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MONETARY POLICY IN A LOW INFLATION ENVIRONMENT: IS THERE EVIDENCE FOR OPPORTUNISTIC BEHAVIOUR?

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Abstract

The Opportunistic Approach to disinflation is an influential model of optimal monetary policy. This strategy for disinflation suggests that in a low inflation environment policymakers' would give higher weight to inflation stabilization when inflation is strengthening, but higher weight to stabilizing output when the economy is already producing lower inflation via favourable supply shocks. A time-varying parameter (TVP) model is estimated to evaluate its empirical likelihood using US data. Preliminary results support this model during the Greenspan regime.

Keywords: Monetary policy; Opportunistic disinflation; Time-varying parameter; Flexible Least Squares; Kalman Filter

JEL Classifications: E52; E58

1. Introduction

The success of monetary policy in restoring price stability in developed economies has shifted attention in recent years to the design of monetary policy in a low inflation environment. As Feldstein (1996) argues, in a low inflation environment questions remain about how fast the central bank should seek to achieve its desired level of inflation and under what conditions, if any, it should not act at all. The recent discussion about "opportunistic disinflation" is an important example of this question.[4]

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[4] Such an approach is motivated by the views expressed by leading central bankers (see Blinder (1994) and Meyer (1996), for example). For theoretical work on this topic see Bomfim and Rudebusch (2000), Orphanides and Wilcox (2002), Minford and Srinivasan (2006) and Aksoy et al., (2006).

The opportunistic approach to monetary policy can be neatly divided into two halves. First and foremost, there is the idea of delay: one should not pursue a target for the inflation rate that is too ambitious in the short run - it is ‘impractical’. Rather one should pursue a practical target that is within grasp in the short term - an interim inflation target. Secondly, there is the idea of asymmetry: one acts to reduce the inflation rate when the economy is already producing lower inflation via a favorable burst of circumstances (a ‘good supply shock’). One does not try to reduce the inflation rate when inflation is strengthening; rather one aims to dampen it then.

Thus a policymaker who is endowed with these preferences gives higher weight to inflation stabilization when inflation is strengthening, but higher weight to stabilizing output when the economy is already producing lower inflation via favorable supply shocks. To quote an example given by Orphanides and Wilcox (2002), “an opportunistic policymaker evaluates a 3 percent rate of inflation today less favorably if inflation yesterday was 2 percent than if inflation yesterday was 4 percent. In the former case, an opportunistic policymaker might well aim to drive output below potential, whereas in the latter case, she would aim simply to hold output at potential.” That is, adverse inflation outcomes are vigorously offset through monetary policy; but favorable inflation shocks are accommodated.

In this article we examine whether U.S. policymakers’ behavior has been consistent with the Opportunistic Approach. Since it is well known that both the structure of the U.S. economy and the way monetary policy was conducted have undergone a fundamental transformation during the sample period, model parameters are allowed to vary, in accordance with the Lucas (1976) critique.[5] Hence time-varying parameter (TVP) model of inflation is estimated in order to evaluate its empirical likelihood.

To anticipate our findings, our results are consistent with the view that while the Greenspan Fed vigorously offset adverse inflation shocks, it accommodated favourable inflation outcomes, which is consistent with the opportunism story. These findings suggest that representing monetary policy during the Greenspan regime in terms of a linear reaction function (as in Clarida et al. (2000) and many subsequent empirical studies) may not be appropriate. This conclusion is consistent with recent empirical evidence which points to important nonlinearities in interest rate setting during the Greenspan regime (Cukierman and Muscatelli (2008) and Martin and Milas (2010)).

The remainder of the paper is structured as follows. Section 2 provides a brief overview of the literature on opportunism and outlines the model to be estimated. To ensure that the paper is self-contained, section 3 reviews the TVP estimation technique. Section 4 summarizes the principal empirical findings of the current study. Section 5 provides concluding remarks.

2. Overview of the Opportunistic Approach to Disinflation

The opportunistic approach to monetary policy is motivated by the views expressed by leading central bankers. For instance in testimony before the Senate committee that was meeting to consider his nomination to the Federal Reserve Board, former Vice Chairman Blinder summarized his views on this issue as follows: “*If monetary policy is used to cut our losses on the*

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[5] Moreover, since our objective is to investigate possible changes in policymakers’ behaviour in a low inflation environment *vis-à-vis* a high inflation environment, a time-varying parameter (TVP) model is appropriate.

inflation front when luck runs against us, and pocket the gains when good fortune runs our way, we can continue to chip way at the already-low inflation rate" (Blinder, 1994, p.48).

Explaining the opportunistic disinflation strategy Governor Laurence Meyer (1996) notes *"Under this strategy, once inflation becomes modest, as today, Federal Reserve policy in the near term focuses on sustaining trend growth at full employment at the prevailing inflation rate. At this point the short-run priorities are twofold: sustaining the expansion and preventing an acceleration of inflation. This is, nevertheless, a strategy for disinflation because it takes advantage of the opportunity of inevitable recession and potential positive supply shocks to ratchet down inflation over time."*

For the process of disinflation from high (double digit) initial levels of inflation, as in the 1970s, such ideas have been widely defended. However, in the conditions of the 1990s when inflation was already well within single digits in the U.S., they seem rather surprising. So a natural question is why would a central bank choose to behave in this way in a low inflation environment?

Feldstein (1996) argues that central banks are ultimately subject to political control. As a result, the Federal Reserve cannot do things that the public and the relevant elected officials strongly disapprove. He argues that there was a great public sentiment in the U.S. in favor of strong disinflation measures in response to the double-digit inflation in 1979-80 but not in the low-inflation environment of the 1990s. For example between July 1980 and January 1981, Paul Volcker and his colleagues pushed the federal funds rate from 9 percent to more than 19 percent, precipitating a recession. The Federal Reserve was able to raise interest rates so sharply because there was very strong public support for disinflation. In contrast, inflation in the 1990s was already low by historical standards. As a result further disinflation lacked the vocal political constituency that low interest rates and fast growth had.

