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 according to which the central bank targets a discounted infinite sum of expected inflation and output gaps. Empirical results suggest that the Fed has a mean forward horizon of 4 to 8 quarters.

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

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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

$$\dot{i}_t = \rho \dot{i}_{t-1} + \theta E_t \pi_{t+h} + \gamma E_t x_{t+q}, \quad (1)$$

where ρ captures the degree of interest rate smoothing, such that current period interest rates (i_t) respond gradually to lead values of inflation (π_{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 horizon¹ 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 models², 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 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*' 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 *et al* (2007),

¹For brevity, we focus on the case of identical targeting horizons, i.e., $h = q$.

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

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, by 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

$$i_t = \rho i_{t-1} + \theta \Theta_t + \gamma \Psi_t, \quad (2)$$

where

$$\begin{aligned} \Theta_t &= (1 - \varphi)E_t(\pi_t + \varphi\pi_{t+1} + \varphi^2\pi_{t+2} + \dots), \quad 0 < \varphi < 1 \\ \Psi_t &= (1 - \tau)E_t(x_t + \tau x_{t+1} + \tau^2 x_{t+2} + \dots), \quad 0 < \tau < 1 \end{aligned} \quad (3)$$

where γ denotes the policymaker's response to deviations from an output target, φ and τ measure the extent to which current and all future inflation rates and output gaps are discounted, respectively. This formulation is akin to Calvo-type contracts (Calvo, 1983) commonly used in New Keynesian Phillips curves. In what follows, we will assume $\varphi = \tau$, as this facilitates direct estimation of the rule. Also, it is not unrealistic to expect central banks to have similar targeting horizons for inflation and output gaps.

The Calvo rule can be interpreted as a feedback from expected inflation and output gap forecasts that continues at any one period with probability φ , switching 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 and output gap forecasts (with $h = 1, 2, \dots, \infty$)

$$i_t = \rho i_{t-1} + \theta_0 \pi_t + \theta_1 E_t \pi_{t+1} + \theta_2 E_t \pi_{t+2} + \dots + \gamma_0 x_t + \gamma_1 x_{t+1} + \gamma_2 x_{t+2} + \dots, \quad (4)$$

albeit one that imposes a specific structure on the θ_i 's and γ_i 's (i.e., a weighted average of future variables 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, first express (3) with $\varphi = \tau$ as

$$\begin{aligned} \Theta_t &= (1 - \varphi)\pi_t + \varphi E_t \Theta_{t+1} \\ \Psi_t &= (1 - \varphi)x_t + \varphi E_t \Psi_{t+1} \end{aligned} \quad (5)$$

Then, using (5) it is possible to manipulate (2) to give

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

One can also consider the case of outcome-based output gap targeting, by replacing Ψ_t with x_t in (2), so that only future values of (predicted) inflation are considered. The rule may be written as

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

We can then estimate the parameter coefficients of (6) and (7) 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) and (7) by introducing a random policy shock ε_t 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 (6) and (7) by GMM using the moment conditions implied by each equation. 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 two different vintages of US quarterly data. We use ‘ex-post’ revised data covering the period 1960:1-2004:4, in essence an updated version of Clarida *et al.* (2000). 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.

In addition, we resort to the dataset studied in Orphanides (2003) spanning until 2002:4, which contains ‘real-time’ measures of inflation and the output gap³. Thus, our results will also reflect information available for policymakers when decisions are made. We present results for the full sample periods, as well as for a restricted sample period starting in 1979:3, as in Clarida *et al.* (2000), coinciding with the Volcker-Greenspan tenure.

Table 1 reports the estimation results⁴. Some interesting features are worth pointing out. First, results are fairly robust and consistent across the different types of data (‘ex-post’ or ‘real-time’) employed in the estimation. Second, we obtain results largely similar to Clarida *et al.* (2000) regarding the differences in the estimated rules across the two sample periods. Indeed, point estimates of the policy reaction to expected inflation appears below the benchmark values of 1 when the full sample is employed, whereas the estimated θ ’s appear significantly larger than 1 for the Volcker-Greenspan period. Interestingly, the ‘real-time’ estimates of the inflation coefficient for the pre-1979 period are higher than with ‘ex-post’ data (and larger than 1 with the CUE). This is consistent with the findings of Orphanides (2003) and the suggestion that, once policymakers’ ‘real-time’ perception is taken into account, the Fed was more activist than

³See paper for details on the construction of the variables. We use the ‘real-time’ output gap measure shown in Fig. 1 of Orphanides (2003, p. 997).

⁴Full estimates of (7) - available upon request - were qualitatively similar to those of (6), so we only report results of the estimated discounting parameter, denoted as φ^* .

previously thought.

As for the full sample estimates of φ , the results are, in general, quite reasonable. The implied average forecasting period ranges from 1 to 3 quarters. Estimates with the restricted rule (φ^*) tend to be higher, most notably ‘ex-post’ 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 full sample ‘ex-post’ CUE produced somewhat low p -values for the pre-Volcker period, which suggests that there may be some problems with this specification for this sample period.

However, if we consider the Volcker-Greenspan period, estimation results appear to be 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 when the revised dataset is used, 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. With ‘real-time’ variables, estimates of θ are somewhat lower, but consistent with the Taylor principle. Last, but not least, estimates of φ are higher than the full-sample ones, corresponding to point estimates of the targeting horizon between 4 and 7 (again, results for φ^* are slightly larger, but within the same range). Note that in all cases, one cannot reject values of φ 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

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

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.⁵ 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.

