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Market Volatility and Central Bank Money Supply Dynamics

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Abstract

Monetary policy made in the real world has to deal with various sources of uncertainties. Ignorance of this aspect in the theoretical formulation causes a gap between the promise of theory and the reality of practice. In this paper, I investigate rigorously the various effects of economic uncertainties on monetary policy making. Based on the economic model of US economy, I show that failing to account for certain economics uncertainties can generate a serious distorted macroeconomic outcomes and result inefficient policy rules. When these uncertainties are taken into account, policy reactions appear a cautionary effect and are less sensitive to the shocks of the economy. In addition, I analyze the effect of the cautionary behavior associated with the uncertainty, especially the trade-off between "caution" and "intensity" when future uncertainty increases.

1. Introduction

A common implicit assumption in policy evaluations is that policymakers observe the current state of the economy accurately (say, without uncertainty) and therefore adjust policy based on this information. However, in reality, decisions are made when there is considerable uncertainty about the economy. For example, exogenous shocks like oil prices changes, or multiplicative uncertainty etc. In those cases, policy is made with partial information.

In this paper, I use an economic model of U.S. economy to evaluate alternative policy rules and to assess the degree of monetary policy responsiveness to inflation and aggregate economic fluctuations. First, I start with a benchmark model assuming the policymaker can predict all model parameters promptly and accurately. Then I develop a parallel experiment in which the policymakers face an economy with various uncertainties. By comparing the results of these alternative models, I show strong evidence of various impacts of future uncertainties on optimal monetary policy design.

The general model with uncertainty leads to a cautious behavior associated with model parameter uncertainty. Mercado (2002) analyzes the trade-off between "caution" and "intensity" in control variable in a one-state, one-control case with a single uncertain parameter, and concludes that the trade-off depends on the timing of the uncertainty. For example, given an increase in current uncertainty and an equal increase in future uncertainty, the caution effect will prevail over intensity. Mercado and Kendrick (2000) analyze a one-state, two-control model , they show that given a rise in future uncertainty, the use of at least control will increase in the first period, and the trade-off between caution and intensity depends on the relative magnitude of those controls' first-period weighted variances. In this study I extend the work by Mercado (2002) and examine if the result holds when there are multiple sources of uncertainty.

I use the deterministic model in Ball (1999) as a benchmark model and I develop a stochastic model incorporating various sources of economic uncertainties. The model performance is tested by Monte Carlo simulation. The experiment results show that (1) there is a cautious effect associated with model parameter uncertainty;

(2) for a given increase in the current uncertainty and an equivalent increase in the future uncertainty, the prevalence of caution will be reduced as the increase in future uncertainty expands into the future. This expansion induces a growing intensity in the first-period reaction to the unpredicted shocks. These findings have important implications for monetary policy design and implementation.

The paper is organized as the follows. Section two describes the basic characteristics of the model with uncertainty; Section three reports the empirical results; and section four discusses and concludes the paper.

2. Model And Methodology

To maintain economic stabilization, central bank will set a target inflation level and apply appropriate monetary policy to achieve the target. In general, there are two types of uncertainties in the economy—exogenous shocks and endogenous shocks. The exogenous shocks presented by additive shocks, such as oil price changes, can be captured by the mean parameter values to the system equations. However, for the endogenous shocks, the parameter is constant but unknown. In this case the uncertainty is captured by the covariance of the parameters. Therefore, policy maker should consider not only the mean value of the parameter but also the covariance estimates. The importance of parameter covariance when the policy makers consider any macroeconomic policy was documented in Amman Kendrick (1999). They state that "the potential damage from ignoring the variances and covariance of the parameter estimates is substantial and that taking them into account can improve matters."

