Belke, Ansgar; Beckmann, Joscha; Dreger, Christian

Conference Paper

Does the foreign interest rate matter for monetary policy? Evidence from nonlinear Taylor rules

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Abstract. Deviations of policy interest rates from the levels implied by the Taylor rule have been persistent after the turn of the century even before the financial crisis. These deviations could be due to lower real interest rates, as stated by the savings glut hypothesis as well as the apparent success of monetary policy in combating inflation. Alternatively, they might reflect the omission of relevant variables in the standard rule, such as international dependencies in the interest rate setting of central banks. By using a smooth transition regression approach for three major central banks, this paper provides evidence for nonlinear threshold dynamics. In fact, the foreign interest rate is well-suited to improve standard Taylor-Rules.

JEL-Code: E43, F36, C22

Keywords: Taylor rule, savings glut, international spillovers, smooth transition

1 Introduction

Since the 1980s central banks switched to policies based on rules, with strong emphasis on price stability. The Taylor rule has become popular to describe the monetary policy stance in both advanced and developing countries (Taylor, 1993). It links policy interest rates to deviations of inflation from its target and real output from its potential. According to the Taylor principle, the central bank should raise the nominal interest rate by more than one percentage point for each one percent increase in inflation. Taylor (1993) emphasized the importance of rule-like behaviour on part of central banks as a key framework to ensure time-consistency, transparency, and independence.

While policy rates have been broadly in line with the Taylor rule during the Great Moderation, they have been persistently below in both advanced and developing countries since the turn of the century. The monetary accommodation implied by this deviation has been blamed as a potential factor in the build-up of imbalances in the period before the financial crisis (Kahn, 2010). Therefore, the explanation of the deviations is of high academic and policy relevance.

On the one hand, lower levels of equilibrium real interest rates may have introduced an upward bias in the Taylor rule. As inflation rates have become firmly anchored to the inflation targets of central banks, nominal and real interest rates declined, thereby causing a wedge between actual policy rates and those suggested by the Taylor rule. Furthermore, capital inflows from emerging markets to industrial countries might have contributed to lower real interest rates, as stated by the savings glut hypothesis (Bernanke, 2005). Underdeveloped financial markets in the emerging countries restricted the ability of their citizens to borrow against future income and redirected their savings to industrial countries. Asset shortages triggered a reduction of equilibrium real interest rates at a global scale, see Caballero, Fahri and Gourinchas (2008). In addition, the development might reflect secular demographic trends in the industrial countries, specifically strong asset demand exerted by the baby boomer generation. A further explanatory factor is an increase in the perceived riskiness of capital assets in the wake of asset price booms and busts after the turn of the century. Thus, policy interest rates fell below the Taylor rule in close synchronization across countries. For example, Hofmann and Bogdanova (2012) have argued that deviations from the Taylor rule can be best interpreted as a change in the global equilibrium real interest rate.

On the other hand, the deviations might suggest that central banks decided on policy rates no longer in an independent way. While interest rates have been set according to national conditions up to the turn of the century, policy reactions are increasingly affected by the international environment. Hence, the deviations might indicate a substantial shift in the monetary policy regime. Among others, Kim (2000) has demonstrated that US monetary policy shocks can affect other countries. Belke and Gros (2005) provided evidence that the ECB followed the Fed in their interest rate decisions. In fact, low domestic interest rates can increase risk taking in other countries, and one way to react is to lower interest rates also abroad, see Bruno and Shin (2012). In addition, central banks tend to resist large appreciations of their currencies, and adjust their interest rates according to the behaviour of other central banks. Deviations from the rule can amplify due to international spillovers, see Taylor (2013). Most importantly, the actions of the Federal Reserve Bank (Fed) have been magnified due to the responses of other central banks (Gray, 2012).

Deviations might also reflect nonlinear dynamics. For example, central bank interest rate setting rules can be different for expansionary and restrictive periods. This distinction might also hold regarding a potential impact of foreign interest rates. Nonlinear Taylor rule have been recently proposed by Riedl and Brüggemann (2011), among others. They might be able to explain interest rates. This paper investigates the likely causes for the deviations from the standard Taylor rule by allowing for nonlinearities. To discriminate between the alternatives, a smooth transition model is specified for three main industrial countries, i.e. the US, UK and Japan. The results show that discriminating between increasing and decreasing interest rates and allowing for an impact of foreign interest rates improve the explanatory power of the Taylor-Rule.

The rest of the paper is organized as follows. The next section (Section 2) reviews the Taylor rule and the deviations from its target. Section 3 presents the econometric methodology. Data issues and empirical results are discussed in Section 4. Finally, Section 5 concludes with some policy implications.

