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Nonlinear Taylor rule for the European Central Bank

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Abstract

In this paper I add to the evidence on possible nonlinearities in the conduct of ECB monetary policy. For this purpose a nonlinear Taylor rule (threshold regression) was estimated and compared to a linear benchmark model. The estimation was carried out with output gap data computed from quarterly GDP time series. The results show that a nonlinear Taylor rule fits the data better than a linear one.

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1 Introduction

The original formulation of Taylor (1993) rule suggests that central banks set short-term interest rates according to how far actual inflation is from its target and how far actual output is below or above its potential. The rule is linear which means that sensitivity to the mentioned distances is symmetrical and proportional.

The fact that Taylor-type rules are attempts to describe central bank behavior means that there is no reason for them to necessary be linear[1]. Nonlinearity in short-term interest rate setting could be expected, for example, because policy makers may prefer economy to be slightly above potential output. In that case it can be as an insurance policy against slipping below full employment when there is uncertainty or measurement errors in economic data.

Nonlinear Taylor-type interest rules have received some attention in literature but empirical research mostly covers cases in the US and the UK. In general it is found that there are significant evidence of nonlinear behavior in short-term interest rate setting (Taylor & Davradakis, 2006; Dolado *et al.* , 2004; Petersen, 2007; Cukierman & Muscatelli, 2008). While there are some evidence documented (Castro, 2011; Klose, 2011; Sauer & Sturm, 2007), the conduct of monetary policy by the ECB has received relatively little attention in this regard.

This paper adds to the evidence on possible nonlinearities in the conduct of ECB monetary policy. For this purpose I estimated a nonlinear Taylor rule (threshold regression) and compared it to a linear benchmark model. The estimation was carried out with output gap data computed from quarterly GDP time series. I find that a nonlinear Taylor rule fits the data better than a linear one.

In the following section I discuss how data used in estimation procedure is constructed. In section 3 a nonlinear Taylor rule for ECB is estimated and the results are compared to a linear one. The final section of this paper provides some concluding remarks and suggestions for future research.

2 Data

Eurozone is not an ordinary economy. It was comprised of 18 member states at the time of writing this paper but only 11 of them were in the monetary union when it came into existence in 1998. The rest joined between 2001 and 2014. Formally the GDP of Eurozone increases by the amount of GDP of the country that joins the monetary union. I accounted for these complications in this part of the paper and discussed peculiarities of data needed for estimation in section 3.

When estimating interest rate rules it is rather common to use monthly industrial output data as a proxy for actual output. Higher frequency than that of GDP time series is often cited as a justification for such decision. Indeed, the ECB monetary policy committee meets bi-monthly and the short-term interest rates can be changed several times over a quarter. While in practice it is not that common, there are several instances when this have happened. However, using industrial output as if it was everything an economy generated involves sacrificing accuracy. Sauer & Sturm (2007) find that industrial output data for ECB decisions is not that relevant. In order to not overlook the role services and other sectors play in the business cycle, I used GDP data in this paper.

Enlargements of Eurozone hinder using readily available GDP time series for estimating output gaps. As a workaround I switch time series at the enlargement dates to the relevant ones. By starting the computations from the first quarter that involves an increase in member states, GDP gaps are calculated as if the new members where in the monetary union from the beginning.

The rest of data used for estimation was fairly standard. The ECB has explicitly stated on its website (ECB, 2014) that it uses annual changes in harmonized index of consumer prices (HCIP) as its measure for inflation. For this reason I use quarter averages of annual HCIP changes. The policy interest rate for a quarter is considered to be the one that was prevailing at the end of the period. The series used in estimation start from the first quarter of 1999 and end with the first quarter of 2014.

[1] Linearity in Taylor rules is an outcome of central bank loss function being quadratic and aggregate supply function being linear. In reality both of these functions may be more complex.