In contrast, Orphanides and Wilcox (2002) place emphasis on preference asymmetry. Specifically, they formulate a loss function for the policymaker that can be thought of as incurring a first-order loss from output deviation, and yet only a second-order loss from inflation deviations when inflation is close to its target. In this regard, Aksoy et al (2006 pp.1880) comment, "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 deviations of inflation from the intermediate target, output stabilization is the primary concern to the opportunistic policymaker. Larger deviations of inflation from the intermediate target, however, cause the policymaker to focus on inflation stabilization".[6]

[6] Martin and Milas (2010) empirically evaluate this model using U.S. data from 1983-2004. There results suggest that U.S. policymakers reacted differently depending on whether inflation was within or outside a target range during this period. Specifically, they find that there was no policy response to inflation when inflation is within 1 per cent of the intermediate target but a strong policy response when inflation was outside this range.

At the very outset we would point out that the type of non-linear behaviour we test in this paper is rather different. It more closely resembles the views expressed by Blinder (1997). He writes *"Under certain circumstances, the optimal disinflation strategy is asymmetric in the following specific way: you guard vigorously against any rise in inflation, but wait patiently for the next favourable inflation shock to bring inflation down. The opportunistic strategy makes the time needed to approach the ultimate inflation target a random variable. When I was the Vice Chairman of the Fed, I often put it this way: the United States is "one recession away" from price stability."* This implies that the weight the policymaker places on output stabilization objective varies with the nature of the shock hitting the economy.

Finally, Minford and Srinivasan (2006) show that adaptive expectations combined with asymmetry in the Phillips curve together provide an optimizing justification for opportunism. The point is when expectations are adaptive, inflation reduction requires a transitional cost in terms of lost output. Hence, authorities wait for favorable supply shocks to bring inflation down rather than engineer a downturn; in this way the transitional cost can be lowered or even eliminated as output need not fall below its natural rate. Furthermore, with a nonlinear Phillips curve the sacrifice ratio is not independent of the size of an intended change in inflation—it rises as the economy goes further into recession. This suggests that inflation should be reduced more when the economy is in an expansionary mode induced by favorable supply shocks.

We neither dispute the validity of these arguments nor run a horserace between them. Rather our objective is simply to examine whether U.S. policymakers' behavior has been consistent with the Opportunistic Approach.

Model

The theoretical framework consists of a stylized model in which the central bank aims to minimize a quadratic loss function with inflation and the output-gap as arguments. The solution to the central bank's optimization problem generates a reduced form solution in which the dynamics of inflation is determined by a combination of the central bank's relative preference for output stability and other structural parameters of the model. This basic setup has been widely used and has proved useful in thinking about monetary policy.

The policymakers' objective is to stabilize the inflation rate, π_t around an interim target, π_t^T, and output, y_t around its natural rate, y^*. While a *deliberate* policymaker consistently strives to eliminate inflation rate deviations from the long-run target, π^*, the *opportunistic* policymaker behaves somewhat differently. Specifically, he announces both an interim inflation target and a long-run target.[7] As long as the inflation rate is moderate he does not take deliberate anti-inflation action to reduce it. However, he will attempt to prevent the inflation rate from strengthening. Moreover, if actual inflation rate happens to fall below the interim target (because of favorable supply shocks) then the opportunistic policymaker resets the interim target to newly achieved lower inflation rate. This process continues until the inflation rate is brought in line with the long-run target.

Formally, the central bank faces the following problem:[8]

$$L(\pi, y_t) = \frac{1}{2}\left[(\pi_t - \pi_t^T)^2 + \lambda_t (y_t - y^*)^2\right], \qquad \text{... (2.1)}$$

[7] For example, in early 1990, New Zealand's central bank announced interim inflation target ranges of 3 to 5 percent by the end of 1990 and 1.5 to 3.5 percent by the end of 1991, as well as an ultimate inflation target range of 0 to 2 percent by the end of 1992 (see Bomfim and Rudebusch, 2000).

[8] We explicitly allowing for time variation in model parameters. This in turn allows us to capture changes in monetary policy preferences to inflationary developments. Moreover, we abstract from demand shocks because both the opportunistic and deliberate policymaker will fully neutralize the influence of those shocks. Thus, excluding demand shocks does not alter our results; their introduction is an uninteresting complication in the model.

where, $0 < \lambda_t < 1$ is the relative weight on output gap stabilization. In addition the model includes an equation describing the determination of the intermediate target as a weighted average of last period's inflation rate and the central bank's long-run target i.e.,

$$\pi_t^T = \omega_t \pi^* + (1 - \omega_t)\pi_{t-1}, \qquad 0 < \omega_t < 1 \qquad \text{... (2.2)}$$

where 'ω_t' is the weight assigned to short-run and long-run inflation objectives. If $\omega_t = 1$, the policymaker consistently strives to eliminate inflation deviations from the long-run target (deliberate disinflation). Intermediate values of ω_t represent the opportunistic approach. In this case, the interim target depends upon both the long-run target and the prior history of inflation itself. Thus, the intermediate target will always lie between last period's inflation rate and the central bank's long-run target.

In this framework the private sector behavior is characterized by an expectations augmented Phillips curve:

$$\pi_t = \pi_t^e + \alpha_t \left(y_t - y^* \right) + u_t, \qquad \alpha_t > 0 \qquad \text{... (2.3)}$$

where, π_t^e denotes expectations conditional upon the information available at time $t-1$. The supply disturbance, u_t, in turn is assumed to fluctuate over time in response to a random shock, ε_t, according to the autoregressive process,

$$u_t = \rho_{1t} u_{t-1} + \varepsilon_t , \qquad \text{... (2.4)}$$

where, $0 < \rho_{1t} < 1$ is the persistence parameter.

Finally, the central bank is assumed to have imperfect control over the rate of inflation. In particular,

$$\pi_t = \pi_t^e + \xi_t , \qquad \text{... (2.5)}$$

where, $\xi_t \sim N(0,\ \sigma_\xi^2)$ is a control error that represents imperfections in the conduct of monetary policy.

