ARE TAYLOR-BASED MONETARY POLICY RULES FORWARD-LOOKING? AN INVESTIGATION USING SUPEREXOGENEITY TESTS

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Abstract

Unlike previous studies which use statistical break tests to analyze the forward-lookingness of monetary policy rules, this study proposes the methodology that if the parameters of the Taylor rule change when the mechanism generating inflation changes, that is the Lucas critique applies, then inflation is not superexogenous for the parameters of the Taylor rule. In this case where superexogeneity fails, the rule is forward-looking. However, although the results indicate that the volatility of inflation (captured by a discrete heteroskedastic variance model of regime shifts) reduced by almost 50 percent, we fail to reject the null that inflation is superexogenous to the parameters of the Taylor rule. This implies that there is no evidence that Taylor-based monetary policy rules are forward-looking.

JEL Classification: C52, E52

Keywords: Taylor Rules, Forward-looking, Superexogeneity Tests

1. Introduction

One of the key challenges that face U.S. monetary policymakers is whether monetary policy rules of the Taylor (1993) type are forward-looking or backward-looking. The basic structure of the Taylor-type policy rule models the short interest rate (the Federal Funds rate) as a function of the inflation gap, the output gap and an interest rate smoothing component. The general notion in the literature is that a variable is forward-looking if it depends on expectations of future variables. Svensson (2003) notes that, formally, a variable is forward-looking if it depends on expectations of future variables and has endogenous one-period-ahead forecast errors. Conversely, a variable is backward-looking if it depends on its past values. An extension of this idea to monetary policy rules would then suggest that interest rate rules are forward-looking if they contain some measures of expected inflation and/or output gap, and backward-looking if the indicator variables enter as lagged representations. However, this paper argues that a more formal test is needed before we can conclude whether a rule feeds forward or backward.

The type of tests that this paper deals with invokes the Lucas (1976) critique and the superexogeneity test of Engle and Hendry (1993). According to the Lucas critique, changes in policy affect the behavior of rational agents and such behavioral changes can invalidate the model relationships estimated under the previous policy regime. In other words, shifts in economic policy change how policy affects the economy because agents in the economy are forward- rather than backward-looking and adapt their expectations

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and behavior to the new policy stance (Linde, 2001). Empirical studies of monetary policy rules suggest that the behavior of the U.S. monetary policymakers changed during the past few decades (Judd and Rudebusch (1998), Taylor (1999), Clarida, Gali and Gertler (1999), and Estrella and Fuhrer (2000)). These studies found that the parameters of the rules are not stable. This evidence would suggest that the Lucas critique holds. However, at the same time, models with lagged representations of the economy such as Vector Autoregressions (VARs) often did not exhibit any structural instability (Bernanke and Mihov (1998), Estrella and Fuhrer (2000), Leeper and Zha (2001)). Recognizing that these two sets of empirical results appear to contradict the Lucas critique, Rudebusch (2003) attempts to reconcile this discrepancy by showing that the apparent policy invariance of reduced form models like the VARs is consistent with the magnitude of historical policy shifts and the relative insensitivity of the reduced forms of forward-looking models.

However, the issue of forward-lookingness still remains unsettled. Studies that investigate the forward- or backward-lookingness of reaction functions derive their conclusions based solely on statistical break or stability tests of the Chow type, Lagrange multiplier (LM) test of Andrews and Fair (1988), predictive test (TS) of Ghysels and Hall (1990), or multiple unknown breakpoints test of Bai (1999). Using these kinds of stability tests and simulation techniques, Estrella and Fuhrer (2003) and Rudebusch (2003) find that the magnitude of the Lucas effect – the reaction of agents' behavioral equations to structural changes in policy – has not been very large in practice.

To help solve the divergence of views on the forward- versus backward-lookingness of policy rules this paper proposes a methodology using superexogeneity tests. The methodology is to test whether the target variable, say, inflation, is superexogenous to the parameters of the Taylor-type rule. If the parameters of the Taylor-type rule change when the mechanism generating inflation changes – that is the Lucas critique applies – then inflation is not superexogenous for the parameters of the Taylor rule. In this case where superexogeneity fails, the rule is forward-looking. The implication of this is that the Fed cannot change the process that determines inflation without affecting the process that determines the Federal Funds rate. Interestingly, this paper shows that the null that inflation is superexogenous to the parameters of the Taylor rule cannot be rejected over the 1983Q1 to 2002Q2 period. This implies that there is no evidence that Taylor-based monetary policy rules are forward-looking.

