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Financial crisis, Taylor rule and the Fed

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We investigate how the Federal Reserve (Fed) hit the zero lower bound (ZLB) interest rate while operating under a Taylor-type policy rule. We estimate a reaction function, and the results indicate that during the crisis Fed increased the weight on output without also increasing the weight on inflation which led them to hit the ZLB.0

Keywords: financial crisis; Taylor rule; zero bound

JEL Classification: E58

I. Introduction

The famous Taylor (1993) rule has received enormous attention in the monetary policy literature. This rule presents the Federal Reserve's (Fed) reaction function that is useful to ascertain how the Fed alters monetary policy in response to economic developments. Within the context of a macro model, the reaction function can be used to analyse the policy Fed adopted to tackle the recent financial crisis. The Fed is using a Taylor-type policy rule which is based on the dual mandate, that is, inflation stability and full employment. So under such policy rule how did the Fed hit the zero lower bound (ZLB) interest rate? Interestingly, there has been little research on this issue. This article attempts to shed some light on this issue by estimating a reaction function for the United States over the period 1954Q3 to 2011Q4.

II. The Taylor Rule

Taylor (1993) suggests a very specific and simple rule for monetary policy. In what follows, we derive this rule to be used in our analysis. Following Svensson (1997), we first specify two simple models of the economy:

Phillips Curve $$\pi_{t+1} = \pi_t + \alpha(y_t - \bar{y}) + \varepsilon_{t+1} \tag{1}$$

IS Curve $$y_{t+1} - \bar{y} = \beta_1(y_t - \bar{y}) - \beta_2(r_t - \bar{r}) + \eta_{t+1} \tag{2}$$

where $\pi_t =$ inflation rate, $(y_t - \bar{y}) =$ output gap, $i_t =$ nominal short-term interest rate (Fed funds rate), $r_t = i_t - \pi_t =$ real interest rate and $(r_t - \bar{r}) =$ deviation of real interest rate (r_t) from 'natural' level ($\bar{r}$). ε_t and η_t are *iid* disturbances. Suppose the central bank minimizes the following loss function:

$$\min_{i_{t+j}} L_t = \frac{1}{2} E_t \sum_{j=0}^{\infty} \delta^j \left(\pi_{t+j} - \bar{\pi}\right)^2 \tag{3}$$

where $\delta =$ intertemporal discount factor with $0 < \delta < 1$. Based on Equations 1 and 2, we can write π_{t+2} as a function of r_t:

$$\begin{aligned}\pi_{t+2} &= \pi_{t+1} + \alpha(y_{t+1} - \bar{y}) + \varepsilon_{t+2} \\ &= \underbrace{(\pi_t + \alpha(y_t - \bar{y}) + \varepsilon_{t+1})}_{\pi_{t+1}} \\ &\quad + \alpha \underbrace{\left[\beta_1(y_t - \bar{y}) - \beta_2(r_t - \bar{r}) + \eta_{t+1}\right]}_{y_{t+1}} + \varepsilon_{t+2} \\ &= \pi_t + a_1(y_t - \bar{y}) - a_2(r_t - \bar{r}) \\ &\quad + \left(\varepsilon_{t+1} + \alpha\eta_{t+1} + \varepsilon_{t+2}\right)\end{aligned} \tag{4}$$

The lag structure of the model implies that the interest rate in period t has no effect on inflation in the period $t+1$ but only beyond $t+2$ period; at the same time the interest rate in $t+1$ will influence the inflation beyond $t+3$ and this process continues. The central bank problem is simplified because it is possible to fix every period t, the interest rate coherent, with the objective to take π_{t+2} close to $\bar{\pi}$. The central bank then will solve for the following problem:

$$\min_{i_t} L_t = \frac{1}{2} E_t(\pi_{t+2} - \bar{\pi})^2$$

$$\text{where} \quad E_t \pi_{t+2} = \pi_t + a_1(y_t - \bar{y}) - a_2(r_t - \bar{r}) \tag{5}$$

Deriving with respect to $i_t(= r_t + \pi_t)$, we obtain

$$-a_2 E_t(\pi_{t+2} - \bar{\pi}) = 0 \Rightarrow E_t \pi_{t+2} = \bar{\pi} \tag{6}$$