In order to understand the implications of such preferences for optimal policy we solve the policymakers' optimization problem. Thus, minimizing the period loss function subject to the constraints provided by the structure of the economy yields:

$$\pi_t^e = a_{0t} + a_{1t}\pi_{t-1} + a_{2t}u_{t-1} , \qquad \text{... (2.6)}$$

where, $a_{0t} = \omega_t \pi^*$, $a_{1t} = \left(1 - \omega_t\right)$ and $a_{2t} = \left(\dfrac{\lambda_t \rho_{1t}}{\alpha_t^{\,2}} \right)$.

In order to empirically evaluate our model we substitute eq. (2.6) in eq. (2.5) for, π_t^e. Thus, our benchmark reduced-form model for inflation is given by,

$$\pi_t = a_{0t} + a_{1t}\pi_{t-1} + a_{2t}u_{t-1} + \xi_t . \qquad \text{... (2.7)}$$

Notice that the solution for inflation depends on the underlying parameters of the model. This is the sense in which the changes in dynamics of inflation are linked to changes in the preferences of the central bank and the structure of the economy.

Our identification strategy relies on the evolution of the slope coefficient (a_{2t}). Under the opportunistic approach, when the inflation rate is moderate but still above the central bank's long-run target, policy response to shocks is asymmetric. That is, adverse inflation outcomes are vigorously offset through monetary policy; but favorable inflation shocks are accommodated. This implies that when the inflation rate is strengthening (owing to adverse supply side developments) the policymaker gives higher weight to inflation stabilization (lower, λ). This implies that the parameter a_{2t} should fall in response to adverse supply shocks. This way the policymaker manages to dampen the effect of the shock on inflation. In practical terms this means that the policymaker would curtail demand (by increasing interest rate) in response to adverse supply side developments.

In contrast, when the economy is already producing lower inflation via a favourable burst of circumstances, output stabilization objective gains precedence (i.e., λ should rise). This implies that the parameter a_{2t} should rise in response to 'good' supply shocks. Thus, inflation is reduced when good fortune runs our way via favourable burst of circumstances. In practical terms this means that interest rates would be left unchanged in response to good shocks. In sum, policy responds non-linearly to shocks under the opportunistic approach.

Contrast this approach with an alternative monetary framework, say, inflation targeting. Unlike opportunism under inflation targeting policy response is linear. If the central bank has a point target for inflation, then in response to adverse shocks interest rates are raised in order to offset the effect of the shock. In contrast, in response to favourable shocks there is risk that inflation might undershoot the target. To guard against this the central bank stimulates demand by lowering interest rates. In this regime one would not expect λ and a_{2t} to vary in response to shocks. In sum, the response of the slope parameter to shocks helps us discriminate among alternative policy regimes.

3. Empirical Methodology

To begin with we use the flexible least squares (FLS) approach of Kalaba and Tesfatsion (1988, 1989) to estimate our reduced form inflation model (2.7). The reason for doing so is that the FLS technique generates an estimated time path for each regression coefficient which can be used to detect qualitative movements in individual coefficients without requiring us to impose a particular stochastic structure for the coefficients and/or assume a specific distribution for the disturbances.

Moreover, since the FLS procedure is cast in a completely deterministic framework, it does not have the capability to automatically update the covariance matrices of the system state. In the absence of a complete set of stochastic assumptions, it is difficult to argue that a model represents an adequate or a poor description of the data generating process. Given this limitation, our FLS estimates should be viewed as a purely diagnostic or exploratory tool - a first pass test to detect time-variation in model parameters.

After establishing that the parameters are changing over time using the FLS procedure, we proceed to estimate our inflation model by maximum likelihood method (MLE) using the

Kalman Filter (KF) algorithm.[9] Kalman Filter estimation is more appealing because it not only generates an estimated time path for each regression coefficient over the sample period but also provides an estimate of the standard errors (uncertainty) associated with these parameters. We begin with a brief overview of these techniques in what follows.

The flexible least squares (FLS) approach

Kalaba and Tesfatsion (1988, 1989) formulate a time varying linear regression problem as follows. Suppose noisy observations, $y_1, \ldots\ldots y_T$ over a time-span 1,…..,T have been generated by a linear regression model with coefficients that evolve only slowly over time. Letting $y_t = \pi_t$ denote the time-*t* observed dependent variable, x_t denote the vector of time-*t* regressor variables, and b_t denote the vector of time-*t* regressor coefficients, the *prior measurement specification* (2.7) can equivalently be expressed as

$$y_t \approx x_t' b_t, \qquad t = 1, \ldots, T \,. \qquad \ldots (3.1)$$

Rather than impose strict time constancy on the coefficients, FLS approach captures time variation through a *prior dynamic specification* (smoothness prior) for successive coefficient vectors:

$$b_{t+1} \approx b_t, \qquad t = 1, \ldots, T\text{-}1 \,. \qquad \ldots (3.2)$$

The measurement and dynamic specifications reflect the prior beliefs of linear measurement and coefficient stability in a simple direct way, without any distributional assumptions about the error term that are required for OLS or Kalman filter estimation.

Associated with each possible coefficient sequence estimate b **= (**b_1 . . . , b_T**)** are two basic types of model specification error. First, b could fail to satisfy the prior measurement specification (3.1) because of discrepancy between the observed dependent variable y_t and the estimated linear regression model $x_t' b_t$ at each time t. This discrepancy could arise because of misspecification, wrong functional form, etc. Second, b could fail to satisfy the prior dynamic specification (3.2) because of possible coefficient variation for the included variables.