The problem that the central bank faces in this model is to minimize a quadratic criterion function subject to linear constraints. In every period the evolution of inflation and output depends on four factors: the levels of inflation, output in the previous period, monetary policy and random shocks. Inflation is determined by an accelerated Phillips curve:

$$\pi_t = \pi_{t-1} + \alpha_y y_{t-1} + \varepsilon_t \qquad (1)$$

Where α is positive. Output is determined by lagged output and interest rates according to

$$y_t = \beta_y y_{t-1} + \beta_r r_{t-1} + \upsilon_t \qquad (2)$$

where π_t is the gap between inflation in period *t* and its long-run target; y_t is the output gap; r_t is the real interest rate (measured as deviation with respect to its long run level), and ε_t and υ_t are serially uncorrelated mean-zero stochastic shocks. α_y, β_y and β_r are constant and unknown parameters. The stochastic shocks in this economy are summarized by a disturbance to inflation, ε_t, which can be seen as capturing "supply" shocks, and a disturbance to output, υ_t, captures "demand" shocks.[1]

Equation (1) is a standard accelerated Phillips curve. Equation (2) is a standard output gap equation (a dynamic IS curve). Notice that in this set-up monetary policy has a two-period control-lag over inflation. In this exercise, I will treat the estimated parameter as the true constant parameters, where α_y =0.5, β_y =0.6 and β_r =-0.4[2].

In this model, inflation and output is the two state variables and risk-free-rate is the control variable. Central bank is to choose a sequence of interest rates $\{r_{t+\tau}\}_{\tau=0}^{N-1}$ to minimize the following target function:

[1] For simplicity, I assume that these disturbances are drawn from independent normal distributions with zero means and variances σ_ε^2 and σ_υ^2. Monetary policy operates with a lag, and consequently the policymaker can never completely offset the effects of contemporaneous shocks on output and inflation since policy can be adjusted until the end of any given period, however, I follow the usual assumption that the policymaker utilizes all information at his disposal including information regarding the contemporaneous shocks for period *t* before setting the interest rate. Thus, the policymaker can set the interest rate in response to his observation of contemporaneous inflation and output.

[2] From estimations.

$$J = E\left\{\frac{1}{2}\left[x_T - x_T^*\right]' W_T \left[x_T - x_T^*\right] + \frac{1}{2}\sum_{t=0}^{T-1}\left\{\left[x_t - x_t^*\right]' W_t \left[x_t - x_t^*\right] + \left[\mu_t - \mu_t^*\right]' \lambda_t \left[\mu_t - \mu_t^*\right]\right\}\right\} \quad (3)$$

Subject to the system of equations:

$$x_{t+1} = A_t x_t + B_t \mu_t + C_t + \xi_t, \quad t=1, 2, \ldots, T\text{-}1 \qquad (4)$$

Where ξ_t = vector of additive noise terms in period t, given the initial condition x_0. Where x_t and x_t^* are the optimal and desired vectors for the state vector in period *k*. the diagonal matrix W_t and the diagonal matrix λ_t are the penalty matrices on deviations of state and control variables from their desired path respectively. μ_t and μ_t^* are the optimal and desired levels of the control variables. For comparison purpose, I calibrated the following matrices based on Ball (1999).

$$A = \begin{bmatrix} 1 & 0.5 \\ 0 & 0.6 \end{bmatrix}$$

$$B = \begin{bmatrix} 0 \\ -0.4 \end{bmatrix}$$

$$C = \begin{bmatrix} 0.0001 \\ 0.0001 \end{bmatrix}$$

$$W = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$\lambda = \begin{bmatrix} 100 & 0 \\ 0 & 100 \end{bmatrix}$$

The covariance of the additive noise term and the covariance of the uncertainty parameters are:

$$Q = \begin{bmatrix} 0.0009 & 0 \\ 0 & 0.000225 \end{bmatrix}$$

$$\theta = \begin{bmatrix} 0.04 & 0 & 0 \\ 0 & 0.0049 & 0 \\ 0 & 0 & 0.0256 \end{bmatrix}$$

To solve the objective function and obtain the feedback rule I use two methods: Certainty Equivalence (CE) and Open Look Feedback (OLF).[3] The main difference between the two methods are that CE uses the mean values of the parameter estimates and ignore any random term in the system of equations, while OLF uses both the mean and the covariances of the parameter estimates. Therefore, the OLF method takes into account the model uncertainty represented by the covariance matrix of the parameters.

