

# Asymmetric effects in the Polish monetary policy rule

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## Abstract

Asymmetric effects in a monetary policy rule could appear due to asymmetric preferences of the central bank and due to nonlinearities in the economic system. In this paper we investigate whether the reaction function of the National Bank of Poland (NBP) is asymmetric according to the level of inflation gap and the level of output gap. Moreover, we test whether these asymmetries might possibly stem from nonlinearities in the Phillips curve. Threshold models are applied and two cases of unknown and known threshold value are investigated. Our results show that the Polish central bank responds more strongly to the level inflation when the level of inflation is relatively high. We find very weak evidence that the level of inflation reacts more strongly to the output gap when the output gap is relatively high. Thus, the asymmetries in the monetary policy rule seem to indicate asymmetric preferences of the central bank.

*keywords:* nonlinear Taylor rule; nonlinear Phillips curve; asymmetries; threshold models;

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## Introduction

The aim of this paper is to search for asymmetric effects in the reaction function of the National Bank of Poland (NBP). We check whether the Polish monetary policy rule is asymmetric concerning levels of the fundamental macroeconomic variables: inflation and output gap. Encompassing the asymmetric elements in the reaction function might give better explanation of the central bank's behavior. This, in turn, could help to form better expectations and forecasts and could be used to build more accurate econometric models of the economy.

If we assume that a central bank has quadratic loss function in the inflation and output gaps and minimizes it subject to linear structure of economy than we will obtain a linear reaction function. However, positive and negative deviations of inflation and output from the reference levels seem to be treated by monetary authorities differently.

On the one hand, central banks may have asymmetric preferences. Some central banks attempt to stabilize output fluctuations accepting inflation being more volatile, it is because they might face some political heat or social pressure. These banks would have greater aversion to recessions than to expansions. Other central banks might be focused on inflation stabilization (e.g. strict inflation targeters) and have greater aversion to high than low inflation because, for instance, they need to build credibility after implementing inflation targeting strategy. Cukierman and Muscatelli (2008) distinguish recession avoidance preferences (RAP) and inflation avoidance preferences (IAP). In the former a central bank takes more precautions against negative output gaps, while in the latter against positive inflation gaps. Such asymmetric preferences lead to nonlinear reaction functions, as the authors show RAP leads to concave Taylor rule while IAP to convex rule in both the inflation and output gaps.

On the other hand, central banks might take into account asymmetries in different channels of the monetary transmission process. Most importantly, the aggregate supply curve might be nonlinear. In empirical studies it is often argued that when the output gap is positive it has positive impact on inflation, while when the output gap is negative it has very small deflationary impact (Laxton et al. 1999, Pyhtia 1999, Baghli et al. 2006, Buchmann 2009). There are various explanations of this phenomenon, discussed later on, such as for instance nominal wage rigidities, capacity constraints, costly price adjustments, volatility of aggregate demand and supply shocks.

Lastly, the uncertainty regarding the NAIRU or the growth rate of productivity may

lead to nonlinear interest rate policy, in such a case monetary authorities might need more time and data to make the decision. Therefore central banks might be more aggressive when the output gap reaches a certain threshold and more cautious when the output gap is small.

The structure of this paper is as follows. The next section contains a brief review of the literature concerning symmetric Taylor rule and asymmetric effects in both Taylor rule and Phillips curve. Section 2 and 3 present our empirical strategy and data set. Section 4 reports the empirical results. The last section concludes.

## 1 Literature review

### 1.1 Studies on the Taylor rule

Originally Taylor (1993) specified a simple monetary policy rule, where a central bank's rate tends to increase when the inflation is above its target value and when the actual output is above the potential output. This original Taylor rule has been modified in many ways. The adjustment of the monetary policy rate appears not to be immediate, because central banks dislike jumps and tend to smooth adjustments in their interest rates (Judd and Rudebusch (1998)). The central bank's rate seems to depend on forecasts, because the effects of the change of a monetary policy rate appear with delay. The monetary authorities taking into account these delays set policy rates according to future movements of inflation and output gap (Clarida et al. (2000)). In estimations it is suggested to use real time data, which are available to policymakers at the time of making the decision (Orphanides (2001, 2010)). Moreover, many economists argue that central banks look on the broader set of factors, thus, standard monetary policy rules should be augmented by other macroeconomic variables. It is often proposed to extend the standard rule by: exchange rate, monetary aggregates, asset prices, long term and foreign interest rates, as well as some measures of financial stability. But in the empirical studies these variables often seem to have negligible impact.

Finally, many recent papers include threshold effects in a monetary policy reaction function. It is argued that the linear specifications can be too simplified. Such approach, also applied in our paper, enables to encompass an asymmetric behavior of central banks.

Bunzel and Enders (2010) find out strong evidence of threshold behaviour of the Federal Reserve in a number of time periods between 1965 and 2007. Among others

the authors present model where the central bank is active when the inflation is higher than the interim threshold and when the output gap is negative. It appears that the central bank is more aggressive when the system is above the threshold than when it is below. The model seems to fit data best, what is more, the models with asymmetric effects give better out-of-sample forecasts than the linear models. But, the authors notice also a number of statistical problems that might arise while analysing the asymmetries and result in quite dubious results. For example, the threshold value and Hansen's F statistic decrease when increasing the starting date, moreover, in the high inflation regime excessive amount of interest rate smoothing may be observed.

Cukierman and Muscatelli (2008) using smooth transition regressions study nonlinearities in the monetary policy rule for the UK and the US. They emphasize that the character of nonlinearities changes substantially over different time periods and depends mainly on the regime and the macroeconomic situation. For instance in the 1979 - 1990 in the UK the Taylor rule seems to be concave, what can be interpreted as dominance of recession avoidance preferences, whereas in the 1992-2005 it appears to be convex, what might be interpreted as dominance of inflation avoidance preferences. The similar findings are presented for the US - where the Taylor rule varies across different chairmen of the Fed - inflation avoidance preference dominated under Martin and recession avoidance preference during Burns/Miller and Greenspan.

