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## HOW FORWARD-LOOKING IS THE FED? DIRECT ESTIMATES FROM A 'CALVO-TYPE' RULE

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# How forward-looking is the Fed? Direct estimates from a 'Calvo-type' rule*

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**Abstract**

We estimate an alternative type of monetary policy rule, termed Calvo rule, according to which the central bank is assumed to target a discounted infinite sum of future expected inflation. Compared to conventional inflation forecast-based rules, which are typically of the Taylor-type with discrete forward looking horizons, this class of rule is less prone to the problem of indeterminacy. Parameter estimates obtained from GMM estimation provide support for Calvo-type rules, suggesting that the Federal Reserve targeted a mean forward horizon of between 4 and 8 quarters.

*Key Words*: Calvo-type interest rules; Inflation Forecast Based rules; GMM; Indeterminacy

*JEL Classification*: C22; E58

# 1　Introduction

Many central banks claim to be forward-looking in their policy actions. In practice, this amounts to targeting conditional forecasts of the feedback variables reflecting macroeconomic conditions. Clarida *et al.* (1998 and 2000) present empirical evidence of this forward-looking behavior for several monetary authorities including the Federal Reserve. They estimate a forward-looking Taylor-type rule

$$i_t = \rho i_{t-1} + \theta E_t \pi_{t+h} + E_t \gamma x_{t+q}, \tag{1}$$

where $\rho$ captures the degree of interest rate smoothing such that current period interest rates ($i_t$) respond gradually to lead values of inflation ($\pi_{t+h}$) and a measure of the output gap ($x_{t+q}$), corresponding to targeting horizons $h$ and/or $q > 0$. Interest-rate feedback rules of this type are extensively discussed in the literature (see Woodford, 2003, for example) and mimic monetary policy behavior reasonably well.

Nevertheless, the analysis and implementation of this type of rule raises difficulties. First, it is clear that the targeting horizon[1] $h$ should be viewed as part of the parameter set $\{\rho, \theta, \gamma\}$ defining policy choices. Yet when attempting to replicate the behavior of central banks, researchers estimating policy rules do not directly estimate $h$, instead fixing it at particular horizons. Values for $h$ may be determined either by their implied stabilization properties in specific macro models[2], or simply chosen at horizons purported to represent central banks' policies. Levin *et al.* (2003), for example, compute ten forecast-based optimized rules used in policy analysis or studied by academic researchers, reporting forecast horizons ranging from from 2 to 15 quarters. This suggests considerable uncertainty concerning the degree of forward-lookingness that central banks should pursue. Second, standard forward-looking rules have been shown to suffer from *indeterminacy* (Batini *et al.* 2006, Levin *et al.*, 2003, Woodford 2003), implying that in the face of a macroeconomic shock, the number of paths leading back to equilibrium for real variables is infinite. This problem worsens as the forecast horizon increases, and the rule becomes less persistent.

This paper adopts an empirical strategy which has the potential to circumvent the obstacles described above. We discuss how a '*Calvo-type' inflation-forecast based rule* (hereafter *Calvo-rule*) can be used to estimate the degree of forward-lookingness. This rule, which is based on a discounted sum of current and all future inflation rates, has recently been proposed by Levine

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[1] For brevity, we focus on the case of inflation forecast targeting and outcome-based targeting of the output gap, i.e., $h > 0$ and $q \leq 0$..

[2] See Batini and Nelson (2001) or Giannoni and Woodford (2003) for a discussion along these lines.

*et al* (2007), who demonstrate its lower susceptibility to indeterminacy and better stabilization properties than conventional rules. Thus, we simultaneously obtain a direct estimate of $h$, while adopting a formulation that is theoretically more appealing.

## 2  Calvo-Rules

The rule we examine falls within a broader class of rule referred to in the literature as Inflation Forecast Based (IFB) rules. Despite their susceptibility to indeterminacy, such rules have strong intuitive appeal, and the arguments in support of them are well known. First, as monetary policy maximally impacts inflation with a considerable lag, it follows that policy decisions should target a horizon where the expected macroeconomic impact is judged greatest. Second, through targeting forecasts IFB rules implicitly draw upon a wide array of information relating to both current and future macroeconomic conditions. In light of these arguments, the development of IFB rules which are less susceptible to indeterminacy is desirable. The *Calvo rule* is such an innovation. Suppose the interest-rate rule is written as

$$i_t = \rho i_{t-1} + \theta \Theta_t + \gamma x_t, \tag{2}$$

where

$$\Theta_t = (1 - \varphi) E_t(\pi_t + \varphi \pi_{t+1} + \varphi^2 \pi_{t+2} + ....),\ 0 < \varphi < 1 \tag{3}$$