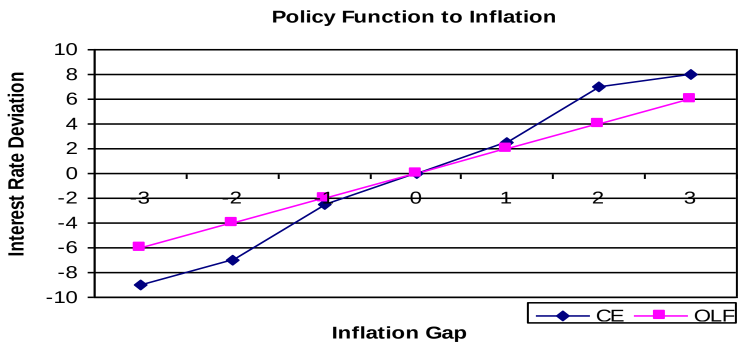
3. Empirical Results

I run 1000 Monte Carlos iterations for each type of method. The quadratic tracking function is calculated in each iteration.[4] There are different types of scenarios faced by the central bank. For simplicity, I change the value of π_0 as if the economy has been hit by a shock that only affect the price level, the range of deviation of inflation from its target goes from (-3, 3). The optimal reaction function is shown in Figure 1.

[3] See Amman and Kendrick (1999a) and Kendrick (2000).

[4] See Kendrick (1982).

Figure 1
The Optimal Reaction Function



It is easy to see that the CE solution is more aggressive than the OLF, one plausible explanation is that since the CB is ignoring the fact that the parameter are stochastic, it can be more certain on how the economy will react to its action. The OLF solution shows a more cautionary reaction, since with the recognition of both types of uncertainties it is better react in a more conservative manner.

Table 1
Criterion Value for CE versus OLF

	Mean	Standard Dev.
Certainty Equivalence	145.36	157.88
Open Loop Feedback	96.32	28.21

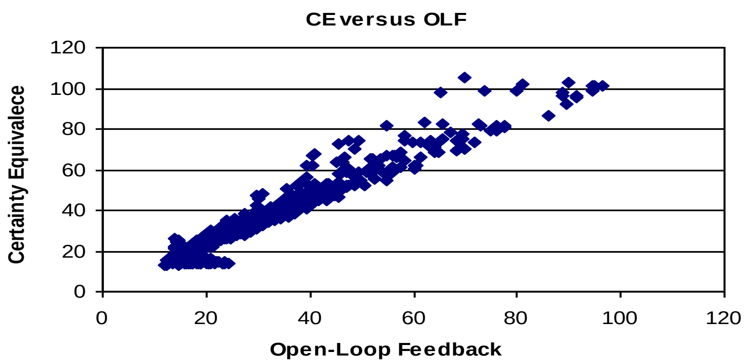
Table 1 reports the criterion values in terms of mean and standard deviation for CE method and OLF method respectively. It shows that the OLF method performed substantially better job than CE not only in terms of the value of the criterion, but also in terms of the standard deviation. This implies that First, the uncertainties of the parameter values are sufficiently large that they cannot be safely ignored. And second, the method of passive learning (OLF) can significantly improve policy outcomes.

Table 2
No. of Runs with the Lowest Criterion Value

Certainty Equivalence	583
Open Loop Feedback	429

Table 2 reports the number of runs on which CE or OLF achieves the lowest criterion value. CE has the lowest criterion value much often than OLF. It seems that the CB is better off by ignoring the uncertainty in the parameters. Nevertheless, in an important number of cases wrong parameters estimates lead the CE solution to an important mistake. This could be seen in the following figure. In figure 2, the points lie on the 45 degree line when the CE and OLF criterion values are equal on a Monte Carlo run. From this figure, we can observe significant amounts of outlier lie on the CE side of the graph. The greater amounts of points above the 45 degree line imply that CE method has higher average cost compared to the OLF method. This result is consistent with Amman and Kendrick (1999b).