Suppose the cost assigned to *b* for the first type of error is measured by the sum of squared residual measurement errors

$$r_M^2(b;T) = \sum_{t=1}^{T} \left[y_t - x_t' b_t \right]^2, \qquad \ldots (3.3)$$

and the cost assigned to *b* for the second type of error is measured by the sum of squared residual dynamic errors

$$r_D^2(b;T) = \sum_{t=1}^{T-1} \left(b_{t+1} - b_t \right)' D \left(b_{t+1} - b_t \right), \qquad \ldots (3.4)$$

where D is a suitably chosen scaling matrix that makes the cost function essentially invariant to the choice of units for the regressor variables. Kalaba and Tesfatsion (1988, 1989) define the

[9] FLS is a generalization of Kalman filtering, as discussed in several works (see Lütkepohl, 1993). Typically, Kalman filtering requires the analyst to assume a particular stochastic structure for the time-varying coefficients and that the disturbances follow a specific distribution.

flexible least squares solution as the collection of all coefficient sequence estimates b which yield vector-minimal sums of squared measurement and dynamic errors for the given observations - that is, which attain the residual efficiency frontier (REF). The REF reveals the cost in terms of residual measurement error that must be paid in order to achieve the *zero* residual dynamic error (time-constant coefficients) required by OLS estimation.

How might the REF be found? The incompatibility cost function $C(b;\delta,T)$ that attains the REF for all possible choices is formed by taking the weighted sum of these two types of specification error as follows.

$$C(b;\delta,T)=\frac{\delta}{1-\delta}\sum_{t=1}^{T-1}\left(b_{t+1}-b_t\right)'D\left(b_{t+1}-b_t\right)+\sum_{t=1}^{T}\left[y_t-x_t'b_t\right]^2, \qquad \text{... (3.5)}$$

where $0<\delta<1$ is the weight factor that assigns a relative priority to the two priors in the model specification.

Suppose we set δ near 1 and obtain the corresponding FLS coefficient-sequence estimate. Then the cost function, $C(b;\delta,T)$, places most of the weight on the dynamic-specification errors, forcing $r_D^2(b;T)$ to be near zero. This reveals the cost in terms of residual-measurement error that must be paid for the analyst to choose the fixed-coefficient solution. This is called the OLS extreme point.[10]

Now suppose we set δ near 0 and obtain the corresponding FLS coefficient-sequence estimate. The cost function, $C(b;\delta,T)$, places most of the weight on the measurement-specification errors, forcing $r_M^2(b;T)$ to be near zero. This reveals the minimum amount of time variation in the coefficients that must be allowed in order to have no residual-measurement error (i.e., a perfect fit for the regression).

If the model truly has time-invariant coefficients, then starting from the OLS extreme point, the REF will indicate (as we move δ toward zero) only small decreases in measurement error for large increases in dynamic error. Thus, the REF would be pretty flat in this case. In contrast, if the true model has time-varying coefficients, then starting from the OLS extreme point large decreases in measurement error will be possible for small increases in parameter variation. Thus, the REF would be pretty steep in this case.

As (3.5) indicates, the incompatibility cost function $C(b;\delta,T)$ generalizes the goodness-of-fit criterion function for OLS estimation by permitting the coefficient vectors *b,* to vary over time. The incompatibility cost function is a strictly convex function of the coefficient sequence estimate *b,* and there exists a unique estimate *b* which attains the minimum cost. The use of a quadratic loss function implies that the resulting problem can be solved within the framework of optimal control.

The flexible least squares (FLS) solution is defined to be the collection of all coefficient sequence estimates which minimizes the incompatibility cost function. The coefficient sequence estimates, b, which attains this frontier is referred to as FLS estimates. In Kalaba and Tesfatsion

[10] OLS is just a special case of FLS in that a restriction is imposed that fixes the potentially time-varying coefficients to constant values. In other words, the OLS solution lies on one end of the REF, so it is just a limiting case of FLS.

(1988, 1989) a procedure is developed for sequentially generating the FLS solution. The algorithm gives directly the estimate $b_t^{FLS}(\delta, t)$ for the time-*t* coefficient vector b_t, conditional on the observations, $y_1, \ldots\ldots y_t$, as each successive observation y_t is obtained. The algorithm also yields smoothed (back-updated) estimates for all intermediate coefficient vectors for times 1 through t - 1, conditional on the observations, $y_1, \ldots\ldots y_t$.

The Kalman Filter approach

Under this approach we cast the model in state space form which consists of a measurement equation and a transition equation.[11] Individual law of motion of each parameter is given in the transition equation, while their relationship to observed variables is governed by the measurement equation. Measurement equation is given by the reduced form inflation model:

$$\pi_t = a_{0t} + a_{1t}\pi_{t-1} + a_{2t}u_{t-1} + \xi_t = \beta_t' Z_t + \xi_t,$$

where, $\xi_t \sim N(0,\ \sigma_\xi^2)$, β_t is the collection of parameters and Z_t the corresponding regressors.

Following Cooley and Prescott (1976), and most of the subsequent empirical literature which allows for time variation in parameters, we assume that the parameter vector follow a random walk (without drift):

$$\beta_t = \beta_{t-1} + \eta_t,$$

where, $\eta_t \sim N(0,\ Q)$.

All the parameters of the model, including the variance of, η_t, can be estimated jointly by maximum likelihood estimation (MLE) using the Kalman Filter algorithm. Provided with an estimate of the variance of, η_t, the time series of the parameters, β_t, can be obtained using the Kalman filter. Since the parameters are no longer constrained to have a fixed mean, the model can accommodate fairly fundamental changes in structure of the economy and monetary policy regimes. This model is widely used in forecasting applications (see Cogley and Sargent (2001) for example).

4. Empirical Analysis

4.1 Data and Basic Facts

The analysis spans the period 1948:2-2008:2 and it is conducted on quarterly data that is obtained from the FRED database at the Federal Reserve Bank of St. Louis. The inflation rate is measured as the year-on-year percentage change in seasonally adjusted consumer price index (CPI) for all urban consumers (all items). With regard to supply shock researchers have traditionally used energy prices as a proxy (see Hooker, 2002). So we use year-on-year percentage change in producer price index (fuel and related products and power) as our proxy for supply shock.

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[11] For a detailed discussion on Kalman Filter and the TVP model see Anderson and Moore (1979), Harvey (1989), and Durbin and Koopman (2001).

