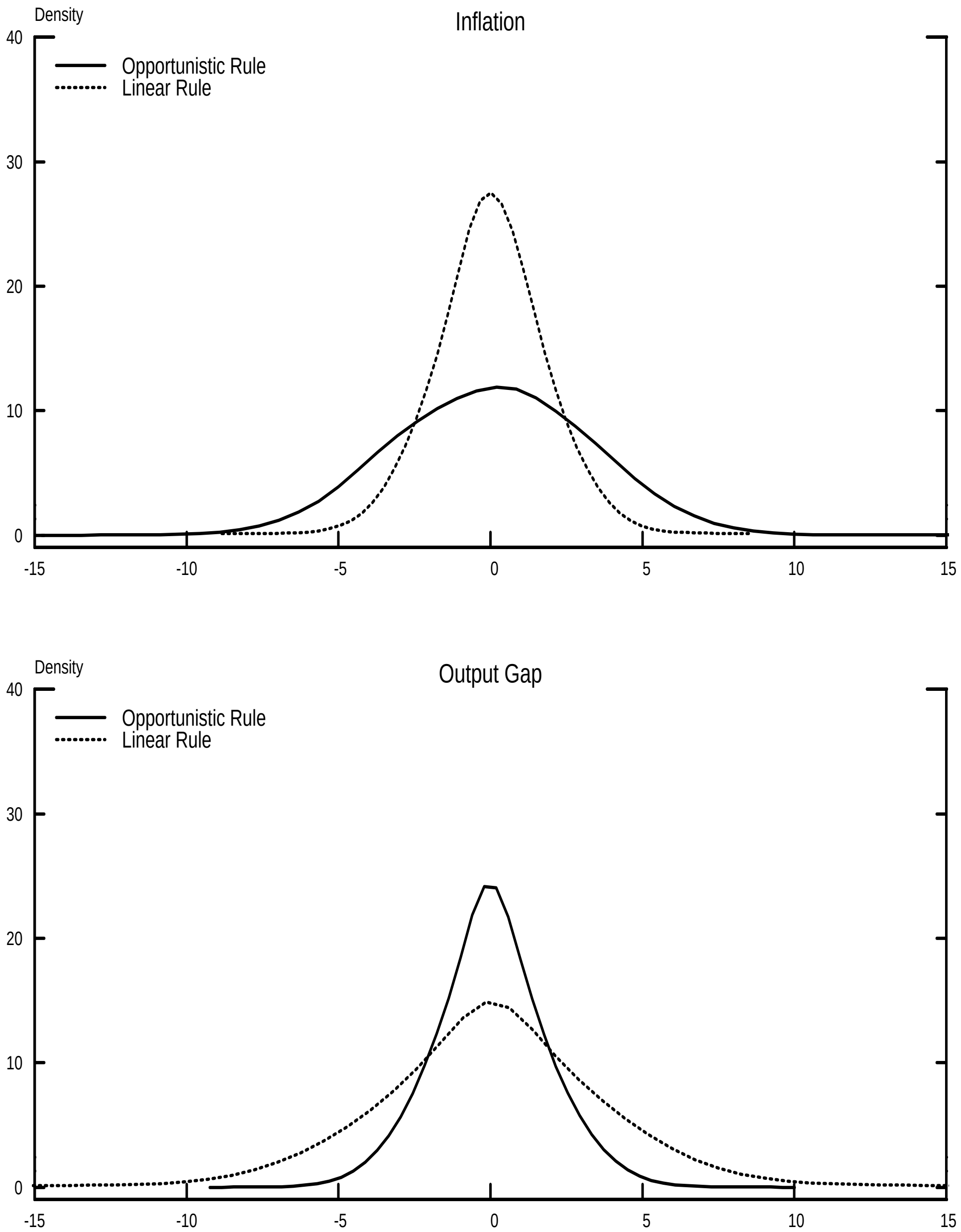
a certain disinflation. It reports the percentage of stochastic simulations for which inflation has fallen below 2 percent (or 0 percent) for the first time in the simulation, by the end of a given year. For example, under the benchmark linear rule, inflation has passed below the 2 percent mark in 43 percent of the simulations by the end of the third year. This is only true for 18 percent of simulations under the benchmark opportunistic rule. The third and fourth columns provide further information regarding the frequency that the long-run target of 0 percent is reached for the first time by the end of a given year. For example, by the end of the fifth year of the deliberate disinflation 76 percent of simulations have passed this mark. For the opportunistic disinflation this is only true for 37 percent of simulations. However, after ten years nearly 3/4 of the simulations under the opportunistic rule have passed the long-run target. Thus, we can conclude that the opportunistic approach is effective in reducing inflation in a stochastic economy by taking advantage of favorable exogenous shocks.