2 Deviations from the Taylor rule

The Taylor rule establishes a simple linear relation between the nominal interest rate, inflation and the output gap. In its standard form

(1) $$i_t = r^* + \pi^* + \alpha_1(\pi_t - \pi^*) + \alpha_2 y_t + \varepsilon_t$$

i is the nominal policy rate, r^* is the long-run equilibrium real interest rate, π^* the central bank's inflation objective, π is the actual inflation rate, and *y* is the output gap, i.e. the deviation of actual and potential output, expressed as a percentage of the latter. The error ε fulfills the white noise properties and the index *t* denotes time. The parameters describe how strongly the policy interest rate should respond to deviations of inflation from the target and of output from its potential. The Taylor rule implies that central banks aim at stabilizing inflation around its target level and output around its potential. Positive (negative) deviations of the two variables from their target or potential level would be associated with a tightening (loosening) of monetary policy. An inflation reaction coefficient (α_1) larger than one ensures that real interest rates respond in a stabilizing way to inflationary pressures (Taylor, 1993, 1999). Thus, an increase in inflation triggers a rise in the real interest rate.

Central banks often prefer to adjust policy rates not instantaneously, but in a gradual fashion, with small, distinct steps in a particular direction. If they partially adjust towards desired levels, interest rate smoothing can be incorporated

(2) $$i_t = \rho i_{t-1} + (1-\rho)(r^* + \pi^* + \alpha_1(\pi_t - \pi^*) + \alpha_2 y_t) + \varepsilon_t$$

via the inclusion of the lagged policy rate (Judd and Rudebusch, 1998). The higher the weight of the latter, the slower policy rates adjust to the intended levels[1]. The lagged interest rate can be also seen as a proxy of further determinants of the policy rate which are less important and excluded from the specification. Equations (1) and (2) are ex post formulations of the Taylor rule, i.e. setting of interest rates evolves conditional to contemporaneous values of the inflation and the output gap. If monetary policy acts with a delay of *k* periods, a forward looking (ex ante) specification

(3) $$i_t = \rho i_{t-1} + (1-\rho)(r^* + \pi^* + \alpha_1(E_t\pi_{t+k} - \pi^*) + \alpha_2 E_t y_{t+k}) + \varepsilon_t$$

is more appropriate, where E denotes the rational expectations operator (Clarida, Galí and Gertler, 2000). Nominal interest rates depend on their past levels, the expected deviations of inflation from its target and output from its long run potential. Expectations exploit all information available at time when the prediction is made. Nominal interest rates fluctuate around a constant equilibrium value, the latter defined as the sum of the real interest rate and the inflation target. It should be noted, that the Taylor rule acts as a rule of thumb and leaves out many factors that might be relevant for monetary policy, for example, the risk that the policy rate hits the zero lower bound.

Many empirical studies have demonstrated that monetary policy of advanced countries can be explained by this kind of reaction function. Despite of the persistence of policy rates, the reaction coefficient of the inflation gap is larger than unity and exceeds the coefficient of the output gap, especially in more recent periods of monetary history. Furthermore, forward-looking models seem to fit the actual behaviour of central banks slightly better than contemporaneous versions.

[1] In contrast, nominal interest rates have been cut aggressively towards the zero lower bound during the global financial crisis to avoid output losses, especially after the Lehman collapse, see Gerlach and Lewis (2011).

Since the turn of the century, however, deviations from the Taylor rule have increased. In particular, actual nominal interest rates fell persistently below the Taylor implied levels, suggesting a loose stance of monetary policy before the financial crisis. This point can be made both for ex ante and ex post rates. According to Clarida (2012) the differences are smaller if ex ante rates are considered. The deviations might be caused by lower equilbrium real interest rates, or the omission of explanatory factors, such as foreign interest rates and nonlinearties, as central bank behavior might be different over the business cycle. Note that an exclusion of relevant variables might erroneously be interpreted as a change in the reaction coefficients with regard to the inflation and output gap.

3. Econnometric methodology

3.1 Linear specification of Taylor rules

As a first step, we carry out linear benchmark estimations of the Taylor-Rule specification in Equation (1) via OLS. To account for autocorrelation, the first two lagged interest changes are additionally included. The results are presented in Table 1. All coefficients are in line with theoretical prredictions although the estimation of the output gap coefficient is frequently considered to be insignificant due to high standard errors. A graphical inspection of the deviations (Figure 1) shows that the Taylor Principle is a reasonable approximation of monetary policy from the late eighties until the start of the Millenium. Outliers occurring during the 1990s might be explained by particular events such as the start of the deflationary period in Japan. However, the limitations of the linear model became evident since then. Therefore, nonlinear specifications are envisaged to capture the actual behavior off central banks.