As a preliminary step Figure 1 plots CPI inflation and our proxy for supply shock (PPI inflation) for the entire sample period. Three critical observations arise immediately from the figure. First, inflation rose steadily from the mid-1960s to 1980, and declined over time thereafter. Second, including the most recent episode, there have been five significant periods of rising oil prices since 1970: 1973-74, 1978-79, 1990, 1999-2000 and 2004-05. Finally, oil price jumped sharply twice in the 1970s, as did the inflation rate. But this relationship appears to have deteriorated over the latter part of the sample.

Hooker (2002) provided formal evidence of this change in the relationship between oil prices and inflation. He found that the relationship between oil prices and inflation had declined considerably, even after allowance was made for a secular decline in the energy intensity of the U.S. economy. This suggests that the conduct of monetary policy since the early 1980s had an important role to play. With this background we proceed to empirically evaluate our model.

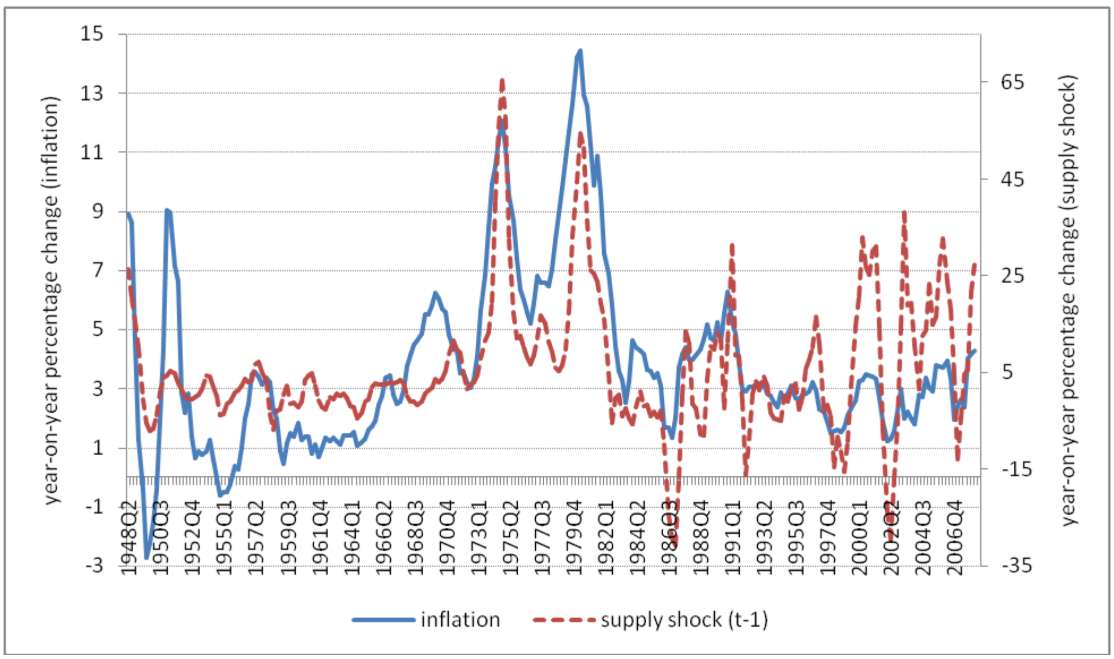

Figure 1. Quarterly U.S. inflation rate and supply shock

4.2 Estimation Results

We begin by estimating our reduced form inflation model by FLS procedure outlined above. The FLS estimation results for the alternative values of δ, along with the corresponding means, standard deviations and coefficients of variation (standard deviation divided by the mean) are shown in table 1. The reason for doing so is to gather evidence concerning which particular coefficient(s) exhibit the most time variation. The coefficient means will vary if the OLS weighting scheme produces a bias; the coefficient standard deviations will increase monotonically if there is coefficient variation. As we change δ by a small amount, the coefficient averages shift, as do the standard deviations. As we move δ toward zero, the coefficient averages and standard deviations stabilize. The REF is graphed in figure 2.

Table 1. The Summary Statistics of FLS Estimates

δ	Equation (2.8)		
	a_{0t}	a_{1t}	a_{2t}
1.00	0.20445	0.931	0.006
0.99	0.850	0.661	0.049
	(0.32)	(0.18)	(0.11)
	[0.38]	[0.27]	[2.27]
0.95	1.187	0.522	0.063
	(0.57)	(0.28)	(0.14)
	[0.48]	[0.54]	[2.27]
0.90	1.327	0.462	0.067
	(0.65)	(0.31)	(0.15)
	[0.49]	[0.68]	[2.26]
0.80	1.456	0.405	0.070
	(0.71)	(0.34)	(0.15)
	[0.48]	[0.84]	[2.26]
0.70	1.525	0.373	0.071
	(0.73)	(0.35)	(0.16)
	[0.47]	[0.94]	[2.27]
0.60	1.570	0.352	0.071
	(0.74)	(0.36)	(0.16)
	[0.47]	[1.02]	[2.27]
0.50	1.603	0.335	0.072
	(0.74)	(0.36)	(0.164)
	[0.46]	[1.08]	[2.28]
0.40	1.629	0.322	0.072
	(0.75)	(0.36)	(0.16)
	[0.46]	[1.14]	[2.29]
0.30	1.65	0.311	0.072
	(0.75)	(0.372)	(0.16)
	[0.45]	[1.19]	[2.29]
0.20	1.667	0.302	0.073
	(0.75)	(0.37)	(0.16)
	[0.45]	[1.24]	[2.3]
0.10	1.682	0.294	0.073
	(0.75)	(0.37)	(0.16)
	[0.45]	[1.28]	[2.30]
0.05	1.688	0.312	0.015
	(0.75)	(0.03)	(0.005)
	[0.44]	[1.30]	[2.30]
0.01	1.6936	0.288	0.073
	(0.75)	(0.38)	(0.16)
	[0.44]	[1.32]	[2.30]

Note: The numbers in the table are time-varying coefficient averages at each specified, δ. The numbers in parentheses are time-varying coefficient standard deviations and coefficient of variations respectively at each specified, δ.