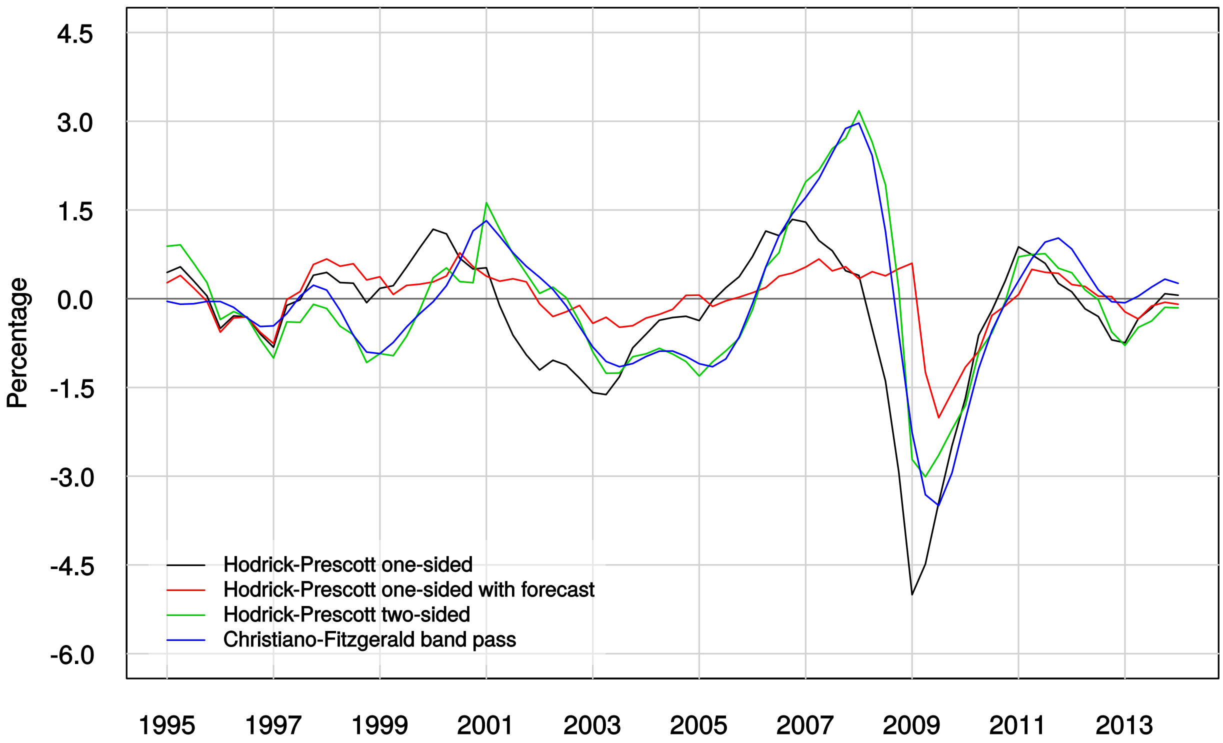

Fig. 1: Estimated output gap series using different filtering techniques

3 Estimation and results

GDP gap calculations require estimates of potential output. To obtain them I filtered the GDP data using Hodrick-Prescott (HP) filter in several flavors: one-sided, one-sided with simple forecasts (auto ARIMA as it is implemented in R package "forecast", see Hyndman & Khandakar, 2008) and two-sided. To overcome possible shortfalls of Hodrick-Prescott filter, potential output series were in addition generated using Christiano & Fitzgerald (2003) band pass (CF BP) filter. For all the filtering exercises the most common ("standard") parameters were used (e.g. the value of λ is set to 1600, minimum and maximum periods of oscillation were set to 6 and 32 respectively). GDP gap series were constructed as a percentage distances of actual GDP from the potential output.

It is clearly evident from Figure 1 that output gap estimates differ significantly between filtering techniques. The output gap series obtained using CF BP filter and HP two-sided filter look fairly similar and they both register the largest overheating in 2007. HP one-sided with a simple forecast series show the least variation, while HP one-sided series register the largest recession in 2009. Only CF BP and HP two-sided series exhibit similar turning points of the cycle. These differences are clearly important, therefore the most appropriate series had to be selected for use in estimation.

For this paper the actual output gap at any given quarter is less relevant than the one that was perceived by the ECB. Thus techniques that treat every point for which an output gap is being estimated as the end of a sample (e.g. one-sided filters) should yield better results[2]. Formal selection of benchmark output gap series done by estimating linear Taylor rules and comparing AIC criteria support the latter proposition. Following Gerdesmeier & Roffia (2004) and Gerlach & Schnabel (2000) linear models are estimated in the following form:

$$i_t = c + \alpha_1 \pi_t^{dev} + \alpha_2 y_t^{gap} + \alpha_3 i_{t-1} + \varepsilon_t, \tag{1}$$

[2] One should note, however, that the data available now has been updated and differs from the first estimates that were available for the ECB at the time of making interest rates decisions.