Figure 1 about here

3.2 Nonlinear specification of Taylor rules

By specifiying the dynamics in a nonlinear form, several questions are addressed: Firstly, the coefficients of the Taylor rule might be different in periods of increasing and decreasing interest rates Second, the deviations from the standard Taylor rule might represent the influence of omitted variables such as foreign interest rates. Due to its importance for the global economy, foreign interest rates are approximated by the US rates.

The nonlinear setting provides a convenient framework to distinguish between the hypothesis of a savings glut (decline in the constant) and the emergence of international determinants in the Taylor rule. Smooth transition models offer the advantage of allowing for more complex dynamics compared to a standard discrete threshold model since they allow for smooth adjustment between two regimes. In the model model

(4) $$i_{t=}[\alpha_1 + \beta_1(y_t) + \beta_2(\pi_t - \pi_t^*) + \beta_3(i_{t-1}^*)] + [\beta_1{}'(y_t) + \beta_2{}'(\pi_t - \pi_t^*) + \beta 3' it-1 * F(zt,\gamma,c) + ut+k,$$

$F(z_t, \gamma, c)$ is a transition function which ascertains the speed of adjustment and could have either a logistic or an exponential shape. The coefficients α_1 and β_1 correspond to the lower regime, while $(\alpha_1 + \beta_1{}')$ and $(\beta_1 + \beta_1{}')$ belong to the upper regime of the adjustment process (van Dijk et al., 2002). By including the foreign interest rates, we allow a reaction of domestic interest changes with regard to monetary policy decisions abroad in the previous period. For the United States, the lagged domestic interest rate is included instead to compare the fit to Japan and the UK.

An exponential and a logistic function are close substitutes and relate to different patterns of nonlinearity. In particular, a logistic transition allows for different estimates above and below a threshold, while the exponential transition accounts for a distinction between small and large deviations from a threshold. Since the aim is to distinguish between increasing and decreasing interest rates, a logistic transition is adopted. Brüggemann and Riedl (2011) have provided evidence that the logistic smooth transition approach is a viable alternative to linear reaction functions for the analysis of monetary policy.

To explain the underlying dynamics, $F(z_t, \gamma, c)$ is a continuous logistic transition function bounded between 0 and 1. It has the following form:

(5) $$F(z_t, \gamma, c) = [1 + \exp(-\gamma(z_t - c)/\sigma_{zt})]^{-1} \quad \text{with } \gamma > 0.$$

It implies that the lower (upper) regime is associated with negative (positive) values of the transition variable z_t relative to the location parameter c. The logistic function increases monotonically from 0 to 1 as the transition variable rises, so that $F(z_t, \gamma, c) \to 0$ as $z_t \to -\infty$ and $F(z_t, \gamma, c) \to 1$ as $z_t \to +\infty$, while it takes the value 0.5 if $z_t = c$. The location parameter can be interpreted as a threshold dividing Equation (4) into three different extreme regimes corresponding to $\lim_{z_t \to -\infty} F(z_t, \gamma, c)$, $\lim_{z_t \to +\infty} F(z_t, \gamma, c)$ and $z_t = c$. For instance, in the case of $z_t = c$, Equation (4) reduces to the linear model expressed by Equation (3), where $\alpha = \alpha_1 + 0.5\alpha_2$ and $\beta = \beta_i + 0.5\beta_i{}'$. Moreover, the smoothness parameter γ shows the speed of transition between the extreme regimes (Baillie and Kilic, 2006).

The choice of an adequate transition variable z_t is of crucial importance. A straightforward choice is the lagged change of the interest rate and a threshold c which is restricted to zero. In this case, the different regimes correspond to a comparison of periods where the domestic interest rates increase or decrease. For robustness, we also consider the output gap as a transition variable.

The smooth transition specification suggested by Teräsvirta (1994) starts with a Lagrange multiplier (LM) test for linearity, :

(6) $$\Delta s_{t+k} = \varphi_0 + \varphi_1(c_t) + \varphi_2(c_t)z_t + \varphi_3(c_t)z_t{}^2 + \varphi_4(c_t)z_t{}^3 + \epsilon_{t+k}\,.$$

see Luukkonen et al. (1988). Under the null hypothesis, the linear model is adequate. Therefore, testing is done by examining $H_0: \varphi_i = 0$, $i = 2,3,4$ against the alternative H_1 where at least one $\varphi_i \neq 0$, implying that the higher order terms are significant (Teräsvirta, 1998). The test statistic has a χ^2 distribution with three degrees of freedom. For both the lagged interest rate changes and the output gap, linearity is clearly rejected. The results are available upon request.