To derive the monetary policy rule, we have to substitute Equation 5 into Equation 6 and solve for r_t:

$$r_t = \bar{r} + \frac{1}{a_2}(\pi_t - \bar{\pi}) + \frac{a_1}{a_2}(y_t - \bar{y})$$

$$\Rightarrow i_t = \bar{r} + \pi_t + \frac{1}{a_2}(\pi_t - \bar{\pi}) + \frac{a_1}{a_2}(y_t - \bar{y})$$

$$\Rightarrow i_t = \gamma_0 + \gamma_1 \pi_t + \gamma_2(y_t - \bar{y})$$

$$\gamma_0 = \bar{r} - \frac{1}{a_2}\bar{\pi}; \gamma_1 = \frac{1 + a_2}{a_2}; \gamma_2 = \frac{a_1}{a_2} \quad \text{with} \quad \gamma_1 > 1; \gamma_2 > 0 \tag{7}$$

McCallum (1997) argued that it is unrealistic to assume, as in Equation 7, that policy can respond to current-quarter values of inflation and output. In empirical estimations, the lagged values of these variables are used and thus Equation 7 becomes

$$i_t = \gamma_0 + \gamma_1 \pi_{t-1} + \gamma_2(y_{t-1} - \bar{y}) \tag{8}$$

III. Empirical Results

Data

We used quarterly data over the period 1954Q3 to 2011Q4 for the United States. The variables used are Fed funds rate (i_t), inflation rate (π_t) and output gap ($y_t - \bar{y}$). π_t is measured by the annual growth rate of the GDP deflator. The output gap ($y_t - \bar{y}$) is measured as the deviation of real GDP (y_t) from its potential ($\bar{y}$), and it is obtained through the univariate unobserved component model technique. This technique is better than the traditional Hodrick–Prescott filter method because it is not affected by end-sample biases. All data were extracted from the Federal Reserve Economic Data (FRED) database.

Figure 1 illustrates the behaviour of i, π and $(y - \bar{y})$ over the sample period. The output gap is quite volatile and has been negative during the periods of recession. The Fed funds rate reached a peak during the early 1980s, and this

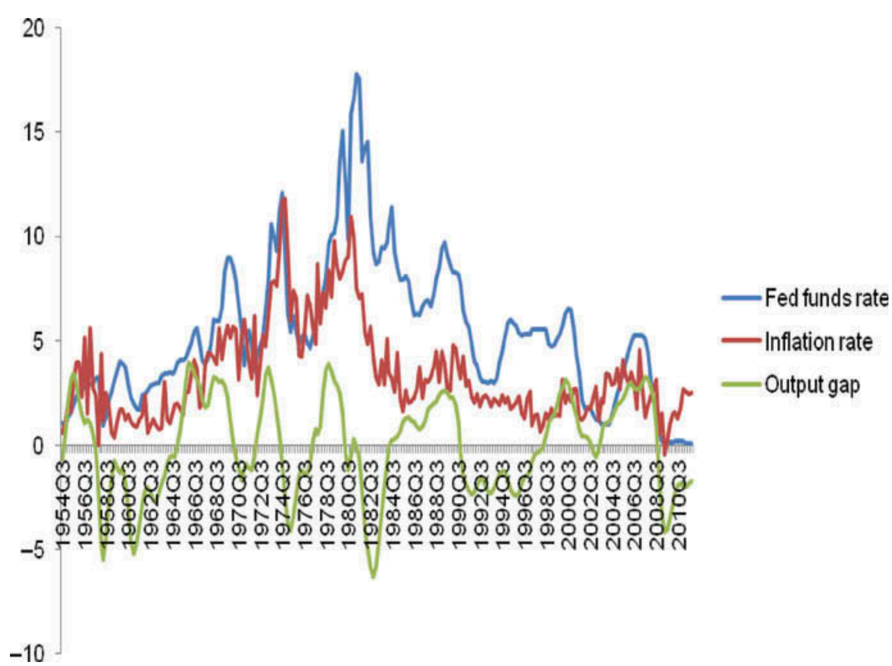

Fig. 1. Fed funds rate, inflation rate and output gap 1954Q3 to 2011Q4

depicts the continued contractionary measures adopted by the Fed since mid-1970s. The Fed funds rate reached the ZLB in 2008Q4. The inflation rate had been highest during the 1970s possibly due to the oil crisis. Overall, inflation and the Fed funds rate show a declining trend in the post-1980 period.

