

# Taylor Rules for Sweden's Monetary Policy Committee\*

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## Abstract

We estimate Taylor rules for Sweden's central bank, the Riksbank, covering the 2000 to 2011 period. Sweden is interesting because of the transparency of its monetary policy deliberations and also because of its unusual experience in the recent recession. Sweden lapsed into a severe recession in 2008 but, unlike other countries, had a rapid and robust recovery. Prior to the recession, the Riksbank's monetary policy appears to have been highly inertial. This finding is compatible with the hypothesis that committee decision-making tends to be inertial. However, the policy response to both the recession and the recovery in Sweden was quick and substantial, exhibiting less inertia than would have been predicted on the basis of pre-recession Taylor rule estimates. A notable feature of our econometric work is the use of a dynamic Tobit specification to account for the lower bound on nominal interest rates encountered during the recession.

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## **I. Introduction**

The Taylor rule has become an increasingly accepted framework for empirically analyzing monetary policy choices (Taylor 1993). During the Great Moderation, the lack of macroeconomic volatility may have made it difficult to get reliable estimates of Taylor rule parameters; if there is little variation in macroeconomic conditions, estimates of the responses to those conditions are likely to be imprecise. With the arrival of a global recession in 2007, this obstacle largely disappeared; large cyclical fluctuations produced notable policy responses from many central banks.

For several reasons, Sweden provides an interesting case for estimating a Taylor rule in the post-recession environment . First, Sweden experienced a sharp recession, but it recovered more quickly than many other countries. We therefore observe policymaker responses both to the downturn and to the subsequent recovery. Second, although Sweden flirted with the lower bound on interest rates, it has subsequently returned to interest rate levels that exceed the bound. In our work, we employ dynamic Tobit specifications that are appropriate for analyzing policy making in the presence of a lower bound on interest rates. Third, although Sweden implemented some policy actions that might be characterized as “quantitative easing,” those actions did not constitute a comprehensive substitute for traditional interest rate policies. Fourth, the Riksbank is among the most transparent of central banks, and it has published timely accounts of the deliberations of its monetary policy committee (MPC). Specifically, discussions of the lower bound on interest rates are described in detail in meeting minutes.

## II. The Taylor Rule

The Taylor rule is conventionally written as

$$i_t = \pi_t + r_t^* + \alpha_\pi (\pi_t - \pi_t^*) + \alpha_y (y_t - \bar{y}_t) + e_t, \quad (1)$$

where  $i_t$  is a selected target interest rate,  $\pi_t$  is the rate of inflation,  $r_t^*$  is the real rate of interest,  $\pi_t^*$  is the target rate of inflation,  $y_t$  is the log of real GDP, and  $\bar{y}_t$  is the log of potential real GDP. The difference,  $y_t - \bar{y}_t$ , is usually referred to as the output gap. As originally proposed, this was a prescriptive rule, with the following parameter values specified:  $r_t^* = 2$ ,  $\pi_t^* = 2$ ,  $\alpha_\pi = 0.5$ , and  $\alpha_y = 0.5$ .

In empirical applications, Taylor rule parameter values are estimated rather than prescribed, and the specification is usually altered to permit inertia in policymaking. There have been variations in the measurement of the output gap and inflation variables. For example, one can use current or lagged measures, or forecasts of future values. Most studies have concluded that the Taylor rule is a useful framework for analyzing Federal Reserve decision-making during the Great Moderation and even over longer horizons (Clarida, Gali, and Gertler 1999, 2000; Judd and Rudebusch 1998; Orphanides 2001, 2003, 2004).

## III. A Critique of Econometric Taylor Rules

From the mid-1980s until 2007, the period of the Great Moderation, business cycles in the United States and much of the world were subdued. GDP growth rates were less volatile than in earlier periods, and inflation rates were low and steady. Some have argued that appropriate monetary policy choices, perhaps choices that were broadly

consistent with Taylor rule prescriptions, were partly responsible for these desirable outcomes. However, if policymakers are successful in suppressing fluctuations, that success may make it more difficult to determine the parameters of empirical Taylor rules. Consider the extreme case where cycles are completely eliminated and inflation is steady. The explanatory variables in the Taylor rule regression specification become constants, and their coefficients cannot be identified.