where $\gamma$ denotes the policymaker's response to deviations from an output target $\varphi$ measures the extent to which current and all future inflation rates are discounted. This formulation is akin to Calvo-type contracts (Calvo, 1983) commonly used in New Keynesian Phillips curves. The Calvo rule can be interpreted as a feedback from expected inflation that continues at any one period with probability $\varphi$ and is switched off with probability $1 - \varphi$. The probability of the rule lasting for $h$ periods is $(1 - \varphi)\varphi^h$, hence the mean forecast horizon is $(1 - \varphi) \sum_{h=1}^{\infty} h\varphi^h = \varphi/(1 - \varphi)$. With $\varphi = 0.5$, for example, we would have a Taylor rule as in (1) with one period lead in inflation $(h = 1)$.

This rule can also be seen as a special case of a Taylor-type rule that targets $h$-step-ahead expected rates of inflation (with $h \to \infty$)

$$i_t = \rho i_{t-1} + \theta_0 \pi_t + \theta_1 E_t \pi_{t+1} + \theta_2 E_t \pi_{t+2} + ... + \gamma x_t, \tag{4}$$

albeit one that imposes a specific structure on the $\theta_i$'s (i.e., a weighted average of future inflation with geometrically declining weights). This has an intuitive appeal and interpretation, reflecting

monetary policy in an uncertain environment: the more distant the $h$-step ahead forecast, the less reliable it becomes, hence the less weight it receives.

Another interesting feature of this specification type is that, conveniently rewritten, it permits direct estimation of the mean lead horizon. In order to estimate the rule, it is possible to manipulate (2) and (3) to give

$$(1 + \rho\varphi)i_t - \rho i_{t-1} - \varphi E_t i_{t-1} = \theta(1 - \varphi)\pi_t + \gamma(x_t - E_t x_{t+1}) \tag{5}$$

Rearranging in terms of $i_t$ yields

$$i_t = \frac{\rho}{1 + \rho\varphi}i_{t-1} + \frac{\varphi}{1 + \rho\varphi}E_t(i_{t+1}) + \frac{\theta(1 - \varphi)}{1 + \rho\varphi}\pi_t + \frac{\gamma}{1 + \rho\varphi}[x_t - \varphi E_t(x_{t+1})] \tag{6}$$

One can then estimate the parameter coefficients of (2) using GMM as explained next.

## 3    Empirical Analysis

Levine *et al.* (2007) analyze the more restrictive 'strict' inflation forecast rule (imposing $\gamma = 0$), in the context of a DSGE model for the Euro Area. For the US case, however, an extended, 'flexible' rule with the output gap as feedback variable seems more appropriate in order to replicate the Fed's behavior. Hence to estimate the reaction function implied (2), we follow the now standard strategy outlined by Clarida *et al.* (1998 and 2000). We augment (6) by introducing a random policy shock $\varepsilon_t$

$$i_t = \frac{\rho}{1 + \rho\varphi}i_{t-1} + \frac{\varphi}{1 + \rho\varphi}E_t(i_{t+1}) + \frac{\theta(1 - \varphi)}{1 + \rho\varphi}\pi_t + \frac{\gamma}{1 + \rho\varphi}[x_t - \varphi E_t(x_{t+1})] + \varepsilon_t \tag{7}$$

that accounts for forecast errors or interest rate deviations from the level prescribed by the rule. If we assume that the shocks are orthogonal to any variable in the information set at time $t - 1$, we can estimate the parameters of (7) by GMM using the moment conditions implied by equation.[3] In particular, we employ the iterative GMM estimator, with a weighting matrix using the Bartlett kernel, with an automated lag-length selection procedure as in Andrews (1991). We also consider the Continuous-Updating GMM estimator (CUE), which possesses superior large and finite sample properties when compared to the standard GMM estimator, as discussed in Newey and Smith (2004).

Our estimations are based on US quarterly data covering the period 1960:1-2004:4. We present results for the full sample, as well as for a restricted sample period starting in 1979:3,

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[3]Following Clarida *et al.* (2000), future values of the variables in (6) are replaced with actual observed values.

as in Clarida *et al.* (2000), coinciding with the Volcker-Greenspan tenure. The interest rate is defined as the average Federal Funds rate, inflation is the annualized quarterly rate of change of the GDP deflator. Regarding the output gap, we use two measures: the output gap constructed by the Congressional Budget Office (CBO), as well the quadratically detrended unemployment rate, as in Clarida *et al.* (2000). The set of instruments comprises 4 lags of the model variables, plus lags of commodity price inflation, M2 growth, wage inflation and the spread between 10-year bond rates and the 3-month Treasury Bill rate.