The asymmetric effects in European Central Bank (ECB) reaction function were studied by many researchers. Aguiar and Martins (2008) point out that when a central bank needs to build credibility than it would be more precautionary as far as a price stability is concerned. Therefore, it would prefer to have inflation below the target level than above. Such asymmetry is shown for the euro area throughout 1995 - 2005, as during this time period the monetary policy had to establish its credibility. Whereas Surico (2003) estimates the asymmetric Taylor rule for ECB concerning the sample 1997:7 - 2002:10 and finds equal reaction to inflation and deflation, but larger policy easing during output recessions than policy tightening during output expansions. In one of the recent papers Gerlach and Lewis (2011) estimate the ECB's monetary policy rule in 1999-2010 and detect a structural break after November 2008 (i.e. the switching point). Interestingly, they use smooth transition model to avoid a discrete break. The authors focus on the recent financial crisis and show that the zero lower bound did not constrain monetary policy during the crisis.

Kolman (2013) examines the nonlinearities in the monetary policy reaction function

in Canada. The author finds that the Bank of Canada reacted more aggressively to positive deviations of inflation from the target than to negative ones. Kolman underlines that the Bank of Canada implemented the inflation targeting (IT) in 1991, what makes it a good case for testing the asymmetric effects. Similarly, the National Bank of Poland, that implemented the IT in 1998, seems to be an interesting case.

Vasicek (2012) investigates the Taylor rules for the Czech Republic, Hungary and Poland and searches for asymmetries assigned to the level of inflation, output gap and financial stress. Vasicek does not find nonlinearities in the Polish Phillips curve and, what is rather strange, he finds little evidence of any linear or nonlinear relationship between inflation and stance of business cycle. The author states that there are no asymmetries in the Taylor rule as far as the level of inflation is concerned, but there are some along the business cycle. Our results are very different, it is probably due to different specifications of the Phillips curve and the Taylor rule, different calculations of the output and inflation gaps, different interbank rates used as well as consideration of different time periods.

## 1.2 Nonlinear Phillips curve and its implications

The Phillips curve has generally been estimated in a linear framework<sup>1</sup>, even though the original work of Phillips (1958) and many other theoretical works pointed to nonlinear relationship. Nonlinearity of the Phillips curve means that the effectiveness of monetary policy depends on the phase of the business cycle and that the cost of disinflation is changing. Thus, a nonlinear monetary policy reaction function might stem from nonlinear Phillips curve.

Convexity of the Phillips curve implies that when the output gap becomes more positive inflationary effects of shifts in aggregate demand are *ceteris paribus* higher while real effects are lower. If the economy is overheated an decrease of economic activity causes faster disinflation (cost of fighting inflation is low), while in the contrary when the economy is in recession further decreases of economic activity do not cause much disinflation (cost of fighting inflation is high). In such case the central bank needs to take significantly more action to reduce inflation than to increase it. Thus, the central bank would react more aggressively to high level of economic activity because the periods of excess demand might cause severe recession to lower the inflation generated when the

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<sup>1</sup>The studies mainly concerned the neutrality of money in short and long term and the existence of the relation between economic activity and inflation at all.

level of economic activity is high.

If the Phillips curve is concave, the monetary policy has more real effects during expansion than during recession. This implies also that monetary easing has more real effects than monetary tightening in either phase of the business cycle. The output cost of fighting inflation is higher during expansions than during recessions. In such a case the bank would react more strongly to low than to high level of economic activity - increasing production and less than proportionally increasing inflation.

There are many reasons for the nonlinear Phillips curve. For instance, workers are resistant to nominal wage cuts, what causes downward rigidity of nominal wages. It is particularly problematic when the level of inflation is low, because when the inflation rate is high it might be enough to keep the nominal wages constant for some time to decrease the wages. Thus, the central bank to restore the balance on the labor market might tolerate higher inflation. Even long run Phillips curve might be down-sloping (in the inflation-unemployment space) because of money illusion (Akerlof et al., 1996), people use to think in nominal terms, therefore in a period of high inflation firms can set lower real wages and hire more workers.

Moreover, firms may face capacity constraints in the short run. When the economy is strong the capacity constraints restrict firms to increase output and encourage them to increase prices, in contrast when the economy is weak it is easier for firms to increase output, what causes a convex Phillips curve.

Costly price adjustment (Ball et al. 1988, Dotsey et al. 1999) are another explanation. Any change in firms' activity is costly, therefore firms might be reluctant to make it. When the level of inflation is high demand shock is expected to have more impact on increasing prices and less on increasing production.

Also volatility of aggregate demand and supply shocks (Lucas 1973) might cause some asymmetric effects. Economic entities do not know if any price change is caused by a change in the economy wide aggregate demand or by a change in relative product demand and thus, they are unable to distinguish between changes in general prices and changes in relative prices. The higher the volatility of inflation the more of price changes are assigned to general prices. Therefore, not only the level of inflation but also its stability is an important aspect for monetary authorities.

There are not only studies which show that the Phillips curve is convex, some studies point that it might be concave. It might be concave because firms facing monopolistic competition are more willing to reduce prices under weak demand (when the output gap

is negative) than to increase them under high demand to avoid being overtaken by rival firms (Stiglitz, 1997). Also in recession firms might be expecting lower profits and cut costs, what also means that they are more reluctant to increase prices than to decrease them.

Filardo (1998) point out that the Phillips curve might be convex when the output gap is positive and concave when the output gap is negative. The author shows that the cost of fighting inflation is higher when the economy is weak (5% of output gap) than when it is overheated (2,1%). Moreover, in both the weak and the overheated economy this cost is higher than it results from the linear model.

## 2 Methods of estimation and testing

### 2.1 The Phillips curve estimation

Before proceeding with the analysis of the Taylor rule we examine nonlinearities in the Polish Phillips curve. As the main aim of this paper is to analyse possible asymmetries in the Taylor rule, the estimations of the Phillips curve aim to show if the asymmetries in the Taylor rule might stem from the nonlinear relation between the inflation rate and the level of economic activity. Therefore, to obtain comparable results we use similar data in both the Phillips curve and the Taylor rule estimations. It means that when estimating the Phillips curve we consider monthly data. We consider two measures of inflation: year on year CPI - as the central bank's target is maintaining this rate at the relevant level and quarter on quarter CPI - as such rate is most often used in the empirical studies.

We use GMM estimation method with lagged values of the measure of inflation, output gap, exchange rate gap and inflation expectations of the Polish customers and bank analysts as instruments.

