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Nonlinearity and structural breaks in monetary policy rules with stock prices

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ABSTRACT

This paper introduces nonlinearity and a structural break to the US forward-looking Taylor rule with a stock price gap, thereby alleviating the robustness problem that the linear Taylor rule is sensitive to minor changes of the sample period since 1991. The path of the time-varying inflation coefficient shows that, unlike in the linear model, the Fed consistently responds to inflationary pressures in an aggressive manner even after 1991. The stock price coefficient stays positive since 1991. However, its time-varying pattern does not show active responses in the early periods of stock price hikes, which is counter to the view that the Fed has preemptively reacted to stock price bubbles.

1. Introduction

Modeling how monetary policy changes in response to economic circumstances has long been an interesting topic in macroeconomics, for various reasons. The policy reaction function is an important element in macroeconomic models, which helps to forecast changes in the federal funds target rate, plays an important role in evaluating the Federal Reserve's monetary policy, and provides a better understanding of various macroeconomic issues. Robust estimation of the Fed's reaction function is consequently of central importance in empirical macroeconomic analysis.

This paper has two objectives. The first is to examine the Fed's response to stock prices, as well as expected inflation, using a forward-looking interest rate rule with addition of a stock price variable. The role of stock prices in the setting of monetary policy has long been an important issue, both in policy making and in academic research. The current research focuses on two questions: 1) should the Fed respond to a stock price change? and 2) has the Fed responded to stock price changes? This paper does not attempt to answer the first question. For detailed discussion, however, see Bernanke and Gertler (1999, 2001) for the standard policy view that, before a bubble collapses, monetary policy should consider changes in stock prices only when they are strongly associated with future inflation expectations. See also Cecchetti et al. (2000, 2002), Borio and Lowe (2002), Bordo and Olivier (2002), Filardo (2004), Tetlow (2004), Akram et al. (2006) and Kannan et al. (2009), for the alternative policy view that the central bank should preemptively respond to non-fundamental stock price changes to obtain macroeconomic and financial stability. In this paper we focus on the second question, that is, we examine whether and how the federal funds target rate has moved in accord with the movements of stock prices. Existing work suggests non-unified answers to this question. Rigobon and Sack (2003) and Björland and Leitemo (2005) find evidence of monetary policy responses to stock price movements, while Fuhrer and Tootell (2008) and Hayford and Malliaris (2005) show that policy responses to stock price changes are not evident. We can also find various empirical findings analyzing the policy behavior of the European Central Bank (ECB). Botzen and Marey (2010) find that the ECB adjusted interest rates in response to deviations of stock prices from their average values before the recent financial crisis. Siklos et al. (2004) on the other hand, find asset prices to be highly relevant as instruments rather than as separate arguments in forward-looking Taylor rules estimated via GMM.

Most of the existing studies assume that the Fed's reaction process is stable and linear. There may however be a structural break in the policy response to inflation, even in the last two decades, as shown in Estrella and Fuhrer (2003) and Jouini and Boutahar (2003). Stock and Watson (2007) find that the explanatory power of stable models of US inflation has diminished in recent decades. Moreover, the estimation results of existing models depend highly on the choice of sample period, another sign of possible instability in the reaction function.

This leads us to our second objective in this paper: to construct a more robust model of monetary policy response, by explicitly

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considering both the time variation in the Fed's response and the structural break. Dupor and Conley (2004) consider a structural break in the reaction function to have occurred in 1991:II, in that, inflation has since then never exceeded 4%. However, their estimation provides the counterintuitive result that the Fed's response to inflation is not clear since this break. Moreover, we find that the estimated inflation coefficient in the linear forward-looking rule shows a substantial change in accordance with a minor shift in the breakpoint, implying that a more rigorous choice of the breakpoint and a more robust model are required.

To tackle this problem, we introduce a nonlinearity based on the 'Series method', along with a single structural break, which allows us to keep using the original GMM representation. Applying the Series method allows for a temporary time variation and smooth change between any two regimes, as well as asymmetry in the responses to inflationary and deflationary pressures, making it possible to capture the nonlinearity due to asymmetric preferences (see Cukierman and Muscatelli, 2008; Dolado et al., 2005; Ruge-Murcia, 2003 for details). Consequently, together with the structural break which captures a permanent change, our method covers a wide range of possible transitory time variations of the response function. Our nonlinear model captures nonlinear dynamics different from those of the Threshold or Smooth Transition Model of Bunzel and Enders (2010) and Lo and Piger (2005), in that they focus only on identifying recurrent regimes. We test whether both nonlinearity and a structural break are present in the reaction function. The test results strongly support nonlinearity in the Fed's responses to inflation pressures. The structural break test detects the existence of a break at 1989:III, even in the nonlinear model.

The time-varying dynamics of the expected inflation coefficient support the asymmetric response of the Fed: the coefficient shows an aggressive Fed monetary policy under high inflationary pressures and a moderate response when inflation is low. However, unlike in the case with linear models such as in Dupor and Conley (2004), we find little evidence of a significant change in the Fed's behavior since the structural break. The estimated coefficient still supports active responses to increased future expected inflation, even after the break, while staying low in the other periods of stable inflation. These results also coincide with the finding of Stock and Watson (2007), that the inflation model is better explained by time-varying coefficients since the 1990s.