Unit root tests

Carrion-i-Silvestre *et al.* (2009) developed a unit root test which allows for multiple structural breaks in the level and/or slope of the trend function under both the null and the alternative hypotheses. Their test comprises the feasible point optimal statistic (Elliott *et al.*, 1996) and a class of *M*-tests (Stock, 1999). The feasible point optimal statistic is given by

$$P_T^{gls}(\lambda^0) = \left\{S(\bar{\alpha},\lambda^0) - \bar{\alpha}S(1,\lambda^0)\right\}/s^2(\lambda^0) \tag{9}$$

where λ is the estimate of the break fraction, $\bar{\alpha} = 1 + \bar{c}/T$ ($\bar{c}$ is the noncentrality parameter) and $s^2(\lambda^0)$ is an estimate of the spectral density at frequency zero of υ_t. The *M*-class of tests is defined by

$$MZ_\alpha^{GLS}(\lambda^0) = \left(T^{-1}\tilde{y}_T^2 - s(\lambda^0)^2\right)\left(2T^{-2}\sum_{t=1}^{T}\tilde{y}_{t-1}^2\right)^{-1} \tag{10}$$

$$MSB^{GLS}(\lambda^0) = \left(s(\lambda^0)^{-2}T^{-2}\sum_{t=1}^{T}\tilde{y}_{t-1}^2\right)^{1/2} \tag{11}$$

$$MZ_t^{GLS}(\lambda^0) = \left(T^{-1}\tilde{y}_T^2 - s(\lambda^0)^2\right)\left(4s(\lambda^0)^2T^{-2}\sum_{t=1}^{T}\tilde{y}_{t-1}^2\right)^{-1/2} \tag{12}$$

with $\tilde{y}_t = y_t - \hat{\psi}'z_t(\lambda^0)$, where $\hat{\psi}$ minimizes the objective function (see eq 4 in Carrion-i-Silvestre *et al.*, 2009, p. 1759). For the definition of $s(\lambda^0)^2$, see eq 6 in Carrion-i-Silvestre *et al.* (2009, p. 1759).

Table 1 presents the unit root test results for i, π and $(y-\bar{y})$. We test for a maximum of five structural breaks when deterministic time trend is included in the test regressions. All the test statistics point to trend stationary processes in the three series. The test statistics are less negative than the critical values, implying that the unit root null can be rejected at the 5% level. The endogenous break dates yield by each test is plausible. Most break dates correspond to recessions that affected the US economy.

Taylor rule estimates

We estimate the Taylor rule (Equation 8) using the seemingly unrelated regression (SUR) method. This method accounts for the disturbance correlation across equations and yields more efficient estimates compared to the ordinary least squares (OLS). In addition, it does not require any instruments as is the case in instrumental variable methods. The Taylor rule estimation is performed as follows: (i) excluding the financial crisis period (1954Q3 to 2006Q4) and (i). adding a quarter sequentially from 2007Q1 to 2011Q4. For the latter, we construct 20 samples, such as 1954Q3 to 2007Q1, 1954Q3 to 2007Q2, …,

Table 1. Carrion-i-Silvestre *et al.* (2009) unit root test, 1954Q3 to 2011Q4

Test and variables		Test statistic (critical value)	Break dates
$P_T^{gls}(\lambda^0)$	i	−12.360 (–5.100)	1974Q2;1981Q2;1995Q1;2007Q2;2007Q3
	π	−6.072 (–1.154)	1980Q1;1984Q3;1991Q4;1992Q1;2008Q1
	$y-\bar{y}$	−23.109 (–20.920)	1973Q4;1980Q3;1992Q2;2002Q3;2007Q4
$MZ_\alpha^{GLS}(\lambda^0)$	i	−16.731 (–9.439)	1980Q4;1981Q3;1994Q4;2000Q1;2008Q2
	π	−6.726 (–3.492)	1991Q4;1992Q1;2001Q3;2007Q2;2007Q3
	$y-\bar{y}$	−11.255 (–4.507)	1974Q1;1981Q4;2007Q1;2007Q3;2008Q2
$MSB^{GLS}(\lambda^0)$	i	−8.090 (–5.641)	1983Q2;1991Q3;1999Q1;2003Q3;2008Q1
	π	−11.364 (–7.750)	1976Q1;1980Q2;1992Q1;1992Q4;2004Q1
	$y-\bar{y}$	−7.300 (–2.321)	1980Q2;1992Q1;2000Q2;2007Q3;2007Q4
$MZ_t^{GLS}(\lambda^0)$	i	−34.745 (–16.755)	1992Q3;1992Q4;2000Q4;2005Q1;2007Q2
	π	−21.387 (–15.023)	1973Q4;1974Q4;1982Q1;1996Q2;2008Q2
	$y-\bar{y}$	−25.651 (–20.907)	1991Q4;2000Q3;2007Q1;2007Q1;2008Q1

Note: All tests consider breaks in constant and time trend. The 5% critical values are given in parentheses.