We estimate the New Keynesian hybrid Phillips curve (Fuhrer and Moore 1995, Gali and Gertler 1999). The curve specification consists of forward and backward looking components of expected price movements, output gap and exchange rate pass-through (cf. the inflation equation in Alichì et al. (2009)):

$$\pi_t = \lambda_1 E(\pi_{t+k}|\Omega_t) + \lambda_2 \pi_{t-k} + \alpha y_{t-n} + \phi e_{t-m} + \epsilon, \quad (1)$$

where:  $\pi_t$  is an inflation rate measured by *cpi1* or *cpi2*,  $y_t$  is an output gap measured by *gap*,  $e_t$  is an exchange rate gap measured by *reer*.  $\Omega_t$  in this and other equations

denotes an information set at time  $t$ .

Next, the asymmetries concerning the level of output gap are tested in the two following ways:

$$\begin{aligned} \pi_t = & (\lambda_{11}E(\pi_{t+k}|\Omega_t) + \lambda_{21}\pi_{t-k} + \alpha_1y_{t-n} + \phi_1e_{t-m})I_t + \\ & + (\lambda_{12}E(\pi_{t+k}|\Omega_t) + \lambda_{22}\pi_{t-k} + \alpha_2y_{t-n} + \phi_2e_{t-m})(1 - I_t) + \epsilon, \end{aligned} \quad (2)$$

$$\pi_t = \lambda_1E(\pi_{t+k}|\Omega_t) + \lambda_2\pi_{t-k} + \alpha_1y_{t-n}I_t + \alpha_2y_{t-n}(1 - I_t) + \phi e_{t-m} + \epsilon, \quad (3)$$

where:

$$I_t = \begin{cases} 1 & \text{if } y_{t-n} \geq \tau, \\ 0 & \text{otherwise.} \end{cases}$$

In the Equation (2) we concern the case when the whole Phillips curve rule changes according to the value of the threshold variable. Whereas in the Equation (3) we concern the case when only the coefficients of the output gap change depending on the value of a known threshold value. The way in which the threshold values ( $\tau$ ) are obtained is presented in Section 4.3.

Dolado et al. (2004)<sup>2</sup> show that when the Phillips curve is nonlinear (convex or concave) than the Taylor rule resembles a linear one but it is extended by the interaction term of expected inflation and the output gap. For example when a Phillips curve is convex, an expected inflation caused by a higher output gap will be larger than in a linear specification, so anticipating this policy makers will react more forcefully (what is captured by the interaction term). Thus, additionally, we perform a similar test to Dolado et al. (2004) and we try to include a nonlinear component  $y_{t-n}y_{t-n}$ . We test whether the additional component is statistically significant in the following equation:

$$\pi_t = \lambda_1E(\pi_{t+k}|\Omega_t) + \lambda_2\pi_{t-k} + \alpha y_{t-n} + \alpha_1y_{t-n}y_{t-n} + \phi e_{t-m} + \epsilon. \quad (4)$$

## 2.2 The Taylor rule estimation

We then turn to an analysis of the Polish Taylor rule. We consider two models with two different measures of inflation target (*cpia* and *cpib*) to check the robustness of the results.

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<sup>2</sup>Dolado et al. (2004), concerning the central banks of Germany, France, Spain, the US and euro area find out that the Phillips curve is convex in all cases except the US.



As previously, to allow for correlation between the error term and the forward looking variables, we use GMM method with instruments such as lagged values of the inflation gap, the output gap, the domestic short term interest rate as well as the short term interest rate in the euro area, and the real effective exchange rate. The short term interest rate in the euro area (Euribor) is used to account for the influence of monetary policy in euro area on the monetary policy in Poland.

Firstly, we estimate the symmetric Taylor rule as in the following equation:

$$i_t = \rho i_{t-1} + \beta E(\pi_{t+h} - \pi_{t+h}^* | \Omega_t) + \gamma E(y_{t+l} | \Omega_t) + \alpha, \quad (5)$$

where:  $i_t$  is the one week Polish money market rate (Wibor 1W),  $\pi^*$  is an inflation target, measured as the actual inflation target (*cpia*) or the smoothed by Hodrick Prescott filter trend of actual inflation (*cpib*),  $y_t$  is the output gap.

Next, we estimate the asymmetric Taylor rules. Namely, we estimate the threshold model for the Polish monetary reaction function as:

$$i_t = \begin{aligned} & (\rho_1 i_{t-1} + \beta_1 E(\pi_{t+h} - \pi_{t+h}^* | \Omega_t) + \gamma_1 E(y_{t+l} | \Omega_t) + \alpha_1) I_t + \\ & + (\rho_2 i_{t-1} + \beta_2 E(\pi_{t+h} - \pi_{t+h}^* | \Omega_t) + \gamma_2 E(y_{t+l} | \Omega_t) + \alpha_2) (1 - I_t) + \epsilon_t, \end{aligned} \quad (6)$$

$$i_t = \rho i_{t-1} + \beta_1 E(\pi_{t+h} - \pi_{t+h}^* | \Omega_t) I_{t+h} + \gamma_1 E(y_{t+l} | \Omega_t) J_{t+l} + \beta_2 E(\pi_{t+h} - \pi_{t+h}^* | \Omega_t) (1 - I_{t+h}) + \gamma_2 E(y_{t+l} | \Omega_t) (1 - J_{t+l}) + \alpha + \epsilon_t, \quad (7)$$

where

$$I_t = \begin{cases} 1 & \text{if } m_t \geq \tau_1, \\ 0 & \text{otherwise,} \end{cases} \quad J_t = \begin{cases} 1 & \text{if } n_t \geq \tau_2, \\ 0 & \text{otherwise,} \end{cases}$$

and  $m_t$  and  $n_t$  are the threshold variables in period  $t$ , in our case it is the inflation gap or the output gap. We consider the case when  $J_t = 1$  for each  $t$  and  $m_t$  is an inflation gap, that is an asymmetry according only to the inflation gap, and the case when  $I_t = 1$  for each  $t$  and  $n_t$  is an output gap, that is the asymmetry according only to the level of output gap.

### 2.3 The choice of the threshold value

In both estimations of the Taylor rule and the Phillips curve we consider two cases of known and unknown threshold values. We apply the two methods because when

estimating the threshold value often the values from the border of the  $\Gamma$  set are chosen. It is so because the asymmetric effects are not strong enough to be captured by the threshold estimation method. This, in turn, might be the result of the small sample size.