Steady-state distributions of output and inflation

Having achieved disinflation in an opportunistic manner, the question remains how the central bank would continue to maintain price stability from that point on. Two alternatives are directly apparent. Either the central bank could abandon opportunism and stabilize inflation around the long-run target of zero percent in a conventional manner from then on, or the central bank could continue to implement an opportunistic rule focusing on output stability whenever inflation is moderate and allowing for drift in its intermediate inflation target. Under opportunistic maintenance of price stability, the policy would remain nonlinear and include a zone of inaction, while the switch to a conventional rule would imply a linear response to inflation deviations in the future. To compare opportunistic versus conventional maintenance of price stability, we compute the distributions of inflation and the output gap in the stochastic steady state under the two benchmark rules. These calculations help quantify the current and future risks to inflation and output stability in the United States.

Intuitively, one would expect that the probability mass of the output gap should be more tightly clustered around zero under opportunism and that the inflation distribution is more diffuse within the opportunistic range. This intuition is confirmed by the stochastic steady state distributions displayed in **Figure 3**. The upper panel of this figure reports the inflation distributions, both centered on the long-run target, of zero percent, while the lower panel reports the output gap distributions. Under the linear rule (dashed lines), inflation and output are distributed normally due to the assumption of normality regarding the shocks in the model. Under the opportunistic rule (solid lines), however, the distributions are non-normal; in particular inflation exhibits a more diffuse hump-shaped distribution than under the linear rule, while the output gap distribution has more mass near zero.

Figure 3: Steady-State Distributions of Output and Inflation



5 Conclusion

Using stochastic simulations, we have derived an optimized linear Taylor-style rule and a nonlinear opportunistic rule, and we have used these rules for a comparative evaluation of the opportunistic approach to disinflation. This approach to monetary policy, which has been discussed extensively by U.S. monetary policymakers, has been formalized by Orphanides and Wilcox (2002) in terms of an opportunistic central bank loss function. Our opportunistic rule is of the same form as the optimal opportunistic policy derived by Orphanides and Wilcox. Furthermore, we have made use of their opportunistic loss function in optimizing the response parameters of this rule to our more general empirical model of the U.S. economy with nominal rigidities and rational expectations.

Based on our quantitative analysis we conclude that the opportunistic approach to disinflation presents an interesting alternative weighting of inflation losses and output losses. In particular, while the opportunistic approach takes longer to achieve a given disinflation, it is effective in taking advantage of exogenous shocks (such as unexpected recessions or favorable cost-push shocks) to achieve disinflation at a lower cost in terms of output losses than a conventional linear strategy just as advocated by proponents of opportunism. Furthermore, we have provided quantitative measures of the output gap and inflation distributions that would obtain if the U.S. central bank continues to pursue an opportunistic strategy in maintaining price stability after the long-run target has been reached.

An important difference between the opportunistic and the deliberate approach to disinflation is that the speed of disinflation under the opportunistic approach depends on the variance of exogenous shocks but not under the deliberate approach. The shocks we have used in simulation are drawn from the historical covariance matrix of structural shocks implied by our model for the 1980s and 1990s. We have assumed that the shocks are symmetric and normally distributed. Thus, merely increasing the variance of shocks would render faster expected convergence to the long-run target under the opportunistic approach, while leaving it unaffected under the deliberate approach. However, if shocks were increased asymmetrically such as the size or frequency of adverse supply shocks, which may for example better reflect the U.S. experience in the 1970s, then the opportunistic policy would be affected more adversely.

Finally, it is important to note that all our results were obtained under the assumption that the central bank commits to following either policy rule and that this commitment is credible. As is well-known, a credible disinflation under rational expectations by market participants will be less costly in terms of output losses than a disinflation where market participants doubt the central banker's resolve to achieve the long-run inflation target. Thus, an interesting extension of our analysis would be to compare the opportunistic and deliberate approach to disinflation under imperfect credibility regarding the central bank's policy rule and inflation target. This could be done by introducing imperfect information regarding the policy rule and having market participants solve a signal-extraction problem. Their estimates of the policymaker's true rule and inflation target would then be updated continually based on observed inflation and output data. In such a setting, the nonlinear and time-dependent opportunistic rule might be less conducive to building reputational capital regarding the central bank's resolve to disinflate than a conventional linear rule. However, one could also argue that a central bank faced with high inflation may not be able to maintain a strong and deliberate anti-inflationary policy stance resulting in a deep recession for several years. Thus, doubts regarding the political feasibility of a deliberate approach to disinflation may render the opportunistic approach advantageous. We leave this question for future research.