2. The Superexogeneity Test Methodology

In the literature, the practical application of the superexogeneity tests is due to Engle and Hendry (1993). Other studies such as Caporale (1996), Darrat *et al* (1998) and Perez (2000) are simplified versions of it. Engle and Hendry (1993) describe a testing methodology based on the superexogeneity concept of Engle, Hendry and Richard (1983). This requires the specification of the conditional and marginal distributions of the variables of interest. In terms of our Taylor-type monetary policy rule the immediate variables of interest are the Fed Funds rate and the inflation gap. The inflation gap, π_t, is measured as the deviation of inflation from a 2 percent target level, which is the target

inflation rate usually used in the literature for price stability. Inflation is calculated following the standard procedure in the Taylor rule literature, that is, the percentage change in the Gross Domestic Product (GDP) price deflator over the previous four quarters. All data are obtained from the St. Louis Federal Reserve Bank online database for the sample period 1983Q1 to 2002Q2. Then the joint distribution of the Federal Funds rate, r_t, and the inflation gap, π_t, can be written as:

$$D_J(r_t, \pi_t \mid F_t; \theta_t) = D_C(r_t \mid \pi_t, F_t; \theta_{1t})\, D_M(\pi_t \mid F_t; \theta_{2t}) \quad (1)$$

where D_J, D_C, and D_M denote the joint density, the conditional density of r_t given π_t, and the marginal density of π_t, respectively, and θ_t, θ_{1t}, and θ_{2t}, the corresponding parameters. F_t represents the field of information including past values of r_t and π_t as well as current and past values of other valid conditioning variables. By Engle and Hendry (1993), π_t would be defined as being superexogenous for θ (a set of parameters of interest) if π_t is weakly exogenous for θ and θ_1 is invariant to changes in θ_2 (i.e. changes in θ_2 do not imply changes in θ_1). π_t is defined as weakly exogenous for θ if θ is a function of the parameters θ_{1t} alone, and θ_{1t} and θ_{2t} are variation-free (that is, over periods of constant θ_{2t} there is no information in θ_2 that would help estimating θ_1 (Engle, Hendry and Richard (1983)). The important distinction between weak and superexogeneity is that weak exogeneity is sufficient for the conditional model to be used in forecasting analysis, whereas policy analysis requires superexogeneity. Pearl (2000) notes that superexogeneity (or what she calls exogeneity) is a notion that captures economists' interest in the structural invariance of certain relationships under policy intervention.

The conditional distribution of the Fed Funds rate is in fact an augmented Taylor rule which can be specified as follows:

$$\begin{aligned} r_t &= \pi_t \beta + z_t' \gamma + u_t \\ &= \beta_0 \pi_t + \gamma_0 r_{t-1} + \gamma_1 + \gamma_2 y_t + u_t \end{aligned} \quad (2)$$

where z_t represents the vector of all other conditioning variables like the lagged Fed Funds rate, r_{t-1}, and the output gap, y_t. The output gap is measured as the percentage deviation of real Gross Domestic Product from real potential GDP as calculated by the Congressional Budget Office (CBO). β and γ are the parameters of the model. This augmented Taylor rule is quite standard in the literature (see Taylor (1999), Kozicki (1999), Woodford (1994, 1999, 2001)). u_t is the error term that follows a stationary AR(1) process:

$$u_t = \rho_0 u_{t-1} + v_t, \; v_t \sim NID(0, \sigma^2), \; |\rho_0| < 1. \quad (3)$$

To test the null hypothesis that the inflation gap π_t is superexogenous for β, we first need to specify the marginal distribution of π_t. Suppose there is a set of instruments Z_t, including z_t, which describes the mean of π_t through:

$$\pi_t = Z_t'\psi + \eta_t \qquad (4)$$

The construction of Z_t is assumed to allow for and define regime shifts in the data generating process of π_t . This specification gives wide scope to specifying changes in policy regime, expectations formation, or states of nature. Essentially equation (4) represents a Phillips curve with the vector Z_t containing the inflation and output gaps. ψ represents the parameters of the marginal distribution and η_t denotes the error term.

Following Engle and Hendry (1993), the superexogeneity test can be formulated based on the following regression:

$$r_t = \pi_t\beta_0 + z_t'\gamma + (\delta_0 - \beta_0)\hat{\eta}_t + \delta_1\sigma_t^2\hat{\eta}_t + \beta_1\hat{\pi}_t^2 + \beta_2\sigma_t^2 + \beta_3\hat{\pi}_t\sigma_t^2 + \varepsilon_t \qquad (5)$$

where σ_t^2 is the conditional variance of η_t. This specification allows for heteroskedasticity in the error term of (4). Then to test the null hypothesis that the inflation gap, π_t , is superexogenous for β_0, we perform the following joint test:

$$H_0 : \phi_1 = \delta_1 = \beta_1 = \beta_2 = \beta_3 = 0 \qquad \text{where } \phi_1 = \delta_0 - \beta_0. \qquad (6)$$