Table 1 reports the estimation results. Some interesting features are worth pointing out. We obtain results similar to Clarida *et al.* (2000) regarding the differences in the estimated rules across the two samples. Indeed, point estimates of the policy reaction to expected inflation appears below the benchmark values of 1 when the full sample is employed (and non-significant for the CBO gap), whereas the estimated $\theta$'s appear significantly larger than 1 for the Volcker-Greenspan period. As for the estimates of $\varphi$, the implied average forecasting period ranges from 1.5 to 3 quarters, the exception being CUE estimates with the CBO gap, with an unreasonable degree of forward-looking behavior. Note, however, that the *J*-test for overidentifying restrictions for the CUE produced somewhat low *p*-values for the pre-Volcker period, which suggests that there may some problems with this specification for this sample period.

However, if we only consider the Volcker-Greenspan period, estimation results appear to be much more sensible. First, all coefficients are statistically significant and the *J*-test produces higher and more reasonable *p*-values, despite the smaller sample. Secondly, the coefficient on inflation expectations is estimated to be well above unity, a result consistent with the conclusion of Clarida *et al.* (2000) that the Fed adopted a more aggressive stance in the combat to inflation after 1979. Last, but not least, estimates of $\varphi$ are higher than the full-sample ones, corresponding to point estimates of the targeting horizon between 4.4 and 7 quarters. Note that in all cases, one cannot reject values of $\varphi$ that deliver targeting horizons between 4 and 8 quarters, but a targeting horizon of just 1 quarter is always comfortably rejected, suggesting a high degree of forward-lookingness during the Volcker-Greenspan tenure.

For completeness, the stability properties of the our estimated rules were computed for a standard New Keynesian model

$$\pi_t = E_t\pi_{t+1} + \lambda x_t \tag{8}$$
$$c_t = E_t c_{t+1} - \frac{1}{\sigma}(i_t - E_t\pi_{t+1}),$$

where $\beta = 0.99$ is calibrated and Bayesian-estimated parameters, using US data, are $\sigma = 3.91$

and $\lambda = 1.41$ (see Batini *et al.* 2006). All estimated rules achieve saddlepath stability, and are highly robust to variations in these values.[4] The more aggressive responses to expected inflation in the Volcker-Greenspan era result in welfare outcomes that are considerably higher than the estimated rules in the full sample period.

# 4   Conclusion

We show the empirical usefulness of Calvo rules by estimating the targeting horizon of the Federal Reserve. Our results suggest that the practice of the Fed is consistent with a substantial degree of forward-looking behavior, reinforcing previous findings in the literature. There are, however ways in which our analysis might be extended. Future work might utilize *forecast* data, known to be integral to the decision on the interest rate by the FOMC, or 'real time' data as in Orphanides (2001). We have also restricted our analysis to US policymaking. The fact that an increasing number of central banks now make publicly available their internal forecasts for inflation and GDP makes a cross country study viable.

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# 5 Appendix

**Table 1: Estimates of the Calvo Rule, US Data**

| Full Sample (1960:1 - 2004:4) | | $\rho$ | $\varphi$ | $\theta$ | $\gamma$ | $J$-test $(p-\text{value})$ |
|---|---|---|---|---|---|---|
| Iterative GMM | CBO output gap | 0.886 (0.032) | 0.743 (0.074) | 0.919 (0.204) | 0.320 (0.069) | 0.847 |
| | Unemployment gap | 0.902 (0.029) | 0.700 (0.119) | 0.726 (0.200) | 0.299 (0.032) | 0.909 |
| CUE | CBO output gap | 0.859 (0.139) | 0.971 (0.067) | 0.809 (1.937) | 0.631 (0.125) | 0.128 |
| | Unemployment gap | 0.859 (0.038) | 0.606 (0.136) | 0.896 (0.267) | 0.283 (0.108) | 0.166 |
| Volcker-Greenspan (1979:3 - 2004:4) | | | | | | |
| Iterative GMM | CBO output gap | 0.730 (0.050) | 0.816 (0.056) | 2.663 (0.554) | 0.219 (0.052) | 0.965 |
| | Unemployment gap | 0.638 (0.056) | 0.876 (0.041) | 3.548 (0.711) | 0.510 (0.123) | 0.958 |
| CUE | CBO output gap | 0.787 (0.091) | 0.872 (0.103) | 2.549 (1.194) | 0.368 (0.144) | 0.346 |
| | Unemployment gap | 0.840 (0.075) | 0.814 (0.085) | 1.536 (0.778) | 0.527 (0.177) | 0.225 |

Note: standard errors in brackets.