In case of unknown parameter we estimate the threshold value using the procedure presented in Caner and Hansen (2004). The threshold value is the one that minimizes the sum of the square errors ( $S_n$ ) of the 2SLS estimation, i.e.:

$$\bar{\tau} = \operatorname{argmin}_{\tau \in \Gamma} S_n(\tau),$$

where  $\Gamma$  is the set of either measures of the inflation gap or measures of the output gap. In both cases we disregard the highest and the lowest 15% of observations. We draw the LR-like statistics:

$$LR_n(\tau) = n \frac{S_n(\tau) - S_n(\bar{\tau})}{S_n(\bar{\tau})}. \quad (8)$$

The shape of this statistic indicates the strength of the threshold effect. When the LR statistic line has a clearly defined minimum (a V-shaped line) it means that the threshold effect is strong. Whereas, when it has irregular shape it is an indication of weaker threshold effects. The critical value cuts off the interval of all possible threshold values.

We compute the Sup test proposed by Caner and Hansen (2004). This test is often used to test the presence of threshold effects (see Bunzel and Enders (2010) or Mandler (2011)). To do so we estimate by GMM the Equation (2) or (6), respectively, for a fixed value  $\tau \in \Gamma$ . Then we calculate the Wald statistic for  $H_0 : \rho_1 = \rho_2, \alpha_1 = \alpha_2, \beta_1 = \beta_2, \gamma_1 = \gamma_2$ , we denote it by  $W_n(\tau)$ . We repeat this calculation for all  $\tau \in \Gamma$  and the Sup statistic is then the largest value of these statistics,  $SupW = \sup_{\tau \in \Gamma} W_n(\tau)$ . The asymptotic distribution of this statistic is not chi-square as the parameter  $\tau$  is not identified under the null hypothesis. Therefore, we need to calculate it by simulation (so-called bootstrapping). We define pseudo-dependent variable  $\bar{\epsilon}_t(\tau)\eta_t$  where  $\bar{\epsilon}_t(\tau)$  is the error term for the Equation (2) or (6) and  $\eta_t$  is i.i.d.  $N(0, 1)$ . We repeat the calculations for the pseudo-dependent variable in place of  $i_t$  for the unrestricted model. The resulting statistic  $SupW^*$  has the needed asymptotic distribution.

In the case of known threshold parameter for the Phillips curve it is  $\tau = 0$  or  $\tau = 0,7$  quantile of the measure of the output gap and for the Taylor rule it is  $\tau = 0$  for both the inflation gap and the output gap. These correspond, respectively, to the regimes of positive and negative output gap, the regime of very high output gap and to the regimes when the level of inflation is above the inflation target and when it is below.

### 3 Data description

The sample starts in January 1998 and ends in December 2012. Before 1998 most of the data are not available. In 1989 in Poland the process of economic transformation from a centrally planned economy into a market economy started. Then the main problems concerned hyperinflation, fast depreciation of zloty, threat of recession and relatively huge foreign debt, thus, the monetary policy was mainly focused on stabilizing the economy and foreign debt restructuring. The first Monetary Policy Council in Poland introduced the inflation targeting strategy in June 1998. Each year the new inflation targets were set. There were, however, significant problems with meeting these targets, even twice within the year the target was changed: in 1999 (due to the Russian crisis) and in 2002, what probably decreased the bank's credibility and, moreover, in both cases the bank did not finally reach the new targets.

We use monthly publicly available data. On the one hand the usage of monthly data enables us to apply threshold models and have sufficient number of observations while on the other hand interest rates and inflation rates are highly persistent at monthly frequencies what might result in the coefficient of lagged dependent variable close to unity and very limited response of independent variables.

In the case of a monetary policy rule estimation an important aspect of the data selection process is determining the dependent variable. The Polish monetary policy rate is usually adjusted by multiples of 25 basis points and the decisions concerning its level are taken once a month. Taking into account this discreteness we decided to concentrate on the money market rate, that is more variable, determines the real rate of making transactions and matches with maturity of the NBP's open market operations. The NBP's open market operations are carried out with one week maturity. Moreover, the reference rate and one week money market rates move almost in line during the examined time period (their correlation equals 0,99). Thus, we use the 1 week money market rate (Wibor 1W) as the dependent variable.

All data are obtain from the web-page of the Polish Central Statistical Office or the National Bank of Poland database. Let us denote the other time series used in the estimations:

- *cpi1* - year on year consumer price index;
- *cpi2* - quarter on quarter consumer price index, seasonally adjusted; It was calculated from month on month consumer price indices, namely in period  $t$  it is equal

a ratio between the price level at the current quarter (calculated as an average from monthly price levels  $t - 2, t - 1, t$ ) and the price level at the previous quarter (calculated as an average from respective monthly price levels  $t - 3, t - 4, t - 5$ ).

- *cpia* - the deviation of *cpi1* from the actual inflation target; in years 1999 - 2001 the inflation target was set as an interval, so in these years we take the middle of the interval.
- *cpiB* - the deviation of *cpi1* from its smoothed by Hodrick Prescott filter trend of inflation;
- *gap* - the difference between logarithm of the seasonally adjusted measure of GDP and the trend obtained by Hodrick Prescott filter, GDP is disaggregated to monthly frequencies; We use Fernandez method to disaggregate quarterly data into monthly frequencies (cf. Fernandez, 1981). We use an output gap computed for monthly industrial production index to augment the related series. Moreover, we lengthen the time series by AR(2) process to diminish the role of last observations.
- *reer* - difference between logarithm of real effective exchange rate deflated by CPI (which is calculated by the National Bank of Poland) and the trend obtained by Hodrick Prescott filter;
- *infe<sub>1</sub>* - inflation expectations of Polish bank analysts for forecasting horizon of 12 months from the survey conducted by Reuters;
- *infe<sub>2</sub>* - inflation expectations of Polish consumers for forecasting horizon of 12 months, calculated from the survey conducted by Ipsos (cf. Łyziak and Stanisławska 2006);
- $\Delta ieu_{ro}$  - the change of 1 month Euribor.

The unit root tests show that the analyzed variables can be treated as stationary. We present the results of Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests in Table 9 in the Appendix. For each of the variables at least one test indicates stationarity.