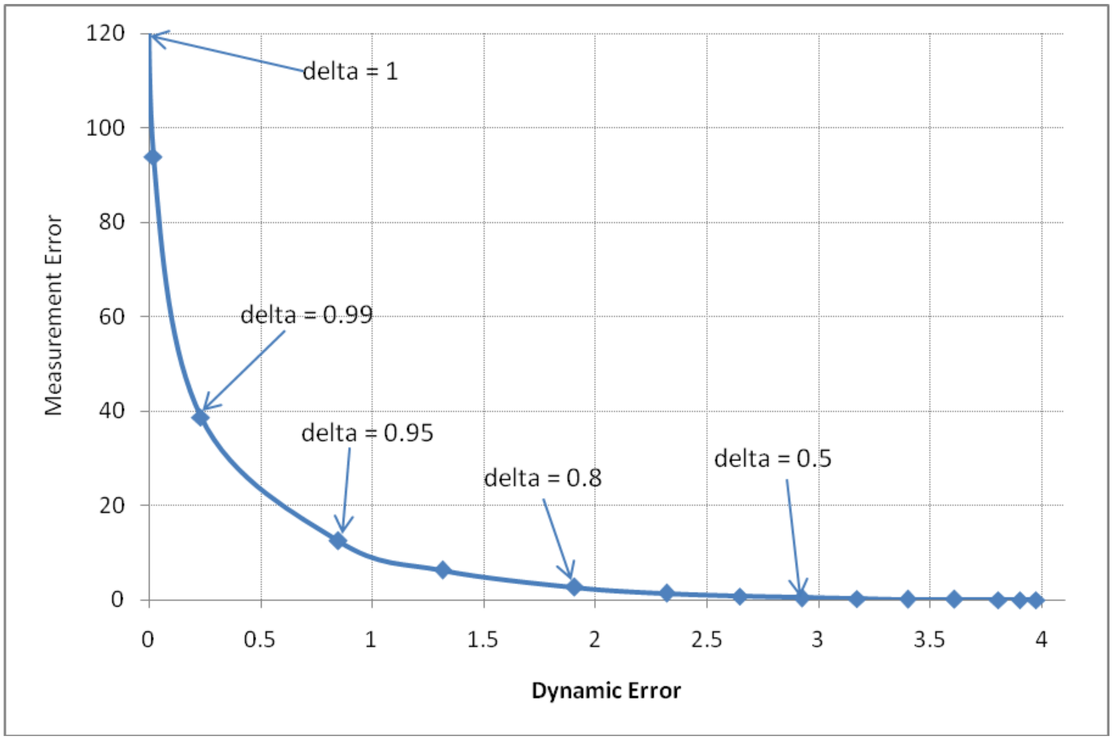

Figure 2. Residual Efficiency Frontier for inflation model

The REF plots squared residual-measurement error on the vertical axis and the squared residual-dynamic error on the horizontal axis. The downward sloping curve is that set of all pair combinations of, r_M^2, r_D^2, which attain the REF conditional on, δ. The slope of the frontier can provide a qualitative indication of whether or not the OLS (i.e., fixed coefficient) solution provides a good description of the data generating process. In figure 2, the residual efficiency frontier is quite steeply sloped in a neighbourhood of the OLS extreme point ($\delta = 1$). This suggests that permitting even a very small degree of time variation in the coefficients of model result in large decreases in measurement error, thereby, providing strong evidence that at least some of the coefficients are changing through time.

With this evidence we now proceed to estimate our model (2.7) by ML method using the Kalman filter algorithm. For this first the model is cast in state space form and the parameters of the measurement equation are allowed to vary. Figure 3 plots the Kalman Filter (smoothed) estimates for parameter, a_{2t}, for the entire sample period. The light time path line represents the time path of the coefficient, while the dark time path lines represent a 95% confidence interval around the coefficient value.

The evolution of the slope coefficient points to a significant difference in the way monetary policy was conducted pre- and post-1979, the year Paul Volcker was appointed Chairman of the Board of Governors of the Federal Reserve System. The estimates suggest that the pre-Volcker regime contained the seeds of macroeconomic instability that seemed to characterize the late sixties and seventies. Notice that the slope coefficient was significantly higher in the pre-Volcker era, suggesting that the Fed was highly "accommodative" during this period. This policy response coupled with adverse supply shocks (increase in the price of oil) led to high and volatile inflation in the 1970.