Tab. 1: Linear Taylor rule models for ECB

	HP one-sided	HP one-sided with forecast	HP two-sided	CF BP
c	0.107 (0.086)	0.069 (0.119)	0.178 (0.114)	0.132 (0.111)
π_{dev}	−0.056 (0.059)	0.068 (0.083)	−0.041 (0.081)	−0.030 (0.083)
y_{gap}	0.198** (0.031)	0.045 (0.127)	0.140** (0.051)	0.116** (0.049)
i_{t-1}	0.966** (0.033)	0.951** (0.046)	0.908** (0.044)	0.926** (0.043)
R^2_{adj}	0.950	0.915	0.925	0.922
AIC	27.653	59.749	52.408	54.113

*Standard errors in parenthesis, all values are reported rounded to three digits after decimal point. "**" and "*" represent 5 and 10 percent significance levels respectively at which the null hypothesis is rejected.*

where i is the short-term interest rates, c – intercept parameter, π^{dev} – deviation from inflation target, y^{gap}– output gap, α_n denotes regression parameters and ε – error term. All the alternatives considered can be seen in Table 1. The model that uses output gap estimates obtained with an HP one-sided filter fits the data better than the other alternatives, therefore HP one-sided output gap series can be considered the most appropriate.

Testing for nonlinearity is a daunting task because there are numerous forms of it. However, it is still useful to have at least some evidence of linear models being misspecified. To test for possible nonlinearity I ran Ramsey RESET test with quadratic and cubic powers. It returned the test statistic of 2.354 with the p-value of 0.044 meaning that the model suffered from mis-specification[3].

To identify the exact form of nonlinearity I rested on less formal arguments. It is reasonable to expect that changes in interest rate should be larger when inflation is considerably higher than the target or when the output is relatively low. Thus threshold regression is a natural candidate for estimation. In my case it takes the following form:

$$i_t = \begin{cases} \alpha_1^l \pi_t^{dev} + \alpha_2^l y_t^{gap} + \alpha_3^l i_{t-1} + \varepsilon_t, \text{ when } \theta_{t-p} \leq \theta^{est} \\ \alpha_1^h \pi_t^{dev} + \alpha_2^h y_t^{gap} + \alpha_3^h i_{t-1} + \varepsilon_t, \text{ when } \theta_{t-p} \leq \theta^{est} \end{cases} \quad (2)$$

where notation is the same as in equation 1 but θ^{est} is the value of a threshold and θ_{t-p} is the variable that triggers the regression to be in a particular regime.

It is reasonable to expect that either some value of inflation deviation from target or some value of output gap could be a potential threshold. However, the value of a threshold is not clear no matter which variable one choses. Therefore, I estimated six regressions with different threshold variables (contemporary inflation deviation and output gap as well as their first and second lags). To find the values of the thresholds, I followed the procedure proposed by Chan (1993).

The first and the last 15% of possible threshold values were discarded to ensure sensible regression regimes. After the grid search I found that the regression with one period output gap threshold at −1.35% yielded the the lowest sum of squared residuals and also had the lowest AIC value (see Figure 2).

As can be seen from Table 2, nonlinear model fits the data better than its linear counterpart. The value of AIC is smaller and the adjusted R^2 is bigger. This suggests that ECB conduct of monetary policy does have nonlinear properties.

In the high regime, i.e. when the output gap in the previous quarter is not lower than −1.35%, ECB reaction to inflation deviation from target and output gap is similar to that of linear model. Interest rate persistence is similar as well. However, as soon as the output gap becomes more negative than −1, 35%,

[3] Ramsey RESET test tests against a general alternative of mis-specification, therefore rejecting null hypothesis does not mean that the mis-specification stems from overlooked nonlinearity.