## 4 Empirical results

### 4.1 A preliminary analysis of the nonlinear Phillips curves

As a benchmark we estimate a linear Phillips curve. Table 1 presents the results of estimation of the Equation (1) for two possible specifications of the Phillips curve for monthly observations.

In the first model we use quarter on quarter consumer price index and in the second model we use year on year consumer price index. Both specifications seem to us to be correct, and thus we estimate both of them to check the robustness of the results. The second specification, which is rarely used in the literature, is important in context of the Taylor rule analysis. Because year on year consumer price index is latter on used in the estimations of the Taylor rule as the NBP targets the CPI index. In Poland the output gap seems to have the maximum impact on the level of inflation after 2-3 quarters and the exchange rate affects the level of inflation after about 1 quarter (see Demchuk et al. 2012). Thus, we choose to present the results for  $k = 6, m = 4$ , but other lags were also tested and the results were similar. The chosen lags and instruments give statistically significant coefficients (t-statistics), proper sign at explanatory variables and correct values of the J-statistic.

In both models all coefficients are statistically significant and have the expected signs. The decrease of  $e_t$  means depreciation of the Polish zloty. Therefore, the relation between the level of inflation ( $\pi_t$ ) and the measure of an exchange rate gap ( $e_{t-4}$ ) is correctly negative. The inflation rate heavily depends on its expected value, both of the coefficients ( $\lambda_1$ ) are close to 0,7, what indicates high degree of forward-lookingness. The property of dynamic homogeneity, which requires that the sum of backward and forward looking components ( $\lambda_1 + \lambda_2$ ) is equal to one, is fulfilled. The standard statistical test do not reject the hypothesis that  $\lambda_1 + \lambda_2 = 1$ .

Hansen's sup-Wald statistic shows if there are any threshold effects when the sample is divided into two subsamples depending on the level of a threshold variable. The reported values of the test indicate strong threshold effect for the second model, suggesting different reaction of the inflation rate when the output gap is relatively high and when it is relatively low. As far as the threshold value is concerned, the LR statistics presented in Figure 2 show positive, but quite different, values for the two models. The evidence of threshold effect seem to be weaker for the first model, as the shape of the LR line is more irregular and it has many possible minimums. Whereas, for the second model the

statistic is more V-shaped with one clearly defined minimum.

Next we proceed to test the asymmetric effects by estimation of the Equations (2),(3), and (4) (see Tables 2, 3, and 4). In the first method the coefficient of output gap is higher when the output gap is above the threshold value than when it is below ( $\alpha_1 > \alpha_2$ ) (see Table 2). It indicates that the Polish Phillips curve might be convex. As it was discussed earlier a stronger reaction of a rate of inflation when a high level of output gap is observed might stem from nominal wage rigidities, capacity constraints, costly price adjustments or volatility of economic shocks. Moreover, it seems that the exchange rate pass-through is slightly higher when the level of economic activity is high than when the level of economic activity is low ( $|\phi_1| > |\phi_2|$ ). More advanced study of this effect in Poland was carried out by Przystupa and Wróbel (2011). They argue that the asymmetry along the business cycle might be caused by behaviour of firms which set their investment decisions according to expected profits, which are the highest in the early expansion and the lowest in the early recession. Furthermore, when applying the second estimation method (see Table 3), where we assume that the threshold value is known and equal to 0 or 0,7 quantile of the output gap, the results point to the same conclusion. The reaction of inflation is stronger to high level of economic activity than to low level of economic activity, nevertheless, in this case the effect is not statistically significant. Indeed, the Wald test do not reject the hypothesis that  $\alpha_1 = \alpha_2$ . Similarly, in the third method (see Table 4) we obtain positive nonlinear coefficients ( $\alpha_1$ ), what could indicate convex Phillips curve, but the coefficients are statistically insignificant.

The results show that the evidence for asymmetric effects is very weak. It is worth emphasizing that they always indicate the same direction of asymmetry, namely the level of inflation is influenced by the measure of economic activity more strongly when the level of economic activity is relatively high. But in many cases the result is not statistically significant and, moreover, the result is sensitive to increasing the starting date. Thus, we conclude that the relationship between the level of inflation and the output gap is linear.

Table 1: The symmetric Phillips curves - Equation (1)

	$\lambda_1$	$\lambda_2$	$\alpha$	$\phi$	$R^2$	J-stat	sup-Wald	p-value (F-stat) $\lambda_1 + \lambda_2 = 1$
model 1	0.699***	0.263***	0.038*	-0.021***	0.64	0.14	14.8	0.27
	(0.090)	(0.073)	(0.022)	(0.006)				
model 2	0.743***	0.247***	0.729***	-0.049*	0.59	0.78	124.2***	0.78
	(0.079)	(0.064)	(0.058)	(0.028)				

Standard errors in parenthesis (Newey-West), \* \ \*\* \ \*\*\* denote statistical significance at the 1% \ 5% \ 10% level, respectively; in the first model (model 1) we use seasonally adjusted quarter on quarter CPI as dependent variable, lead and lag values in Equation (1) are selected as  $n = 3$ ,  $k = 6$ ,  $m = 4$ ; in the second model (model 2) we use year on year CPI as dependent variable; lead and lag values in Equation (1) are selected as  $n = 12$ ,  $k = 6$ ,  $m = 4$ ; J-stat represents p-value of Hansen's J-statistic for testing over-identifying restrictions;

Table 2: The asymmetric Phillips curves - Eq. (2)

		$\lambda_1$	$\lambda_2$	$\alpha$	$\phi$	No.obs.	$R^2$	p-value(J-stat)	$\tau$
model 1	$I_t=0$	0.686**	0.208***	0.013	-0.035***	78	0.55	0.60	-0.002
		(0.135)	(0.107)	(0.022)	(0.010)				
	$I_t=1$	0.653***	0.290***	0.059	-0.011	90	0.55	0.10	
		(0.199)	(0.092)	(0.054)	(0.008)				
model 2	$I_t=0$	0.561***	0.383***	0.589***	-0.091***	101	0.32	0.64	0.004
		(0.192)	(0.084)	(0.211)	(0.072)				
	$I_t=1$	0.596***	0.254***	1.009***	-0.115**	57	0.74	0.13	
		(0.098)	(0.040)	(0.083)	(0.027)				

Standard errors in parenthesis (Newey-West), \* \ \*\* \ \*\*\* denote statistical significance at the 1% \ 5% \ 10% level, respectively.