4. Data and Empirical findings

4.1 Data

Our analysis is based on quarterly data from 1982:1 until 2008:9 for the United States, the United Kingdom and Japan. The starting point of our analysis is motivated by the end of the so called “pseudo monetarism” policy period of the Federal Reserve. We exclude the developments during the recent financial crisis owing to the fact that we are interested in developments prior to the crisis. Our analysis is based on three months interest rates, consumer prices for calculating inflation and real GDP. All series are from International Financial Statistics. Output Gap is obtained through the Hodrey Prescott Filter based on a substraction from real GDP. Since our sample includes more than 30 years of data, real-time series are not available throughout the sample. Considering the fact that we are primarily interested in reducing deviations from a standard Taylor-Rule by including foreign interest rates and nonlinearities, a distinction between real-time and revised data does not seem of crucial importance.[2]

4.2 Empirical findings

The nonlinear findings are presented in Table 2 and Table 3. Interestingly the coefficients frequently differ between the two regimes, suggesting that a distinction between the regimes is indeed important. Figure 2 shows that the inclusion of foreign interest rates and nonlinear dy-

[2] In a recent paper, Belke and Klose (2013) also base their analysis on revised data.

namics will improve the explanatory power of the Taylor rule compared to the linear setting The coefficients for output and inflation gaps display a smaller magnitude.

Table 2 and 3 and Figure 2 about here

The coefficients for the first regime correspond to decreasing domestic interest rates. For the US and the UK, the coefficient for the output gap turns out to be positively signed and significant while this is not case for Japan where the coefficient is positive but insignificant. The coefficient for inflation turns out to be significant and positive the UK and Japan it is but insignificant for the US. The lagged interest rate of the US is positive and significant for all three economies. Overall, the magnitude of the estimates is in line with theoretical considerations.

In a regime of increasing interest rates, the importance of the output gap decreases for the UK and the US while insignificance is still observed for Japan. The additional inflation coefficient is insignificant and decreases for the UK and the US. For both Japan and UK, the lagged US interest rate turns out to be significant. Overall, these findings show that periods of decreasing interest rates are more influenced by domestic output developments while the importance of the US increases in periods of rising interest rates. A declining constant is observed for both the UK and Japan leaving a decreasing real interest rates according to the Global Savings Glut as a possible explanation.

Finally, the results in Table 4 correspond to the case where the output gap is chosen as the transition variable. The results are less clear-cut but are also mostly in line theory. In particular, an impact of US interest rates still turns out to be significant and positive for Japan and UK, providing further evidence that the corresponding central banks have been heavily influenced by monetary policy decisions in the US.

5. Conclusion

This study has allowed for various nonlinear adjustment patterns and impact of foreign interest rates when analyzing monetary policy against the background of the Taylor rule. Our approach fits the data reasonably well and reduces deviations compared to a standard Taylor rule estimations.

From a general point of view, our findings suggest that central bank behavior is different for expansionary and contradictory interest rate decisions. This is also true for the impact of foreign interest rates. For the UUK, previous changes of US interest rates gain more significance in cases of increasing domestic interest rates. Hence, expansionary monetary policy decisions have been more frequently related to changes of US monetary policy. In contrast, the output gap plays a larger role in periods where the central bank decides to provide stimulus through a reduction of interest rates. We also observe different constants, leaving changes in real interest rates according to the saving glut hypothesis as another possible explanation. However, despite the progress made by the introduction of nonlinearities, the extended model fails to explain some rapid changes in the interest rate prior to 2007, suggesting that monetary has left the traditional path prior to the crisis.

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Tables

Table 1: Linear Estimations

	Constant	Gap	$INFG$	ΔI_{t-1}	ΔI_{t-2}
US	3.983*** [10.979]	0.087 [0.460]	1.323*** [5.901]	-0.309 [-0.851]	-0.346 [-0.794]
UK	5.824*** [27.830]	0.063 [0.365]	1.206*** [10.229]	0.220 [0.805]	0.119 [0.496]
Japan	4.767*** [14.912]	0.080 [0.774]	1.761*** [12.297]	-0.561 [-1.208]	-0.388 [-0.838]

Note: * Statistical significance at the 10% level, ** at the 5% level, *** at the 1% level. T-values are given in parentheses.