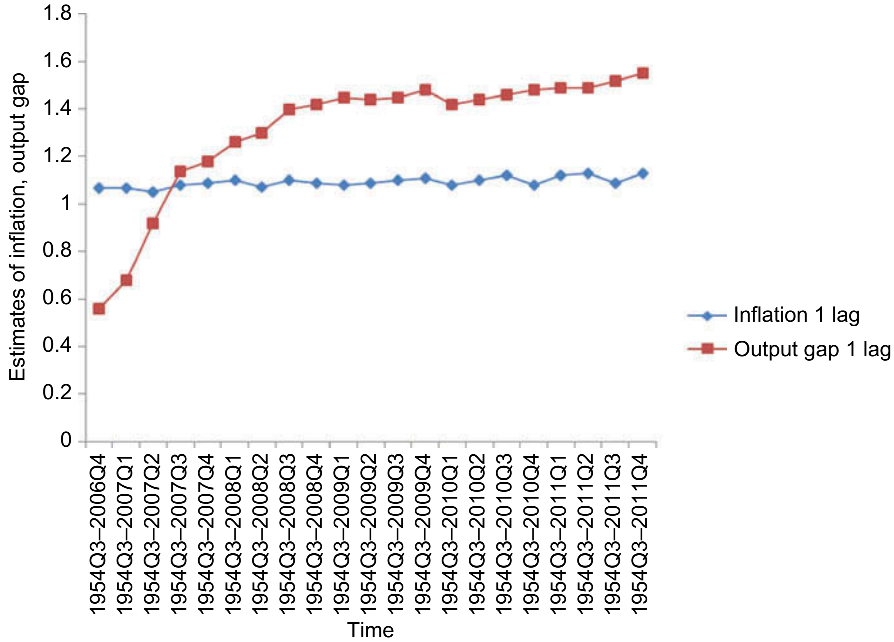

Fig. 2. SUR estimates of inflation and output gap

1954Q3 to 2011Q3 and 1954Q3 to 2011Q4. In all estimations, we integrate three dummy variables,DUM73, DUM80 and DUM91.[1] The former corresponds to the oil crisis, while the latter two highlight the occurrence of recessions in the United States. The sequential estimation samples also include a dummy (DUMFC) to capture the impacts of the recent financial crisis.[2]

Figure 2 illustrates the coefficients of inflation (γ_1) and output gap (γ_2).[3] In all equations, γ_1 and γ_2 are statistically significant at the 5% level.[4] The estimate of γ_1 is fairly consistent overtime (around 1.1 in pre-crisis and crisis-inclusive periods). Since the real interest rate drives private decisions, the size of γ_1 needs to be larger than 1. This is the so-called 'Taylor principle' (Clarida *et al.*, 1998). Further, monetary policy to effectively stabilize output, a less restrictive condition has to be fulfilled, that is, $\gamma_2 > 0$. Prior to the crisis, the estimate of γ_2 was 0.56. However, when the sample is extended to include the crisis period, γ_2 increased to around 1.6.

Implications

Our results indicate that until 2007Q2 the Fed gave higher weight to inflation than to output gap. The Fed's reaction to inflation is fairly consistent overtime (pre-crisis and crisis-inclusive periods). However, Fed's reaction to the output gap increased rapidly during the crisis. Increasing the weight on output without also increasing the weight on inflation signifies the possibility of hitting the ZLB. Actually the Fed funds rate did reach the ZLB in 2008Q4 and remained low thereafter. If the central bank decides to reduce the volatility of output, this results in unrealistically large volatility in inflation (Gavin and Keen, 2012). Consequently, there was some concern over the rising inflation uncertainty during the crisis; see Wright (2011).