Table 3: The asymmetric Phillips curves - Eq. (3)

	$\tau$	$\lambda_1$	$\lambda_2$	$\alpha_1$	$\alpha_2$	$\phi$	$R^2$	p-value(J-stat)	Wald test $\alpha_1 = \alpha_2$
model 1	0,7 quantile	0.706***	0.256***	0.041	0.033	-0.022***	0.64	0.15	0.87
		(0.092)	(0.073)	(0.037)	(0.029)	(0.007)			
	0	0.667***	0.257***	0.065*	0.014	-0.023***	0.65	0.17	0.38
		(0.099)	(0.072)	(0.040)	(0.033)	(0.007)			
model 2	0,7 quantile	0.738***	0.200***	0.844***	0.616***	-0.048*	0.62	0.91	0.34
		(0.099)	(0.063)	(0.156)	(0.114)	(0.030)			
	0	0.741***	0.199***	0.829***	0.635***	-0.046	0.62	0.90	0.44
		(0.107)	(0.064)	(0.159)	(0.122)	(0.030)			

Standard errors in parenthesis (Newey-West), \* \ \*\* \ \*\*\* denote statistical significance at the 1% \ 5% \ 10% level, respectively.

Table 4: The nonlinear Phillips curves - Eq. (4)

	$\lambda_1$	$\lambda_2$	$\alpha$	$\phi$	$\alpha_1$	$R^2$	p-value(J-stat)
model 1	0.682***	0.265***	0.033	-0.022***	0.555	0.65	0.17
	(0.095)	(0.073)	(0.022)	(0.007)	(0.995)		
model 2	0.759***	0.209***	0.719***	-0.044	1.708	0.60	0.90
	(0.101)	(0.067)	(0.066)	(0.030)	(3.054)		

Standard errors in parenthesis (Newey-West), \* \\*\* \\*\*\* denote statistical significance at the 1% \5% \10% level, respectively;  $\alpha_1$  is the coefficient of nonlinear component  $y_{t-10}y_{t-10}$ .

## 4.2 The symmetric Taylor rules

We begin the analysis of the Polish Taylor rule with estimating the symmetric monetary policy rules. We consider two models to check if the results change when applying different measures of inflation target. Model 1 uses the actual inflation target and model 2 uses the HP filter of inflation (CPI). We use the two measures of the inflation target because in certain time periods the actual inflation target was a little bit unrealistic and impossible to reach and, then, the trend of inflation seems to be a better measure. We estimated also the models with inflation expectations (*infe1* and *infe2*) instead of the inflation gap (measured by *cpia* or *cpib*)<sup>3</sup>, however, we obtained less statistically significant inflation coefficients, what might indicate that the Polish monetary authorities take their decisions basing on the shorter term inflation forecasts. The results for all specifications of the symmetric monetary policy rule are presented in Table 5.

The lagged interest rate term  $\rho$  is statistically significant in all equations. The coefficient is very close to unity, it oscillates from 0,96 to 0,97. The  $\rho$  coefficient measures the extend of monetary policy inertia and its significant value is interpreted as the desire of the central bank to smooth interest rate adjustment process and indicates persistent policy of the central bank. The smoothing coefficient absorbs serial correlation, which in case of the interest rates in monthly frequency is substantial. Moreover, high value of the smoothing coefficient might stem from the omission of other persistent variables and exogenous shocks (Rudebusch, 2002, 2006). Therefore, the interpretation of the smoothing parameter is not straightforward. All coefficients have expected signs. The coefficients on inflation and output gap are positive and significant at conventional levels.

The Polish central bank probably takes into account more information (than the inflation and output gaps) when setting its interest rate. But we decided to present the

<sup>3</sup>We do not report these results as the models with the inflation gaps seem to fit the data better.



results for the Taylor rule without the additional variables due to relatively small number of observations as well as the suggestions of Przystupa and Wróbel (2006). However, the real effective exchange rate and the change of short term euro area interest rate are taken as instruments in our GMM estimations. These are the two variables which seem to be especially important for the Polish monetary authorities when making their decisions.

The sup-Wald statistics presented in Table 5 reject the null hypothesis of no threshold effects only according to the level of output gap. Moreover, the LR-statistics shown in Figure 1 indicate that in case of inflation gap the asymmetric effects are not very clear. In the next section we proceed with testing the possible asymmetric effects in the Taylor rule. We suspect that not all coefficients change significantly when changing the inflation gap or output gap regime, especially it might not be the case of lagged interest rate coefficient. Therefore, we are especially interested in the results of the second estimation method.

### 4.3 The asymmetric Taylor rules

The results of testing the degree of dissimilarity between all (four) coefficients in each regime are presented in: Table 6 - for an inflation gap as the threshold variable and in Table 7 - for an output gap as the threshold variable.

In case of the asymmetry according to the level of the inflation gap for both models  $\beta_1 > \beta_2$  and  $\beta_2$  is not statistically significant, what suggests that the central bank reacts more aggressively to the level of inflation gap when it is higher than the threshold value. Also in case of the asymmetry according to the level of the output gap  $\beta_1 > \beta_2$ . The periods of high level of economic activity are often associated with the periods of high level of inflation rate, thus, the results seem to indicate more active monetary policy in respect to inflation gap in such economic conditions. When applying the second estimation method quite similar results are obtained. The asymmetry is also in form of stronger central bank's reaction to relatively high than relatively low level of inflation ( $\beta_1 > \beta_2$ ).

It might be justified by the fact that the Polish central bank implemented inflation targeting strategy in 1998. Thus, the central bank tried to make its policy more credible and transparent to better influence inflation expectations and could have more inflation avoidance preferences. In January 2004 permanent inflation target  $2,5\% + / - 1\%$  was set, actually it was announced in February 2003 and since then the realization of the strategy really starts. The permanent target enables the verification of the effects of

monetary policy action every month and not at the end of year as before. Moreover, inflation forecasts are published since August 2004, GDP forecasts since 2005, and MPC minutes since 2007.

Concerning the output gap coefficient in the first estimation method it appears to be lower when the output gap is relatively high (see Table 7) and lower when the inflation gap is high (see Table 6). Thus, the level of output gap seems to bother monetary authorities more when it is low. But when applying the second estimation method the opposite result appears, namely the central bank seems to react more strongly to the high level of output gap ( $\gamma_1 > \gamma_2$ ). So concerning the first estimation method the stronger reaction to low level of economic activity appears to be rather some compensation for strong reaction to high level of inflation and not necessary the result of monetary authorities' decisions.