Some have argued that the macroeconomic variables in the Taylor rule should be forecasts rather than actual values. However, a central bank that successfully targets inflation will insure that, over a sufficiently long period, expected inflation will be equal to the inflation target. Replacing actual inflation with expected inflation in an empirical Taylor rule could therefore exacerbate the identification problem—even if actual inflation fluctuates, expected future inflation will be more stable, and its coefficient will be difficult to estimate precisely.<sup>1</sup>

If observed values of inflation are used in the Taylor rule, estimation is still problematic. Suppose that underlying inflation trends are low and steady. Further, suppose that a one-time shock affects the price level and the current measured inflation rate. If underlying inflation remains low and steady, a good argument can be made for ignoring the shock for purposes of monetary policymaking. The implication is that in a scenario when underlying inflation is generally on target, observed variations in inflation are precisely those variations that should be ignored. Even though policymakers would

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<sup>1</sup> Estimates could be biased as well as imprecise. Consider a scenario where inflationary pressures are strong. Even when the central bank reacts to fight inflation, the two-year forecast of average inflation starting from the current period will probably be above the target by a small amount. That is, even if inflation will be back to a target pace in two years, above-target inflation will affect the average in the intervening two-year period. This argument suggests that small deviations of the two-year inflation forecast from its target could be associated with large policy responses, and a large inflation coefficient estimate could result. This is because a small inflation deviation from target is an indication of what would have been a large deviation, absent the endogenous response.

react strongly to a *persistent* change in inflation, estimated Taylor rules might indicate a muted response to *observed* inflation.

For much of the period we study, the Riksbank calculated expected future inflation rates under the assumption that the repo rate, its policy target, would be unchanged. Such a forecast is probably most appropriate for inclusion in the Taylor rule—it measures inflation pressures that are purged of an expected endogenous policy response.

#### **IV. The Zero Lower Bound on Nominal Interest Rates**

The recession that began in 2007 produced large drops in real GDP in the United States and other countries. Inflation rates also fell, although less dramatically. In response, central banks reduced their interest rate targets. In the United States, the federal funds rate fell from 5.25% in September 2007 to near-zero in December 2008. The rate has remained at its effective lower bound since then. Given the impossibility of lowering rates further, the Taylor rule has become largely irrelevant as a description of U.S. monetary policy since that time.

Events have unfolded somewhat differently in Sweden. Output began to plunge in late 2008, the GDP gap reached -7.5% in September 2009, and the target repo rate fell to 0.25%. Although some members of the Riksbank's MPC argued for a further reduction to zero, the majority of the committee believed that 0.25% was an effective lower bound. For econometric purposes, we will report estimations that assume a lower bound on the repo rate at that level.

After September 2009, the economy rebounded, and real GDP grew at a rate exceeding 7% in calendar year 2010. The repo rate was adjusted upward beginning in June 2010, and reached a level of 1.75% by April 2011. Although Sweden undertook measures that might be described as “quantitative easing” during the recession, the repo rate remained the primary tool for monetary policy. Because of the rapid recession and recovery, and because complications associated with quantitative easing were minimal, estimation of a Taylor rule for the Riksbank using data from the recent recession should be feasible and informative.

## V. Econometric Issues

The Taylor rule can be regarded as an empirical model for describing a central bank’s monetary policy choices. In an empirical context, equation (1) is viewed as a regression specification in which a central bank’s interest rate target is the dependent variable, and prevailing inflation and output gap measures are independent variables. Empirical Taylor rules normally include lagged dependent variables to account for inertia and to lessen problems with serial correlation (Orphanides 2004).