Gavin and Keen (2012) argued that a central bank must be committed to a long-run average-inflation objective if it wishes to achieve a dual mandate while avoiding the ZLB. The problem with the Taylor rule is that it targets the short-run inflation rate and therefore it becomes difficult to achieve the dual mandate and at the same time avoid the ZLB. Reflecting on Fig. 2, the Fed would not have encountered ZLB if it had lowered the weight on output. Gavin and Keen (2012) showed that placing more weight on output increases the likelihood of a ZLB event and the volatility of inflation but decreases the volatility of output.

[1] Dummies are selected according to the test results of Carrion-i-Silvestre *et al.* (2009). Other dummies are ignored because they are statistically insignificant at the conventional levels. These dummies are constructed as follows: DUM73 = 1 from 1973Q1 to 1974Q4 and 0 otherwise, DUM80 = 1 from 1980Q1 to 1981Q4 and 0 otherwise and DUM91 = 1 from 1991Q1 to 1992Q4 and 0 otherwise.
[2] For example, DUMFC in 1954Q3 to 2007Q1 sample is constructed as 1 in 2007Q1 and 0 otherwise. DUMFC in 1954Q3 to 2007Q2 sample is constructed as 1 in 2007Q1 and 2007Q2 and 0 otherwise. A similar process is used to construct DUMFC for samples beyond 2007Q2.
[3] Estimates of the intercept and dummies are not reported for brevity.
[4] The *t*-statistics or *p*-values are not reported for brevity.

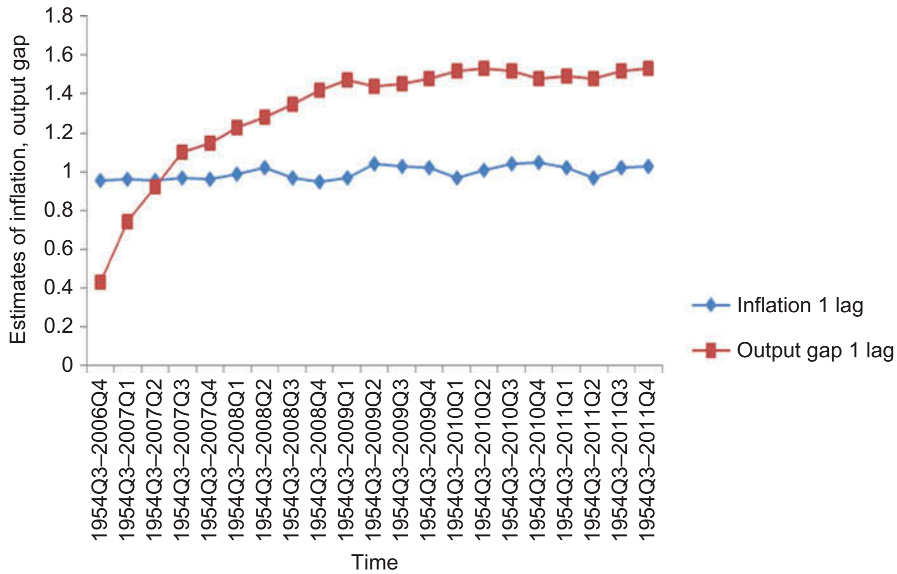

Fig. 3. TSLS-IV estimates of inflation and output gap

Robustness

To assess robustness in our results, we estimate the reaction function using the two-stage least-squares instrumental variable (TSLS-IV) method. The instruments used are long-term interest rates, unemployment rate and price volatility.[5] In most equations, instruments lagged up to three periods were used; we do not report the exact instruments for each estimated equation for brevity. In all cases, Hansen's (1982) *J*-test indicates that our selected instruments are valid. DUM73, DUM80, DUM91 and DUMFC were used as dummy variables. Figure 3 illustrates the estimates of inflation and output gap, and they are very consistent with our SUR estimates. These results also indicate that Fed's reaction to inflation is fairly constant, while reaction to the output gap is much stronger throughout the crisis period.

IV. Conclusion

We investigated how the Fed hit the ZLB interest rate while operating under a Taylor-type policy rule. In doing so, we estimated a reaction function to attain insights on how much weight the Fed placed on inflation and output during the recent crisis. Our results indicate that Fed's reaction to inflation has been fairly consistent overtime (i.e. pre-crisis and crisis-inclusive periods). However, Fed's reaction to the output gap increased rapidly during the crisis period. Since the Fed increased the weight on output without also increasing the weight on inflation, it led them to hit the ZLB. Our inferences are consistent with Gavin and Keen (2012).

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[5] We derive price volatility using the GDP deflator. GARCH model was used to attain the series.