What is important for the second estimation method, the Wald tests reject the null hypothesis of equal coefficients only when the inflation gap is a threshold variable. These asymmetric effects seem to be the strongest ones, while the others are not statistically significant.

The asymmetries in the Taylor rule might, as it was mentioned before, stem from nonlinearities in the economic system. When the Phillips curve is convex the central bank would react more aggressively to high level of economic activity because the periods of excess demand might cause severe recession to lower the inflation generated when the level of economic activity is high. While if the Phillips curve is concave the bank would probably react more strongly to low than to high level of economic activity - increasing production and less than proportionally increasing inflation. The stronger reaction of the NBP to high level of inflation, which might be associated with high level of economic activity, could be justified by the convex Phillips curve, for which we find very weak evidence. Thus, taking into account statistically insignificant asymmetries in the Phillips curve, we conclude that the source of asymmetries in the Taylor rule are asymmetric preferences of the central bank and not the nonlinearities in the economic system.

Table 5: The symmetric Taylor rules - Eq. (5)

	$\rho$	$\beta$	$\gamma$	$\alpha$	$R^2$	p-value (J-stat)	sup Wald	
							$\pi_t$	$y_t$
model 1	0.964*** (0.000)	0.056** (0.028)	0.072** (0.016)	0.002*** (0.005)	0.99	0.30	19.63	57.39*
	0.967*** (0.000)	0.143** (0.019)	0.037 (0.335)	0.002*** (0.001)				

Standard errors in parenthesis (Newey-West), \* \\*\* \\*\*\* denote statistical significance at the 1% \5% \10% level, respectively; lead values in Equation (5) were selected as  $h = 3$ ,  $l = 1$ ; as the measure of the inflation target: in the first model (model 1) we use actual inflation target, whereas in the second model (model 2) we use the trend of inflation rate; p-value(J-stat) represents p-value of Hansen's J-statistic for testing over-identifying restrictions.

Table 6: The asymmetric Taylor rules, an inflation gap as a threshold variable - Eq. (6)

		$\rho$	$\beta$	$\gamma$	$\alpha$	No. obs.	$R^2$	J-stat	$\tau$
model 1	$I_t=0$	0.952*** (0.007)	0.016 (0.023)	0.076*** (0.023)	0.002*** (0.000)	145	0.99	0.74	0.02
		0.961*** (0.021)	0.291* (0.146)	0.028 (0.030)	-0.003 (0.002)				
	$I_t=1$	0.953*** (0.006)	0.014 (0.055)	0.080*** (0.022)	0.002*** (0.000)	136	0.99	0.61	
		1.001*** (0.016)	0.370* (0.223)	0.061 (0.043)	-0.005 (0.003)				

Standard errors in parenthesis (Newey-West), \* \\*\* \\*\*\* denote statistical significance at the 1% \5% \10% level, respectively.

Table 7: The asymmetric Taylor rules, an output gap as a threshold variable - Eq. (6)

		$\rho$	$\beta$	$\gamma$	$\alpha$	No. obs.	$R^2$	p-value(J-stat)	$\tau$
model 1	$I_t=0$	0.941*** (0.008)	-0.005 (0.032)	0.109** (0.050)	0.003*** (0.001)	111	0.99	0.49	0.01
		0.991*** (0.012)	0.042 (0.031)	0.052* (0.032)	0.000 (0.001)				
	$I_t=1$	0.948*** (0.004)	0.062** (0.031)	0.048** (0.021)	0.003*** (0.000)	137	0.99	0.52	
		1.000*** (0.010)	0.149* (0.089)	0.043 (0.113)	-0.001 (0.003)				

Standard errors in parenthesis (Newey-West), \* \\*\* \\*\*\* denote statistical significance at the 1% \5% \10% level, respectively.

Table 8: The asymmetric Taylor rules - Eq. (7)

An inflation gap as a threshold variable

	$\rho$	$\beta_1$	$\beta_2$	$\gamma$	$\alpha$	$R^2$	p-value(J-stat)	Wald $\beta_1 = \beta_2$	-
model 1	0.955***	0.220***	-0.078	0.045	0.000	0.99	0.40	0.05	
	(0.009)	(0.077)	(0.084)	(0.029)	(0.001)				
model 2	0.955***	0.349***	-0.087	0.059*	0.001	0.99	0.46	0.02	
	(0.007)	(0.104)	(0.102)	(0.030)	(0.001)				

An output gap as a threshold variable

	$\rho$	$\beta$	$\gamma_1$	$\gamma_2$	$\alpha$	$R^2$	p-value(J-stat)	-	Wald $\gamma_1 = \gamma_2$
model 1	0.965***	0.067*	0.086*	0.025	0.001	0.99	0.25		0.39
	(0.010)	(0.031)	(0.043)	(0.046)	(0.001)				
model 2	0.964***	0.139***	0.064	0.014	0.002***	0.99	0.51		0.47
	(0.008)	(0.041)	(0.046)	(0.037)	(0.001)				

Standard errors in parenthesis (Newey-West), \* \\*\* \\*\*\* denote statistical significance at the 1% \5% \10% level, respectively.

## 5 Concluding remarks

The paper concerns asymmetries in a monetary policy rule, which could possibly appear because of asymmetric preferences of the central bank and because of nonlinearities in the economic system. It might be suspected that monetary authorities are more aggressive to the inflation rate when it is above its target level than when it is below. It also seems probable that monetary authorities have different preferences and react more strongly when the level of economic activity is low than when it is high.

In the paper we check the existence of the threshold effects in the reaction function of the National Bank of Poland and in the Polish Phillips curve. We estimate a number of models with unknown and known threshold values. When the threshold value is assumed to be unknown we estimate it by minimizing the sum of squared errors from the relevant equation. We consider two different measures of an inflation rate in the Phillips curve as well as two different measures of an inflation target in the Taylor rule.

Our preliminary analysis of the Phillips curve for Poland suggests that the curve is not asymmetric according to the level of output gap. We find only very weak evidence, in all cases except one statistically insignificant, that the rate of inflation is more strongly influenced by the output gap when the output gap is relatively high.