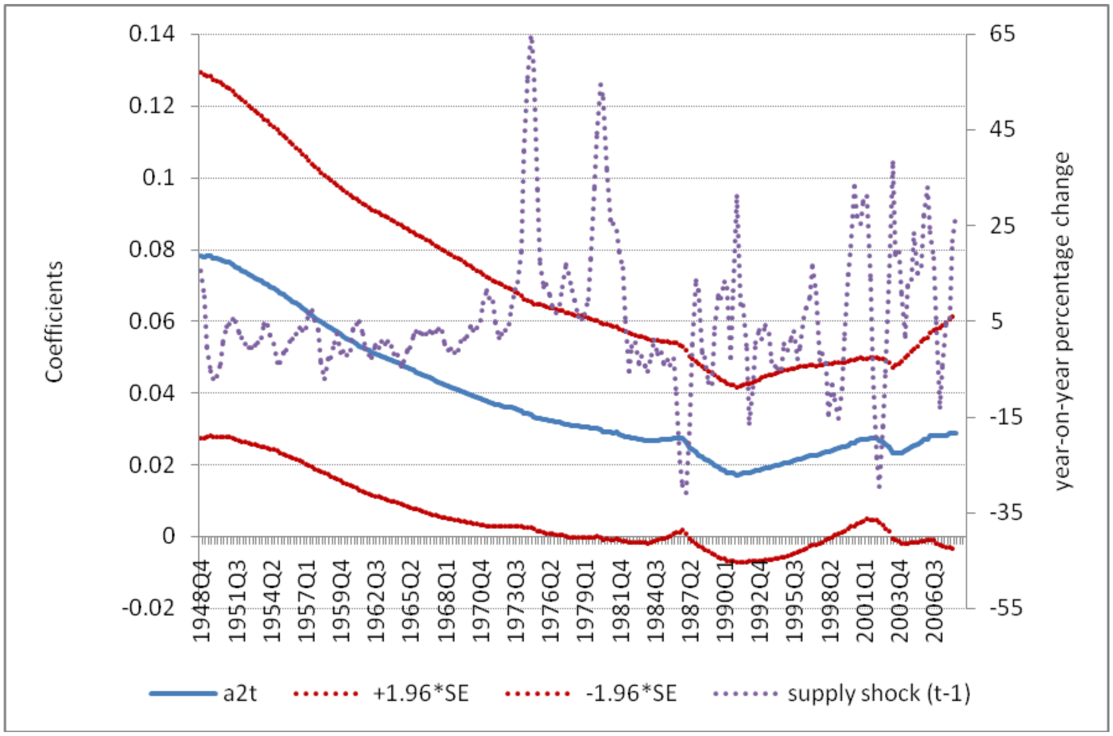

Figure 3. Kalman Filter estimates of slope coefficient and supply shock

By the end of the 1970s, inflation had reached levels unheard of in peacetime (popularly dubbed the "Great Inflation"). Public opinion eventually turned against allowing inflation to continue. Politicians, in turn, came to accept the need for an abrupt tightening of policy. Political and popular support allowed Volcker to take decisive action against inflation, which involved monetary tightening and the raising of policy interest rates to double digits.

In 1980, Volcker explained the policy (cited in Romer and Romer 2004, p.145): "*In the past, at critical junctures for economic stabilization policy, we have usually been more preoccupied with the possibility of near-term weakness in economic activity or other objectives than with the implications of our actions for future inflation. . . . The result has been our now chronic inflationary problem. . . The broad objective of policy must be to break that ominous pattern. . . . Success will require that policy be consistently and persistently oriented to that end. Vacillation and procrastination, out of fears of recession or otherwise, would run grave risks*".

Indeed, our estimates point to a significant decline in the slope coefficient during the Volcker regime, suggesting that the Fed under Volcker (and later under Greenspan) adopted a more proactive stance toward controlling inflation (lower, λ). By the time Greenspan took office inflation was already well within single digits. It was during Greenspan's regime (1987:3-2006:1) some senior policymakers at the Fed argued for 'opportunism' in monetary policy and opposed the setting of a single central inflation target.

Was the Greenspan Fed opportunistic? Figure 4 plots our proxy for supply shocks along with Kalman filter estimates of the slope coefficient. The behaviour of the slope coefficient during this period suggests that adverse inflation shocks were offset through monetary policy; but favourable inflation shocks were accommodated. That is, when inflation rate was strengthening owing to adverse supply side developments (for example during the Gulf War in 1990-91) the Greenspan Fed actively tried to dampen it by lowering, λ. As a result the slope coefficient, a_{2t}, fell in response to adverse shocks. In contrast, when the economy was producing lower inflation via a favourable burst of circumstances, for example in the late 1990s, output stabilization objective gained precedence (λ rose). As a result the slope coefficient, a_{2t}, rose in response to favourable supply shocks. In sum, the behaviour of the slope coefficient during this period is consistent with the opportunistic approach to disinflation.

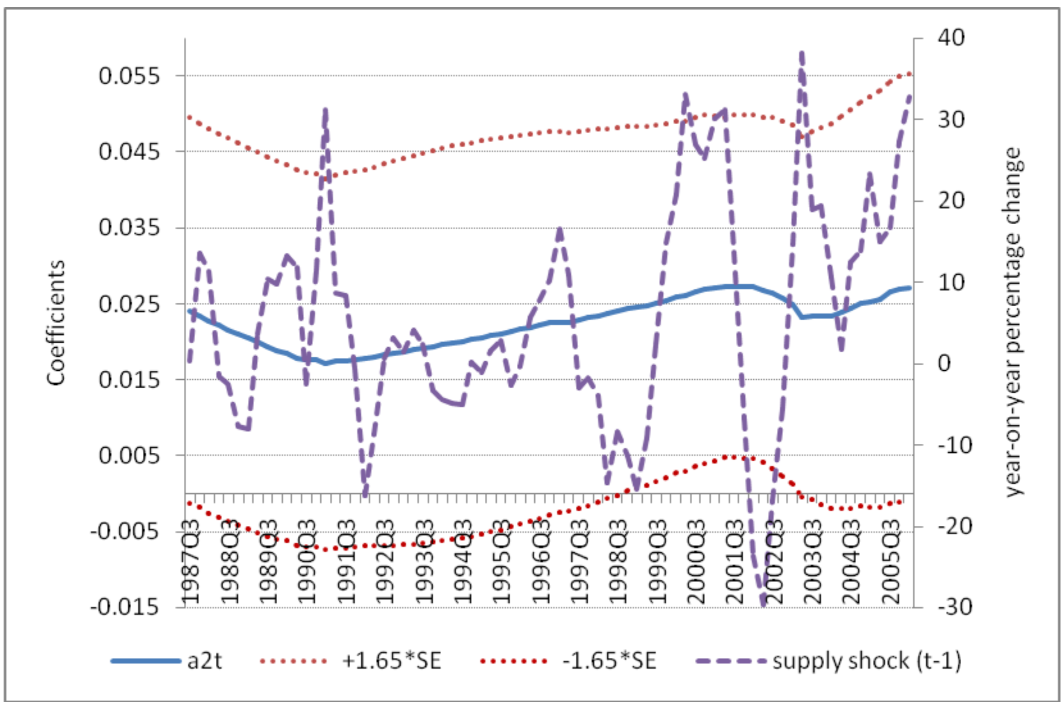

Figure 4. Kalman Filter estimates of slope coefficient and supply shock: Greenspan Regime

Should one take our results and interpretation seriously? An obvious limitation of our identification strategy is that the slope parameter, a_{2t}, is not a structural parameter. It can vary for a variety of reasons other than changes in changes in preferences. For example, changes in the slope of the Phillips curve (parameter, α_t) or time-variation in the persistence coefficient (ρ_{1t}) can cause time-variation in, a_{2t}. If so, our identification strategy could mistakenly attribute time-variation in a_{2t} to changes in the preference parameter, λ.

