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Estimating monetary policy reaction functions using quantile regressions

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ABSTRACT

Monetary policy rule parameters are usually estimated at the mean of the interest rate distribution conditional on inflation and an output gap. This is an incomplete description of monetary policy reactions when the parameters are not uniform over the conditional distribution of the interest rate. I use quantile regressions to estimate parameters over the whole conditional distribution of the federal funds rate. Inverse quantile regressions are applied to deal with endogeneity. Real-time data of inflation forecasts and the output gap are used. I find significant and systematic variations of parameters over the conditional interest rate distribution. Testing for structural changes in regression quantiles shows that these parameter variations cannot be explained by preference shifts of the Fed. Asymmetric interest rate responses can rather be related to expansions and recessions and are consistent with a recession avoidance preference of the Fed during the Volcker–Greenspan era.

1. Introduction

Policy rules of the form proposed by Taylor (1993) to understand the interest rate setting of the Federal Open Market Committee (FOMC) in the late 1980s and early 1990s have been used as a tool to study historical monetary policy decisions. Although estimated versions describe monetary policy in the US quite well, in reality the Federal Reserve does not follow a policy rule mechanically: "The monetary policy of the Federal Reserve has involved varying degrees of rule- and discretionary-based modes of operation over time," Greenspan (1997). This raises the question how the FOMC responds to inflation and the output gap during periods that cannot be described accurately by a linear policy rule. Except anecdotal descriptions of some episodes (e.g. Taylor, 1993; Poole, 2006) there appears to be a lack of studies that analyze deviations from policy rules systematically and quantitatively.

In addition to changes between discretionary and rule-based policy regimes, economic theory provides several reasons for deviating at least at times from a symmetric and linear policy rule framework. First, asymmetric central bank preferences can lead in an otherwise linear model to a nonlinear policy reaction function (Gerlach, 2000; Surico, 2007; Cukierman and Muscatelli, 2008). A nonlinear policy rule can be optimal when the central bank has a quadratic loss function, but the economy is nonlinear (Schaling, 1999; Dolado et al., 2005). Even in a linear economy with symmetric central bank preferences an asymmetric policy rule can be optimal if there is uncertainty about specific model parameters: Meyer et al. (2001) analyse uncertainty regarding the NAIRU and Tillmann (2010) studies optimal policy with uncertainty about the slope of the Phillips curve. Finally, when interest rates approach the zero lower bound, responses to inflation might increase to avoid the possibility of deflation (Orphanides and Wieland, 2000; Kato and Nishiyama, 2005; Tomohiro Sugo, 2005; Adam and Billi, 2006). Despite these concerns in the empirical literature estimation of linear policy rules prevails.

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Among the few papers that consider the estimation of nonlinear policy rules, different assumptions regarding nonlinearities in monetary policy rule specifications lead to very different empirical results. For example Cukierman and Muscatelli (2008) find important nonlinearities that correspond to a recession avoidance preference of the Fed. Bunzel and Enders (2010) find in addition asymmetric reactions to inflation and Florio (2006) detects nonlinearities in the degree of interest rate smoothing. Rabanal (2004) shows that the Fed attaches a lot of weight on stabilizing output during contractions, while focussing more on controlling inflation and increasing interest inertia during expansions. In contrast, Dolado et al. (2005) find no evidence for a nonlinear policy rule in the US and Surico (2007) finds asymmetric inflation and output responses only prior to 1979.

I take a more general approach to detect and analyze deviations from linear monetary policy rules. While standard linear policy rule estimates characterize the conditional mean of the interest rate, deviations from this linear rule correspond to interest rate responses above or below the conditional mean estimate. I use quantile regression to estimate the whole conditional distribution of the interest rate. In contrast to nonlinear monetary policy rules, there is no need to make particular assumptions regarding the functional form of asymmetries or nonlinearities. Asymmetric reactions of the interest rate to inflation, the output gap and the lagged interest rate are flexibly determined by the data. In contrast to nonlinear policy rule estimation, quantile regression does not yield a characterization of nonlinearities depending on the level of inflation or economic activity. Parameter estimates at different parts of the conditional distribution rather correspond to higher or lower than average interest rate reactions given inflation, the output gap and possibly the lagged interest rate. Thus, the estimated parameters for each quantile of the conditional interest rate distribution can directly be interpreted as deviations from a mean reaction or standard linear policy rule estimate.