For the Riksbank, we write our base empirical Taylor rule specification as

$$i_t = \alpha_0 + \rho_1 i_{t-1} + \rho_2 i_{t-2} + \alpha_\pi (\pi_t - \pi_t^*) + \alpha_y (y_t - \bar{y}_t) + e_t. \quad (2)$$

The dependent variable is a short-term interest rate, the repo rate. As a measure of inflation, we employ the inflation forecast that is developed by the Riksbank staff and presented to the MPC. This is a two-year-ahead forecast of annual inflation according to the consumer price index. The inflation forecasting method used by the Riksbank changed several times during the period we study. We will address complications

resulting from these changes in section VII. The output gap used in estimation is published by Sweden’s National Institute of Economic Research (NIER). The original gap data were quarterly, but we have interpolated to obtain output gap estimates at committee meeting dates.<sup>2</sup>

Our sample of Riksbank data begins with the May 2000 MPC meeting and extends to the April 2011 meeting. In that period, the MPC met 82 times. In five of the meetings, from July 2009 through April 2010, the repo rate was set at the boundary level of 0.25%.

In the presence of a lower bound on the dependent variable, the appropriate specification is a Tobit model, as described in (3):

$$i_t^* = \alpha_0 + \rho_1 i_{t-1} + \rho_2 i_{t-2} + \alpha_\pi (\pi_t - \pi_t^*) + \alpha_y (y_t - \bar{y}_t) + e_t, \quad (3)$$

with

$$i_t = i_t^* \text{ if } i_t^* \geq 0.25$$

and

$$i_t = 0.25\% \text{ if } i_t^* < 0.25.$$

The dependent variable in this specification is a “desired” interest rate,  $i_t^*$ . The desired rate is not bounded; the MPC could have a desired interest rate that is negative, even though the actual rate cannot be. The model specifies that when  $i_t^*$  is below its lower limit of 0.25%, it is unobserved, and the actual interest rate,  $i_t$ , takes the boundary value of 0.25%. Note that in (3) we have specified that the lagged interest rates on the right-hand side are the actual observed rates. We refer to this as the Tobit I specification.

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<sup>2</sup> Jansson and Vredin (2003) and Berg, Jansson, and Vredin (2006) have previously analyzed Swedish monetary policy experience using estimated Taylor rules.

It is plausible that lagged values of the underlying desired interest rates (not actual interest rates) should appear on the right-hand side, as in (4):

$$i_t^* = \alpha_0 + \rho_1 i_{t-1}^* + \rho_2 i_{t-2}^* + \alpha_\pi (\pi_t - \pi_t^*) + \alpha_y (y_t - \bar{y}_t) + e_t. \quad (4)$$

We refer to this as the Tobit II specification. In this model, unobserved variables appear on both sides of equation (4), making the estimation problem more difficult. To estimate this model, we use the maximum simulated likelihood (MSL) method. For each observation in the sample, any missing values of the unobserved right-hand side variables are simulated repeatedly according to the process specified to determine them. The likelihood function is then calculated for each simulated observation, and the likelihood for an observation is calculated as the average over the simulated values. See Chang (2011) for details about various simulation methods for estimating dynamic Tobit models.

## **VI. Model Estimates**

We initially estimate the Taylor rule model for data spanning the period preceding the recession in Sweden, i.e., for the period from May 2000 to December 2007. We then estimate the model for the period including the recession and recovery, covering meetings from February 2008 through April 2011. The latter period includes the meetings in which the interest rate encountered a presumed lower bound at 0.25%, so that the Tobit specification is appropriate. For purposes of comparison, we estimate via both OLS and Tobit for the latter period. Two versions of the Tobit model are employed, as described by (3) and (4). In the first version, observed lagged values of the interest rate appear on

the right-hand side; in the second version, lagged values of the model's unobserved desired rates appear. Results are provided in Table 1.