One possibility for why the slope coefficient fell (rose) in response to adverse (favourable) supply shocks during the Greenspan regime is that the Phillips curve become steeper (flatter). Another possibility for why the slope coefficient feel (rose) in response to adverse (favourable) supply shocks is that the persistence parameter fell (rose) during the Greenspan regime. For this the Phillips curve slope and/or the persistence coefficient should vary in response to supply shocks. We believe that there is no theoretical basis for this. As a result we attribute time-variation in the slope coefficient as predominantly arising due to changes in the preference parameter.

5. Conclusion

Central banks in different countries have adopted different strategies for achieving price stability. One strategy for disinflation prescribes a deliberate path toward price stability. In contrast to a deliberate approach, an opportunistic strategy for disinflation has recently gathered attention. We empirically evaluate this hypothesis using U.S. data.

Our results lend support to the view that the Greenspan Fed gave higher weight to inflation stabilization when inflation was strengthening, but higher weight to output stabilization objective when the economy was producing lower inflation via favorable supply shocks. This suggests that representing monetary policy during the Greenspan regime in terms of a linear reaction function may not be appropriate.

Our results are, of course, dependent upon the modeling choice that we have made, but still we see them as useful, not for their precise quantitative answers, but for the qualitative support it provides for the opportunistic approach to disinflation.

References

Aksoy, Yunus., Orphanides, Athanasios., Small, David., Wieland, Volker and Wilcox, David, (2006). "A quantitative exploration of the opportunistic approach to disinflation," *Journal of Monetary Economics*, vol. 53(8), pages 1877-1893.

Anderson, B. D. O. and Moore, J. B. (1979). *Optimal Filterinng*, Englewood Cliffs: Prentice-Hall.

Blinder, Alan S. (1994), 'Prepared Statement', in *Nominations of Alan S. Blinder, Steven M. H. Wallman and Philip N. Diehl*. Hearing Before the Committee on Banking, Housing, and Urban Affairs, United States Senate, Washington DC: US Government Printing Office.

Blinder, A.S., (1997) 'What Central Bankers Can Learn from Academics - and Vice Versa,' *Journal of Economic Perspectives*, Spring , 3-19.

Bomfim, A., and Glenn. D Rudebusch, (2000). "Opportunistic and deliberate disinflation under imperfect credibility," *Journal of Money, Credit, and Banking*, Vol. 32(4), 707–721.

Clarida, Richard, Jordi Galí, and Mark Gertler (2000). "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory," *Quarterly Journal of Economics*, Vol. 115(1), 147−180.

Cogley, T., and T.J. Sargent (2001), "Evolving Post-World War II U.S. Inflation Dynamics," *NBER Macroeconomic Annual*, pp. 331-73.

Cooley, T.F and E.C. Prescott (1976), "Estimation in the Presence of Stochastic Parameter Variation," *Econometrica*, 44:1, 167-84.

Cukierman, Alex and Anton Muscatelli, (2008), "Nonlinear Taylor Rules and Asymmetric Preferences in Central Banking: Evidence from the United Kingdom and the United States," *Contributions to Macroeconomics*, *Berkeley Electronic Press*, vol. 8(1), pages 1488-1488.

Durbin, J. and Koopman S.J. (2001), *Time Series Analysis by State Space Methods*, Oxford University Press.

Feldstein, Martin (1996) "Price Stability," in Achieving Price Stability, Annual Conference of The Federal Reserve Bank of Kansas City.

Harvey, A. C. (1989). "*Forecasting, structural time series models and the Kalman filter*", Cambridge, U.K.: Cambridge University Press.

Hooker, Mark. A. (2002), "Are Oil Shocks Inflationary? Asymmetric and Nonlinear Specifications versus Changes in Regimes," *Journal of Money, Credit, and Banking*, 34(2), 540—561.

Kalaba, Robert and Leigh Tesfatsion (1988), "The Flexible Least Squares Approach to Time-Varying Linear Regression", *Journal of Economic Dynamics and Control*, Vol. 12, No. 1 (March), 43-48.

Kalaba, Robert and Leigh Tesfatsion (1989), "Time-Varying Linear Regression Via Flexible Least Squares", *Computers and Mathematics with Applications*, Vol. 17, pp. 1215-1245.

Lucas, Robert E. Jr. (1976), "Econometric Policy Evaluation: A critique," *Carnegie Rochester Conference Series on Public Policy*, 1, 19-46.

Lütkepohl, Helmut (1993), "The Sources of the U.S. Money Demand Instability," *Empirical Economics* 18(4), 729-743.

Martin, Christopher and Costas Milas (2010), "Testing the Opportunistic Approach to Monetary Policy," *The Manchester School*, Vol. 78, No. 2, pp. 110-25.

Meyer, Lawrence.H., (1996) 'Monetary policy objectives and strategy' speech at the National Association of Business Economists 38th Annual Meeting, Boston, Massachusetts, September.

Minford, Patrick., and Naveen Srinivasan, (2006) "Opportunistic monetary policy: An alternative rationalization," *Journal of Economics and Business*, vol. 58(5-6), pp. 366-372.

Orphanides, Athanasios. and David Wilcox (2002). 'The Opportunistic Approach to Disinflation', *International Finance,* 5, pp 47-71.

Romer, Christina. D and David. H. Romer, (2004), "Choosing the Federal Reserve Chair: Lessons from History," *Journal of Economic Perspectives*, Vol. 18(1), pages 129-62.

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