Table 2: Nonlinear estimates based on lagged interest rates changes as transition variable

Country	a_0	a_1	β_1	β_1'	β_2	β_2'	β_3	β_3'	γ_1
UK	4.152*** [4.603]	-0.644 [-1.107]	0.279*** [2.639]	-0.378 [-1.281]	0.958*** [20.623]	-0.279 [-1.175]	0.239** [2.167]	0.369*** [2.628]	3.761 [0.910]
US	-0.553** [-2.062]	1.838** [2.426]	0.137*** [3.665]	-0.211** [-2.040]	-0.085 [-0.669]	0.411 [1.011]	1.059*** [16.690]	-0.323* [-1.709]	2.404** [2.189]
Japan	2.851*** [5.736]	-2.990*** [-3.833]	-0.006 [-0.076]	0.173* [1.706]	1.311*** [7.383]	-0.318 [-0.918]	0.333*** [6.873]	0.270*** [3.318]	47.443 [1.636]

Note: * Statistical significance at the 10% level, ** at the 5% level, *** at the 1% level. The coefficients are estimated by nonlinear least squares. T-values are given in parentheses.

Table 3: Nonlinear estimates based on Output Gap as transition variable

Country	a_0	a_1	β_1	β_1'	β_2	β_2'	β_3	β_3'	γ_1
UK	1.402 [1.560]	3.482* [1.684]	-0.236 [-0.553]	0.359 [0.627]	0.879*** [14.161]	-0.432*** [-2.897]	0.742*** [5.853]	-0.404* [-1.814]	2.309* [1.842]
US	-1.378 [-1.086]	2.999 [1.239]	-0.165* [-1.794]	0.108 [0.777]	-0.241 [-0.654]	0.581 [0.906]	1.149*** [6.293]	-0.404 [-1.222]	0.381 [0.892]
Japan	2.691*** [3.749]	-1.963*** [-2.670]	0.196** [2.365]	-0.326* [-1.659]	1.481*** [11.464]	-0.703*** [-3.335]	0.324*** [5.486]	0.224*** [3.082]	2.721 [0.764]

Note: * Statistical significance at the 10% level, ** at the 5% level, *** at the 1% level. The coefficients are estimated by nonlinear least squares. T-values are given in parentheses

Figures

Figure 1: Deviations from a linear Taylor rule

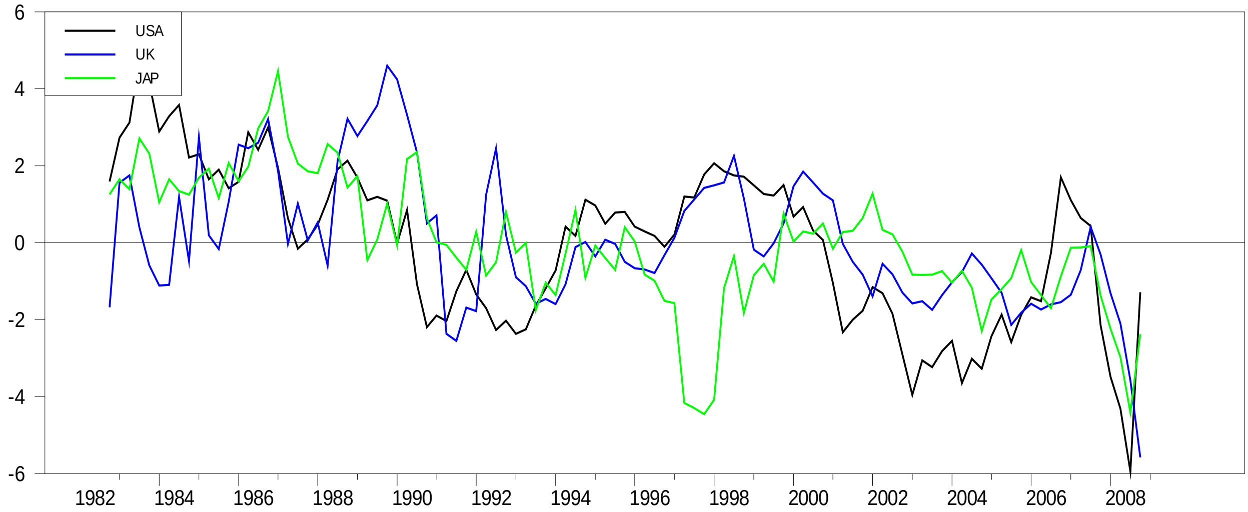

Figure 2: Deviations from a nonlinear Taylor rule including foreign interest rates