Figure 2
Average Cost Comparison



Therefore, if the policy makers use CE method and ignore the parameter uncertainty, they will do well if the estimates are *close* to the true parameter, which is the case when economy is fair stable and there is not much uncertainties in the future. However, if the parameter estimates are *not close* to the true parameter, or when future uncertainties are unpredictable, then the policy makers run into high risk of destabilizing the economy using a strong policy. In these cases, OLF method will do a much better job in that the policy makers are more cautious about using policy variables than CE method. Therefore, the results suggest a more conservative approach for the policy makers who pursue an optimal monetary policy rule.

Next, will extend the work by Mercado (2002) and examine if the result holds when there are multiple sources of uncertainty. I will focus on the analysis of the first-period behavior and apply the Open Loop Feedback with parameter updated using Kalman filter.[5]

For simplicity, I assume parameter β_r is unknown and $\sigma^2_{\beta_r}$ =0.0256. The covariance between the two parameters is fixed at zero for simplicity, so that the variance-covariance matrix is a diagonal matrix. The corresponding first-period optimal response is $r_{0(base)}$ =0.15. I examine the effect on the first-period use of the control variables of an temporary increase in $\sigma^2_{\beta_r(T)}$ to 0.05 with $T \in \{1,2,3,4,5,6\}$.

Increase in current uncertainty (T=1) induces a more cautious first-period response than the baseline response, while more intensity is apparent when the increase in uncertainty occurs in the future. As the increase in uncertainty moves farther away into the future (T=2, 3, 4,5 and 6), the intensity of the first-period use of *r* decreases, yet the magnitude of $r_{\beta 0}$ still remains above $r_{\beta 0(base)}$ so that a future increase in the variance of β_0 has the effect of making *r* to be used more intensively in the first period.

Table 3
Caution vs. Intensity Effect

T	$r_{\beta 0}$	$\lvert r_{\beta 0} - r_{\beta 0(base)} \rvert$
1	0.36	0.21
2	0.33	0.18
3	0.27	0.12
4	0.22	0.07
5	0.18	0.03
6	0.16	0.01

The absolute value of the different between the policy response from the experiments is larger for T=1 (current uncertainty increase) than any other case. This finding confirms that “caution prevails in all cases.”

4. Conclusion

In this paper, I investigate the effects of various parameter uncertainties on the optimal monetary policy using a economic model of US economy. The results show that in the absence of noise, deterministic model without capturing future uncertainty could substantially improve upon the actually macroeconomic performance. However, this improvement is illusory—it provides a seriously distorted picture of feasible outcomes that would occur once the uncertainty in the economy is taken into account. I apply CE versus OLF method for comparison. Empirical results showed that CE outperforms OLF if the policymakers start at the points where the predicted parameter values are very close to the true parameters. But if the parameter estimates are not close to the true parameter, the policy maker run into high risk of destabilize the economy through a strong policy. By using OLF, the policy maker is more cautious about using policy variables than CE method. Therefore, the policy reactions appear a cautionary effect and are less sensitive to the shocks of the economy.

[5] See Mercado and Kendrick (2000).

Moreover, I analyze the effect of the cautionary behavior associated with the uncertainty and the trade-off between "caution" and "intensity" when future uncertainty increases. I extend Mercado (2002)'s analysis, and modified his conclusion for the case in which there are more than one source of uncertainty. I find that for a given increase in the current uncertainty and an equivalent increase in the future uncertainty, the prevalence of caution will be reduced as the increase in future uncertainty expands into the future. This expansion induces a growing intensity, though at a decreasing rate, in the first-period reaction to the unpredicted shocks.

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