The estimations of the asymmetric Taylor rule seem to indicate that the central bank reacts more strongly to the level of inflation when it is relatively high, what might be the result of implementing the inflation targeting strategy and the need to build credibility.

Thus, it appears that the NBP has rather inflation avoidance preferences and not the recession avoidance ones. The results show that the asymmetric effects in the Taylor rule do not stem from nonlinearities in the Phillips curve but from asymmetric preferences of the central bank.

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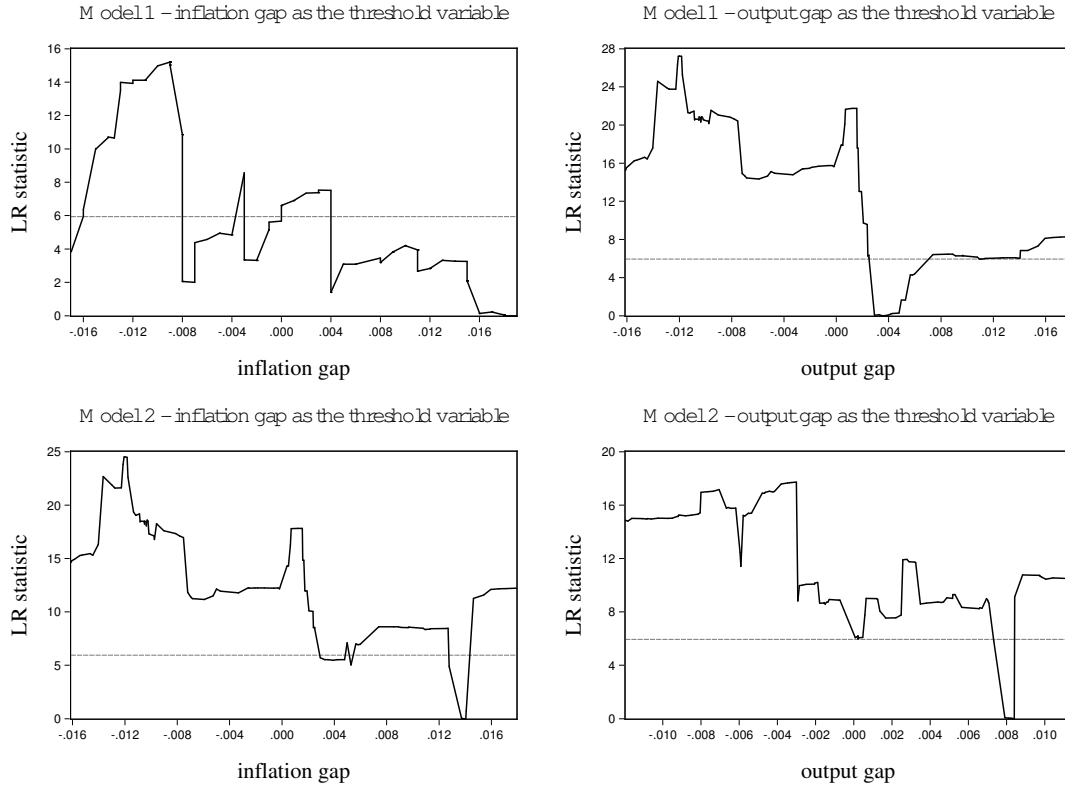
## A Unit root tests

Table 9: Unit root tests 1998:01 - 2012:12

<i>cpi1</i>	0.08*	0.08*	0.29
<i>cpi2</i>	0.01***	0.04**	0.30
<i>cpi</i>	0.02**	0.04**	0.15
<i>cpi</i> <sub>b</sub>	0.01***	0.02**	0.30
<i>gap</i>	0.06*	0.38	0.12
<i>WIBOR1W</i>	0.07*	0.04*	0.36*
<i>reer</i>	0.00***	0.00***	0.06
<i>infe</i> <sub>1</sub>	0.00***	0.00***	0.34
<i>infe</i> <sub>2</sub>	0.00***	0.00***	0.31
$\Delta ieuro$	0.00***	0.00***	0.07

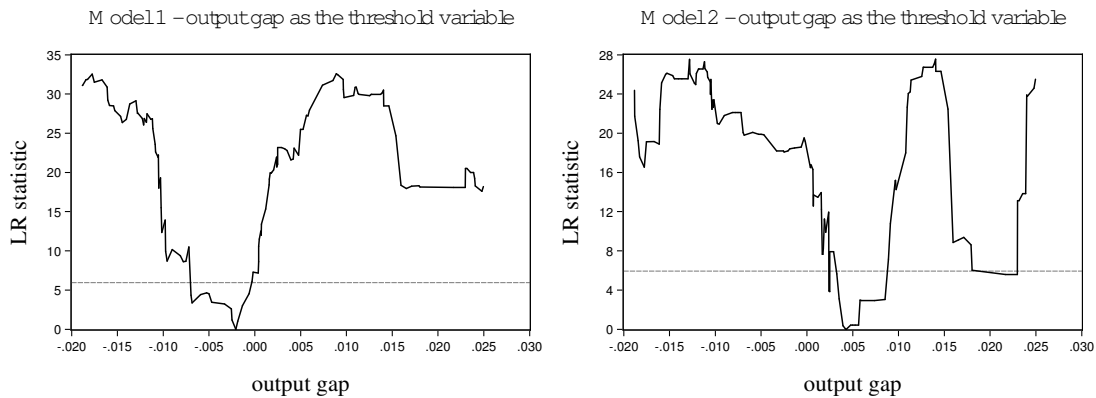
The description of the variables is presented in the Section 3; the Table presents the results of Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests; in the ADF test, the Schwarz Criterion is used to indicate the lag length, whereas for the PP and KPSS tests we use the Bartlett kernel estimation with the Andrews bandwidth selection method; \* \ \*\* \ \*\*\* denotes that the null hypothesis is rejected at the 1% \ 5% \ 10% level, respectively.

Figure 1: The likelihood ratio statistics for the Taylor rule



The graphs present LR-statistics for possible values of the threshold variable. It tests whether particular value belongs to the threshold interval (Hansen 2000). The dashed line corresponds to 90% critical value.

Figure 2: The likelihood ratio statistics for the Phillips curve



The graphs present LR-statistics for possible values of the threshold variable. It tests whether particular value belongs to the threshold interval (Hansen 2000). The dashed line corresponds to 90% critical value.