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Appendix

Methods for solving linear versions of the rational expectations model

We compute the unique stationary rational expectations solution of linear versions of our model using the Anderson and Moore (1985) implementation of the Blanchard and Kahn (1980) method, modified to take advantage of sparse matrix functions. The algorithm is discussed in more detail in Anderson (1997).

We use this method for three different purposes in our paper. First, in preparation of our quantitative analysis we computed the structural residuals of the model based on U.S. data from 1980 to 2000. The process of calculating the structural residuals would be straightforward if the model in question were a purely backward-looking model. For a rational expectations model, however, structural residuals can be computed only by solving the full model and computing the time series of model-consistent expectations with respect to historical data. The structural shocks differ from the estimated residuals to the extent of agents' forecast errors. In computing the structural historical shocks we assumed that monetary policy is set according to an estimated linear policy rule. We then computed the covariance matrix of those structural shocks for further use in the quantitative analysis. Secondly, we used the Anderson/Moore algorithm for deterministic and stochastic simulations of disinflations under linear policy rules. Thirdly, we derived unconditional moments of output and inflation given the historical covariance of shocks and alternative linear rules. The unconditional variances were computed using the doubling algorithm described in Hansen and Sargent (1997), also modified to take advantage of sparse matrix functions. Finally, The methodology for optimizing the coefficients of linear policy rules that we used to obtain the benchmark linear rule in our paper is described in further detail in Levin, Wieland and Williams (1999).

Methods for nonlinear versions of the rational expectations model

A quantitative analysis of the opportunistic approach to disinflation in a model with rational expectations requires methods that can deal with nonlinearity. Because of the large number of state variables in our models (which include all lags and shocks) we have used a simulation-based approach to assess the implications of opportunism. Using the covariance matrix, we generated 1000 sets of artificial normally-distributed shocks with 100 quarters of shocks in each set. We then used these shocks to conducted stochastic simulations of the model. With these simulations we obtained expected disinflation paths as well as stochastic steady-state distributions of the endogenous variables under alternative nonlinear policy rules.[16]

[16] If it were not for the nonlinearity induced by opportunism, we could use the reduced form of the model corresponding to the alternative policy rules to compute unconditional moments of the endogenous variables without having to resort to stochastic simulations.

In an earlier version of this paper, we simulated the model using an algorithm implemented in TROLL and based on work by Boucekkine (1995), Juillard (1994) and Laffargue (1990). This algorithm is closely related to the well-known Fair-Taylor (1983) extended path algorithm but substantially faster because it employs Newton-Raphson nonlinear equation solution instead of Gauss-Seidel iteration in solving for model-consistent expectations of endogenous variables in a stacked-time approach. However, in this version of the paper we have employed 'Resolver', an alternative program for solving nonlinear forward-looking models described in Madigan (1998) and used in Fuhrer and Madigan (1997). Resolver is also a stacked-time algorithm but it differs from the TROLL implementation we used earlier by employing the above-mentioned linear Anderson-Moore algorithm to establish initial estimates for solution trajectories and to impose economically sensible boundary conditions. Resolve is more efficient than the TROLL implementation in terms of computation time because it uses linear methods for an initial approximation and efficiently computes symbolic derivatives for use in the Newton-Raphson nonlinear equation solution.

A limitation of both algorithms, the Troll implementation of Fair-Taylor's method and Resolver, is that the model-consistent expectations of market participants are computed in a manner that neglects the fact that the variance of *future* shocks is nonzero. This means, when solving for the dynamic path of the endogenous variables from a given period onwards, the algorithm sets future shocks equal to their expected value of zero. Thus the variance of future shocks has no bearing on the formation of current expectations and economic performance. This would be correct in a linear model. However, when monetary policy follows the opportunistic nonlinear approach to disinflation, we are able to show that the variance of future shocks ought to be expected to influence the speed of disinflation (see section 4 of this paper). To be clear, we should emphasize that the variance of shocks in principle has both a direct and an indirect effect on the results. The direct effect is that a greater variance of shocks gives the opportunistic policymaker greater scope for asymmetric behavior. The indirect effect is that all agents (private as well as public) should be taking this into account when they form their expectations. The above simulation algorithm captures the direct effect but not the indirect one. Underestimating the effect of the variance of shocks likely biases our results against the opportunistic approach to disinflation. There are other solution algorithms for nonlinear rational expectations models that do not have this limitation. But these alternative algorithms would be prohibitively costly to use with our model, which has more than twenty state variables.