The stock price coefficient remains positive for most of the time since the break. This, however, does not necessarily imply that the Fed has preemptively responded to possible stock market bubbles. Note that it is generally expected that the Fed has two possible responses to movements in stock prices: one is the standard policy of responding to stock prices when they convey information about the future paths of inflation and output. The other is the more contentious, so-called bubble policy, of preemptive reaction to reduce a possible stock price bubble. If the Fed responds actively to possible bubbles, it can be expected to respond more actively in the early periods of bubbles. However, the time-varying pattern of the stock price coefficient reveals that it remains low until the late periods of bubbles, when it then quickly spikes.

The remainder of this paper is organized as follows. Section 2 derives and specifies the forward-looking interest rate rule including a stock price gap variable. Section 3 discusses the results of linear estimation and the instability issue. Section 4constructs a nonlinear model based on the Series method and discusses its estimation results and the movement of its time-varying coefficients. Section 5 explores the test of structural change for the nonlinear framework, and Section 6 concludes.

2. Fed's policy reaction function: a forward-looking rule with a stock price gap

This section outlines the theoretical framework of the forward-looking monetary policy reaction function. Conventional interest rate rules explain the policy interest rate as a function of current (Taylor, 1993) or past inflation, in addition to the output gap. Clarida et al. (2000) provide the theoretical basis for a forward-looking policy rule, and modify the reaction function based on expected inflation, while also accounting for policy fine tuning by introducing speed of adjustment to changes in economic conditions. Dupor and Conley (2004), Fuhrer and Tootell (2008) and Botzen and Marey (2010) add a stock price gap to the forward-looking Taylor rule, used in this paper. A simple forward-looking rule with a stock price gap is expressed by Clarida et al. (2000) as

$$R_t^* = R^* + \alpha\left[E(\pi_{t+k}|\Omega_t) - \pi^*\right] + \beta E\left(y_{t+q}|\Omega_t\right) + \gamma s_t \tag{1}$$

where R_t^* is the target rate for the nominal interest rate (e.g. the federal funds rate), R^* is the desired nominal rate when both inflation and output are at their target levels, π_{t+k} is the k-step ahead inflation, Ω_t is the information set available at time t when the interest rate is set, π^* is the inflation target, y_{t+q} is the q-step ahead output gap, and s_t is the stock price gap at time t. We assume that, unlike the cases with inflation and the output gap, the Fed responds to the current stock price gap, in that it is more likely to respond to stock prices after observing their current movements than to respond based on their expected future values. This can be also understood in that, while monetary policy can affect output and inflation with a certain extent of lag, e.g. 4 quarters, it can affect the stock market simultaneously, as Fuhrer and Tootell (2008) indicate. In order to better understand the intuition of Eq. (1), we introduce the following two identities that represent short- and long-run Fisher equations, respectively:

$$r_t^* \equiv R_t^* - E(\pi_{t+k}|\Omega_t) \quad \text{and} \quad r^* \equiv R^* - \pi^* \tag{2}$$

where r^* is the long-run equilibrium real interest rate, which is assumed to be constant and independent of monetary policy. After substituting Eq. (2) into Eq. (1), we obtain the ex-ante implied real interest rate rule:

$$r_t^* = r^* + (\alpha - 1)\left[E(\pi_{t+k}|\Omega_t) - \pi^*\right] + \beta E\left(y_{t+q}|\Omega_t\right) + \gamma s_t. \tag{3}$$

The basic intuition of Eq. (3) is that interest rate rules characterized by $\alpha > 1$ imply active or aggressive responses to expected inflationary pressures, while those with $\alpha \le 1$ are likely to accommodate inflation shocks. A similar logic can be applied to the output gap and stock price gap coefficients, i.e., an active or aggressive response to the output gap (stock price gap) is implied if β (γ) is positive, and an accommodative response otherwise.

Since the policy rule represented by Eq. (1) ignores the Fed's tendency of smoothing changes in interest rates, we consider a more realistic adjustment of interest rates to the target rate R_t^* as follows:

$$R_t = \rho R_{t-1} + (1 - \rho) R_t^* \tag{4}$$

where R_t is the actual interest rate (i.e., the actual federal funds rate). Eq. (4) implies that, in each period, the Fed adjusts its interest rate by a fraction $(1 - \rho)$ of its current target level. The gap between the current interest rate and the current target level can be represented by some linear combination of the one-period lagged realized actual interest rate and its current target level. Finally, after substituting Eq. (1) into Eq. (4), and using the long-run Fisher equation, we obtain the testable forward-looking interest rate rule:

$$R_t = \rho R_{t-1} + (1 - \rho)\left[\theta + \alpha \pi_{t+k} + \beta y_{t+q} + \gamma s_t\right] + e_t \tag{5}$$

where $\theta = r^* - (\alpha - 1)\pi^*$, and $e_t = (1 - \rho)[\alpha(E(\pi_{t+k}|\Omega_t) - \pi_{t+k}) + \beta(E(y_{t+q}|\Omega_t) - y_{t+q})]$. Note that e_t is a linear combination of forecasting errors, and thus orthogonal to any variables in the information set