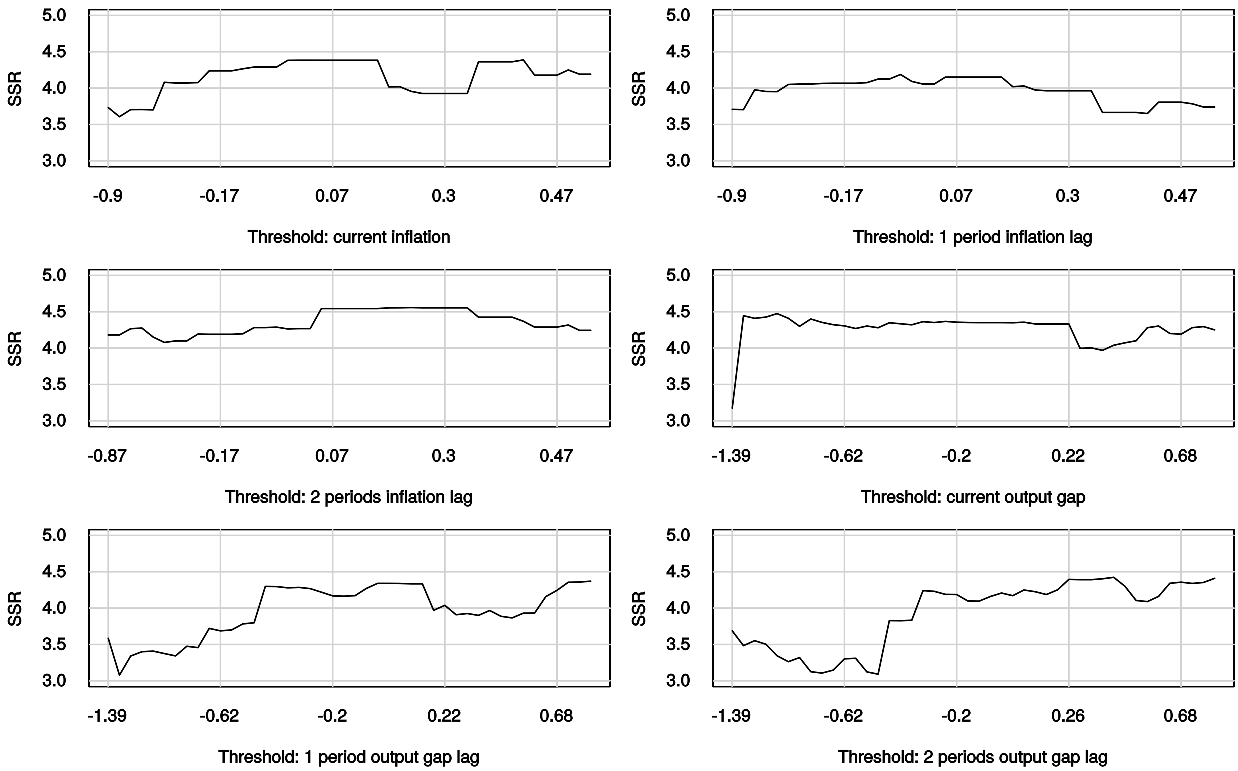

Fig. 2: Sum of squared residuals using different thresholds

Tab. 2: Comparison of linear and nonlinear Taylor rules for ECB

	Linear	Nonlinear (low regime)	Nonlinear (high regime)
c	0.107 (0.086)	0.056 (0.073)	
π_{dev}	-0.056 (0.059)	-0.464** (0.177)	0.064 (0.060)
y_{gap}	0.198** (0.031)	0.271** (0.114)	0.216** (0.045)
i_{t-1}	0.966** (0.033)	0.888** (0.109)	0.980** (0.028)
R^2_{adj}	0.950	0.966	
AIC	27.653	8.063	

*Standard errors in parenthesis, all values are rounded to three digits after decimal point. "**" and "*" represent 5 and 10 percent significance levels respectively at which the null hypothesis is rejected.*

ECB starts acting more aggressively and gives less importance to the smoothness of the path of short-term interest rates.

Counter intuitively the sign of inflation deviation parameter in the low regime is negative. This outcome is affected by small sample size and should normalize once it increases. Most of the observations in the low regime come from the Great Recession. During this period ECB only initially decreased the interest rates and held them fixed at 1% from the second quarter of 2009 to the second quarter of 2011. For most of this period inflation was below ECB's target. Nevertheless, it is reasonable to think that when the economy is suffering great distress, the central bank is prone to pay more attention to output gap rather than inflation target.

4 Concluding remarks and suggestions for future research

In this economic paper I added evidence to the existing literature of nonlinearities in the conduct of ECB monetary policy. I showed that nonlinear Taylor rule (threshold regression) fits the data better than its linear counterpart. This means that estimation of linear Taylor rules fails to capture interest rates setting asymmetries between times when economy is below or above potential.

In contrast to what is common when estimating interest rate setting rules I used quarterly GDP data for evaluation of output gap. Series of lesser frequency and of better precision still suggest that there are nonlinearities in ECB interest rate setting behavior. However, the sample size is relatively small, therefore, it is a good idea to rerun the estimation after several years.

In this paper I did not go into trouble of deciding what particular form of nonlinear behavior describes ECB actions the best. In the future, it may be beneficial to consider at least the most commonly used forms of nonlinear models. Checking if the results hold with alternative output gap measures (such as provided by OECD or estimated using a new-Keynesian model) would also benefit future research.

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