3. Estimation Results

Phillips Curve Marginal Equation. Different studies in the literature provide different specifications of the Phillips curve. Some are what is referred to as forward-looking (Roberts (1995), McCallum and Nelson (1999), Clarida, Gali and Gertler (1999), and Svensson (2003)), and some with inflation inertia (Bomfim and Diebold (1997) and Razzak (2002)). However, some studies such as Fuhrer (1997), Fair (1993), Chadha *et al* (1992), Roberts (1995, 2001), Laxton et al (1998), Rudebusch and Svensson (1999), Rudebusch (2001), and Estrella and Fuhrer (2003) argue that there is some evidence that expectations in Phillips curve are backward-looking. Our estimation results seem to support the specification of Phillips curve that has a lagged representation of inflation and output gap:

$$\pi_t = \underset{(11.39)}{1.253}\pi_{t-1} - \underset{(-2.48)}{0.277}\pi_{t-2} + \underset{(1.81)}{0.030}y_{t-1} + \eta_t \qquad (4')$$

R^2=0.93, LM=0.27 [p-value=0.87]

where the numbers in parentheses represent t-statistics, R^2 is the coefficient of determination and LM is the Lagrange-Multiplier test for serial correlation. This result is consistent with the findings in the literature: there is a great deal of inertia in the inflation process while the output gap is mildly important. While there is no serial correlation in the residuals, we model below the possibility of heteroskedasticity.

Since the construction of Z_t in (4) is assumed to allow for and define regime shifts in the data generating process of π_t , we perform a series of Chow breakpoint and dummy variable tests for specific dates where we believe *a priori* (based on underlying economic reasons) that there could be a certain structural change in the inflation process. For instance, Chairman Greenspan is believed to have been successful in controlling inflation. So, we carried out a Chow breakpoint test for 1987Q2 to allow for any regime shift that

could possibly exist when Greenspan was appointed. Such a point was also identified by Estrella and Fuhrer (2003). However, the test turns out to be insignificant with an F statistic of 1.12 [p-value=0.35]. Similar tests for the 1987 stock market crash, the 1990 S&L and Persian Gulf crises, the 1994 Mexican Peso crisis, the 1997 Pacific Rim crisis and the 1998 Russian Default crisis fail to identify any structural break. However, the Chow breakpoint test captured the 2001 recession, the F statistic being 4.48 [p-value=0.01]. In fact, in 2001, inflation was higher than in the surrounding years. To account for the period of high productivity growth in the mid to late 1990s, where inflation declined substantially, dummy variables were included; however, they turned out to be insignificant. Overall, Chow breakpoint and dummy variable tests do not seem to suggest that there is a structural break in the inflation process.

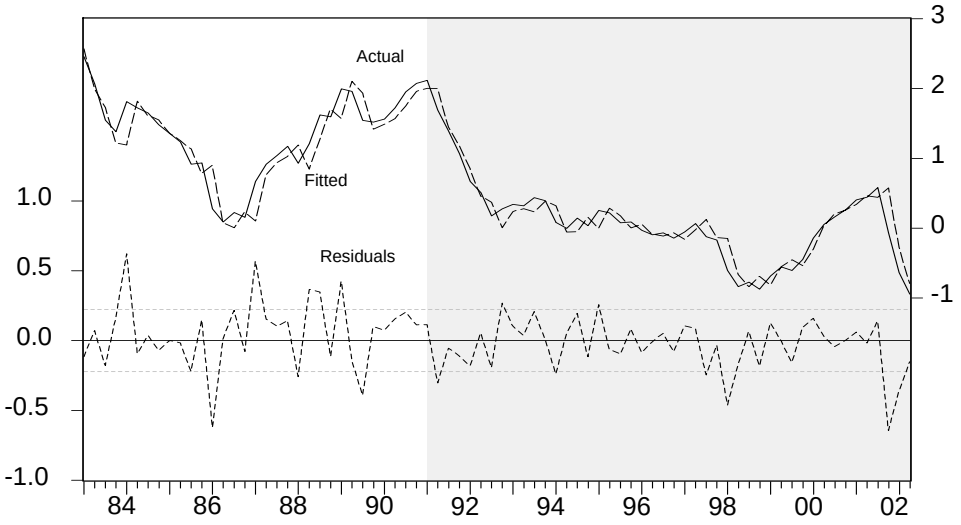

Figure 1. Inflation Gap: Actual (solid), Fitted (dash) and Residuals

However, a closer look at the inflation data in Figure 1 suggests that the volatility of inflation has indeed changed over the sample period. After the 1991 recession, it appears that there has been less variability in inflation (shaded area). Although the residuals (measured on the left scale) from the estimated Phillips curve are within the 2 standard error bounds (dotted straight lines) except for just a couple of years, they tend to be more erratic before 1990-1991 than afterwards. A check on the recursive residuals in the spirit of Hendry (1988) was also done and it also suggests the same. To model for the different regimes of inflation volatility, we allow the variance of the error term η_t in (4) to follow a discrete heteroskedastic process as follows:

$$V(\eta_t) = \alpha_0 + \alpha_1 d_t \tag{7}$$

where d_t is a dummy variable that equals 1 for 1991Q1 onwards and 0 prior to 1991. Using the estimates $\hat{\alpha}_0$ and $\hat{\alpha}_1$ we then construct the following conditional variance series for η_t:

$$\hat{\sigma}_t^2 = \underset{(0.01)}{0.068} - \underset{(0.01)}{0.035} d_t \tag{8}$$

The numbers in parentheses represent standard errors. The coefficient of the dummy variable, being significant and negative and almost half of the intercept term, implies that the variability in the inflation process almost halved for the post-1991 period. Indeed, the 1990s were a period of sustained productivity growth, stock market optimism and confidence, and a hawkish Fed whose primary objective was to maintain price stability. Hence, a reduction in inflation uncertainty seems to be a verified empirical fact.

Conditional Taylor Rule and Superexogeneity Tests. Using $\hat{\sigma}_t^2$ and $\hat{\pi}_t$ we construct $\hat{\pi}_t\ \hat{\sigma}_t^2$ and estimate the model given in (5). The results are as follows:

$$\begin{aligned} r_t = {} & \underset{(2.12)}{2.199} + \underset{(1.06)}{0.600}\pi_t + \underset{(3.46)}{0.346} y_t + \underset{(3.41)}{0.426} r_{t-1} + \underset{(1.47)}{0.897}\hat{\eta}_t - \underset{(-1.21)}{14.484}\hat{\sigma}_t^2\hat{\eta}_t \\ & - \underset{(-0.67)}{0.092}\hat{\pi}_t^2 + \underset{(0.74)}{17.243}\hat{\sigma}_t^2 + \underset{(0.44)}{5.296}\hat{\pi}_t\hat{\sigma}_t^2 \end{aligned} \tag{9}$$

Numbers in parentheses represent t-statistics. Several results fall out from (9). First, as Engle and Hendry (1993) points out, the weak exogeneity of π_t for β_0 in (5) entails a zero effect from $\hat{\eta}_t$. The insignificance of the coefficient of $\hat{\eta}_t$ as shown in (9) implies that the inflation gap is indeed weakly exogenous for β_0. Second, constancy of δ_1 entails $\delta_1 = 0$. Indeed, the result in (9) indicates that the coefficient of $\hat{\sigma}_t^2\hat{\eta}_t$ is not significantly different from zero (t-statistic being -1.21). Third, the invariance of β in (2) entails that $\beta_1 = \beta_2 = \beta_3 = 0$. A joint test produces an F-statistic of 1.93 [p-value=0.133] suggesting that β is invariant. Finally, the joint test that $H_0 : \phi_1 = \delta_1 = \beta_1 = \beta_2 = \beta_3 = 0$ produces an F-statistic of 1.53 [p-value=0.192], indicating that we cannot reject the null that the inflation gap is superexogenous for the parameters of the Taylor rule. This means that there is not sufficient evidence to reject the hypothesis that the Lucas critique fails and the claim that Taylor rules are not forward-looking. Estrella and Fuhrer (2003) showed, through a set of stability tests, that backward-looking reaction functions are more stable and do not undergo parameter instability when policy changes.

4. Conclusion

This study has examined an important policy question, namely whether Taylor-based monetary policy rules are forward-looking. Studies that investigate the forward- or backward-lookingness of reaction functions derive their conclusions based solely on statistical break tests. This study, on the other hand, proposes a simple test of forward-lookingness in policy rules by appealing to the Lucas critique and superexogeneity tests.

The methodology adopted is that if the parameters of the Taylor-type rule change when the mechanism generating inflation changes, that is the Lucas critique applies, then inflation is not superexogenous for the parameters of the Taylor rule. In this case where superexogeneity fails, the rule is forward-looking. To conduct the analysis this study first estimates a Phillips curve of the form that is well established in the literature. Then it carries out a set of structural break tests to identify possible regime shifts. The structural break in the inflation process was best captured by a discrete heteroskedastic variance model which explains the volatility of inflation. However, although the results indicate that the volatility of inflation reduced by almost 50 percent over the second half of the sample period, we fail to reject the null that inflation is superexogenous to the parameters of the Taylor rule. There is also no sufficient evidence to reject weak exogeneity, parameter constancy and structural invariance. Overall, the results suggest that there is no evidence that Taylor-based monetary policy rules are forward-looking.

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