⁵Full results are available upon request.

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. Orphanides and Wieland (2008), for example, show that Fed decisions are well captured by a forecast-based policy rule, consistent with the Fed's projections, rather than 'ex-post' observed outcomes. Our framework complements this perspective by pinning down the degree of the Fed's forward-lookingness.

There are, however ways in which our analysis might be extended. Future work might consider different targeting horizons for the feedback variables. However, given that an extra coefficient would have to be estimated, such rule would not be estimable in our single-equation setup. On the other hand, we have also confined 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.

References

- [1] Andrews, D. W. K. (1991), Heteroskedasticity and Autocorrelation Consistent Covariance Matrix Estimator, *Econometrica*, 59, 817-858.
- [2] Batini, N., Justiniano, A., Levine, P. and Pearlman, J. (2006), Robust inflation-forecast-based rules to shield against indeterminacy, *Journal of Economic Dynamics and Control*, 30, 1491-1526.
- [3] Batini, N. and Nelson, E. (2001), Optimal horizons for inflation targeting, *Journal of Economic Dynamics and Control*, 25, 891-910.
- [4] Calvo, G. A. (1983), Staggered Prices in a Utility-Maximizing Framework, *Journal of Monetary Economics*, 12, 383-98.
- [5] Clarida, R., Gali, J. and Gertler, M. (1998), Monetary policy rules in practice: some international evidence, *European Economic Review*, 42, 1033-1067.
- [6] Clarida, R., Gali, J. and Gertler, M. (2000), Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory, *Quarterly Journal of Economics*, 115, 147-180

- [7] Giannoni, M. P and Woodford, M. (2003), How Forward-Looking is Optimal Monetary Policy?, *Journal of Money, Credit and Banking*, 35, 1425-1469.
- [8] Levin, A., Wieland, V.. and Williams, J. C. (2003), The Performance of Forecast-Based Monetary Policy Rules Under Model Uncertainty, *American Economic Review*, 93, 622-645.
- [9] Levine, P., McAdam, P. and Pearlman, J. (2007), Inflation Forecast Rules and Indeterminacy: A Puzzle and a Resolution, *International Journal of Central Banking*, 3, 77-110.
- [10] Newey, W. K. and Smith, R. J. (2004), Higher Order Properties of GMM and Generalized Empirical Likelihood Estimators, *Econometrica*, 72, 219-255.
- [11] Orphanides, A. (2003), Historical monetary policy analysis and the Taylor rule, *Journal of Monetary Economics*, 50, 983-1022.
- [12] Orphanides, A. and Wieland, V. (2008), Economic Projections and Rules-of-Thumb for Monetary Policy, *Federal Reserve Bank of St. Louis Review*, 90, 307-24.
- [13] Woodford, M. (2003), *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton, New Jersey, Princeton University Press.

5 Appendix

Table 1: Estimates of the Calvo Rule, US Data

Revised data		ρ	φ	θ	γ	J -test (p -value)	φ^*
<i>Full sample</i>							
Iterative GMM	CBO output gap	0.841 (0.028)	0.592 (0.075)	0.720 (0.255)	0.207 (0.048)	0.857	0.743 (0.074)
	Unemployment gap	0.791 (0.034)	0.484 (0.084)	0.716 (0.273)	0.172 (0.069)	0.772	0.700 (0.119)
CUE	CBO output gap	0.898 (0.035)	0.600 (0.117)	0.794 (0.255)	0.120 (0.048)	0.138	0.971 (0.067)
	Unemployment gap	0.892 (0.030)	0.509 (0.121)	0.772 (0.219)	0.119 (0.044)	0.150	0.606 (0.136)
<i>Volcker-Greenspan sample</i>							
Iterative GMM	CBO output gap	0.621 (0.051)	0.816 (0.046)	3.564 (0.59)	0.384 (0.152)	0.954	0.816 (0.056)
	Unemployment gap	0.645 (0.052)	0.754 (0.056)	3.325 (0.558)	0.253 (0.106)	0.968	0.876 (0.041)
CUE	CBO output gap	0.723 (0.074)	0.859 (0.080)	3.331 (1.206)	0.686 (0.360)	0.488	0.872 (0.103)
	Unemployment gap	0.743 (0.072)	0.821 (0.087)	2.978 (1.016)	0.575 (0.258)	0.409	0.814 (0.085)
‘Real-time’ data							
<i>Full sample</i>							
Iterative GMM		0.620 (0.056)	0.712 (0.058)	0.957 (0.170)	0.199 (0.071)	0.736	0.625 (0.058)
CUE		0.453 (0.081)	0.710 (0.060)	1.325 (0.187)	0.174 (0.039)	0.805	0.709 (0.066)
<i>Volcker-Greenspan sample</i>							
Iterative GMM		0.480 (0.051)	0.871 (0.031)	1.201 (0.146)	0.195 (0.067)	0.841	0.871 (0.038)
CUE		0.706 (0.090)	0.754 (0.076)	1.633 (0.224)	0.200 (0.199)	0.996	0.804 (0.044)

Note: standard errors in brackets; φ^* : Calvo mechanism on inflation only (Eq. 7)