The results show some noticeable differences across samples, estimation methods, and specifications. For the pre-recession sample, OLS estimates show significant positive coefficients for both the output gap and expected inflation. The coefficients on these variables are small; however, the sum of the lagged interest rate coefficients is high, at 0.97. These results indicate a slow, inertial response of the repo rate to changes in economic conditions.

For the recession sample, the gap variable remains significant and positive in all estimations. The inflation variable remains marginally significant only in the OLS results. In the recession sample, and especially in the Tobit specifications, inertial effects are considerably weaker—the sum of the coefficients of the lagged dependent variables is 0.635 in the Tobit I specification and 0.544 in the Tobit II specification. With a larger gap coefficient and less inertia, the estimated reaction to the recession appears to be much stronger than would have been predicted by the Taylor rule estimated with pre-recession data. Other results are similar for the two versions of the Tobit model; standard errors for most coefficients are smaller for Tobit I, the specification including observable lagged interest rates, but qualitative results are similar, as are overall fits (the log-likelihoods are -1.58 for Tobit I and -1.82 for Tobit II).

## **VII. Expected Inflation in the Taylor Rule**

Until October 2005, the Riksbank calculated inflation forecasts under the assumption that the current repo rate would remain unchanged over the forecast horizon.

However, from October 2005 onward, different forecasting assumptions were employed. In October 2005, the inflation forecast in the Monetary Policy Report was calculated under the assumption that “the repo rate would develop in line with expectations in the financial markets as they are expressed in implied forward rates.”<sup>3</sup> Beginning with the February 2007 meeting, the forecast was instead based on “the interest rate path that the Riksbank currently considers will provide a well-balanced monetary policy.”<sup>4</sup> In December 2010, the forecasting assumption changed again. This time the forecast was based on the path of interest rates that “would gain the support of a majority of the members of the Executive Board.”<sup>5</sup>

The discussion above implies that four distinct methods were used in constructing the Riksbank’s expected inflation measure over our sample period. For our analysis, we will assume that there have really been just two regimes: the constant repo rate regime and three essentially equivalent endogenous repo rate regimes. If a majority of the MPC favored what is also a well-balanced policy, and if markets anticipated such a policy, then the three regimes would be equivalent. There is no indication given in minutes or Monetary Policy Reports that any substantive differences were expected under the three endogenous rate regimes. Further, the three regimes were each in effect for short periods, so distinguishing them empirically is not likely to be practical.

The forecasts that assume endogenous interest rate movements are subject to the problem identified in our Section III critique. If interest rates are adjusted in an

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<sup>3</sup> Source: Separate Minutes of the Executive Board meeting for October 19, 2005.

<sup>4</sup> Source: Monetary Policy Report, 2007:1.

<sup>5</sup> Source: Separate Minutes of the Executive Board meeting for December 14, 2010.

appropriately balanced fashion, then the Riksbank should come close to hitting its inflation target, and the forecast of inflation should routinely be close to the target value.

To investigate whether the Riksbank's changing forecasting methods affects Taylor rule estimates, we have altered our models to permit parameter shifts related to the forecasting regime. To do so, we define a dummy variable,  $DNEW_t$ , to indicate meetings held after August 2005. This corresponds to the regime under which interest rates were assumed to be adjusted endogenously. We also create an interaction of the dummy variable with the inflation forecast,  $\pi_t$ .

Table 2 reports estimates of Taylor rules for the pre-recession period that add these two variables to the original specification. The dummy variable itself has an estimated coefficient that does not differ significantly from zero. However, the interaction of the dummy variable with expected inflation is negatively signed and suggests that the coefficient of the inflation forecast goes to zero when once the forecast is made endogenous (we are unable to reject the hypothesis that the coefficients of  $\pi_t$  and  $DNEW_t * \pi_t$  sum to zero). Therefore, in the pre-recession period, the change in forecasting method appears to explain the disappearance of an expected inflation effect on the repo rate. This also suggests that the absence of an estimated inflation effect in the recession period could be a consequence of the forecasting method rather than a shift in the behavior of the MPC.