For example Cukierman and Muscatelli (2008) find a recession avoidance preference of the Fed. During recessions the interest rate deviates downwards from the values implied by a linear policy rule. The central bank, thus, reacts more to the negative output gap than on average, which leads to interest rate realizations in the lower tail of the conditional interest rate distribution. Another example is the Volcker disinflation. The Fed reacted much more to inflation than during other times to bring inflation down. The federal funds rate was set higher than on average by reacting more to inflation than conditional mean estimates would suggest. Hence, the federal funds rate was set at the upper part of the conditional interest rate distribution.

Chevapatrakul et al. (2009) (CKM henceforth) estimate interest rate reactions at various points of its conditional distribution. They interpret parameters on the lower part of the conditional distribution of the interest rate as interest rate reactions to inflation when interest rates are low. However, the *unconditional* interest rate distribution and the *conditional* interest rate distribution need not necessarily to coincide.[1] The lower and upper part of the conditional interest rate distribution can directly be interpreted as deviations from a mean inflation and output gap response. Rather than reactions at low interest rates, the lower part of the conditional distribution shows that the central bank has set the interest rate lower than on average in response to a given rate of inflation and a given output gap.

In addition to these differences in the interpretation of quantile regressions my paper is distinct from CKM's work in three important aspects: I use real-time data, a recent IV quantile method and I take into account a gradual adjustment of interest rates. First, using real-time data is crucial as the output gap has been perceived by the Federal Reserve to be negative in real-time for almost the whole period between 1970 and 1990. Furthermore, real-time inflation forecasts from the Fed are at times quite different from ex post realized inflation rates. Orphanides (2001) finds that the use of real-time data yields critically different results compared to estimations using ex post revised data. Second, using Hausman tests I find evidence that inflation forecasts and output gap nowcasts are endogenous with respect to the interest rate. Therefore, I use in addition to quantile regression (QR) an inverse quantile regression (IVQR) estimator proposed by Chernozhukov and Hansen (2005). IVQR yields, in contrast to the two-stage estimator used by CKM, consistent estimates even if changes in the endogenous variables affect the shape of the distribution of the dependent variables. In the presence of a zero lower bound of the interest rate this is clearly the case. The estimator of CKM leads to a bias in the estimated constant. IVQR yields unbiased and consistent estimates of *all* parameters. Third, interest rate smoothing has been documented in various studies (see e.g. Clarida et al., 1998; Clarida et al., 2000) to be an important element of US monetary policy and therefore needs to be included in a realistic monetary policy rule specification.[2]

I find clear evidence of a nonlinear relationship between the interest rate, inflation, the output gap and the lagged interest rate. Policy parameters fluctuate significantly over the conditional distribution of the federal funds rate. These deviations from the parameter estimates at the conditional mean of the interest rate are systematic. I find that the inflation coefficient increases over the conditional interest rate distribution. This confirms the result from CKM. For the output gap I find a decrease of the output gap coefficient over the conditional interest rate distribution. In the estimates by CKM this decrease is less pronounced, but they also find that the interest rate response to the output gap is only significant for the lower 50% of the conditional interest rate distribution. While CKM impose a zero interest rate smoothing parameter, I find highly significant

[1] For example, when the zero lower bound on nominal interest rates becomes binding, the central bank sets interest rates at the lowest part of the *unconditional* interest rate distribution. However, a binding zero lower bound means that the central bank would like to set interest rates even lower if this would be possible *given* current inflation and the output gap. Therefore, the interest rate is *not* set a the lowest part of the *conditional* interest rate distribution and possibly above its conditional mean.

[2] Other authors have argued that a large and significant interest rate smoothing coefficient is the results of a misspecified monetary policy rule (see e.g. Rudebusch, 2002). However, tests by English et al. (2003); Castelnuovo (2003) and Gerlach-Kristen (2004) show doubts that these concerns are justified. I estimate two specifications of monetary policy rules, one with and one without interest rate smoothing, to get results comparable to the different views in the existing literature.