## **VIII. Conclusions and Discussion**

We have estimated Taylor rules for Sweden's Riksbank over a period extending from 2000 to 2011. This period is interesting because it includes the late years of the "Great Moderation," a severe recession, and a robust recovery. Our results show that the policy response to the recessionary output gap was stronger and faster than would have been predicted from Taylor rules estimated using only pre-recession data points. Policy appeared to be highly inertial before the recession, but much less so afterward.

Our estimates also suggest that the repo rate was adjusted in response to expected inflation in the pre-recession period, but not in the recession period. This may be a consequence of a change in the method for forecasting inflation rather than a fundamental change in policy behavior. In future work, we plan to investigate this issue more carefully. We will also investigate alternative Taylor rule specifications, including those proposed by Driffill and Rotondi (2007). Driffill and Rotondi have suggested that much of apparent policy inertia is driven by inertia in macroeconomic conditions, rather than the policymaking process per se. The preliminary results reported here offer some support for this conjecture.

**Table 1. Taylor Rule Estimates: Riksbank**

OLS: May 2000 to December 2007

Variable	Coefficient	Standard Error	t-statistic	P-value
<i>Constant</i>	0.061505	0.077051	0.798242	[.428]
$i_{t-1}$	1.06988	0.130778	8.18087	[.000]
$i_{t-2}$	-0.101566	0.130502	-0.778266	[.440]
$y_t - \bar{y}_t$	0.067314	0.019914	3.38018	[.001]
$\pi_t$	0.264007	0.109724	2.40609	[.019]

OLS: February 2008 through April 2011

Variable	Coefficient	Standard Error	t-statistic	P-value
<i>Constant</i>	0.797651	0.25825	3.08868	[.007]
$i_{t-1}$	1.0445	0.19947	5.23636	[.000]
$i_{t-2}$	-0.262446	0.162306	-1.61698	[.125]
$y_t - \bar{y}_t$	0.173087	0.042222	4.09942	[.001]
$\pi_t$	0.276056	0.146441	1.8851	[.078]

Tobit I: February 2008 through April 2011

Parameter	Estimate	Standard Error	t-statistic	P-value
<i>Constant</i>	1.54605	0.548228	2.82009	[.005]
$i_{t-1}$	0.566373	0.353007	1.60442	[.109]
$i_{t-2}$	0.069062	0.254019	0.271878	[.786]
$y_t - \bar{y}_t$	0.259266	0.065206	3.97609	[.000]
$\pi_t$	-0.347138	0.427101	-0.812778	[.416]

Tobit II: February 2008 through April 2011

Parameter	Estimate	Standard Error	t-statistic	P-value
<i>Constant</i>	1.93391	1.15651	1.6722	[.094]
$i_{t-1}^*$	0.370915	0.675451	0.549137	[.583]
$i_{t-2}^*$	0.172786	0.510518	0.338453	[.735]
$y_t - \bar{y}_t$	0.283445	0.134478	2.10775	[.035]
$\pi_t$	-0.528919	1.04304	-0.507095	[.612]

**Table 2. Taylor Rule Estimates under Alternative Inflation Forecasts: Riksbank**

OLS: May 2000 to December 2007

Variable	Coefficient	Standard Error	t-statistic	P-value
<i>Constant</i>	-0.00887	0.115122	-0.07708	[.428]
$i_{t-1}$	0.984090	0.134629	7.30967	[.000]
$i_{t-2}$	-0.002703	0.139115	-0.01943	[.440]
$y_t - \bar{y}_t$	0.056101	0.031279	1.79357	[.001]
$\pi_t$	0.388766	0.125554	3.09641	[.003]
$DNEW_t$	0.166729	0.112696	1.47946	[.145]
$DNEW_t * \pi_t$	-0.558667	0.269068	-0.7001	[0.43]

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