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Applied asset prices and currency strength in backward- and forward-looking Taylor models

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Abstract

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Key words: *Taylor rule, Monetary policy, Asset prices, TCW-Index, Inflation*

Purpose: The purpose of the thesis is to examine if the Swedish Central Bank, the Riksbank, reacts to changes in asset prices and the strength of the currency when regulating the short term interest rate. The application of backward- and forward-looking Taylor rules will help us evaluate the outcome of the Riksbank's inflation forecast.

Method: The thesis is based on the Taylor rule, augmented with the deviation of asset prices from its trend and the deviation of the TCW-index from its average, to examine if the variables are taken into consideration by the Riksbank. The models were regressed with OLS and TSLS, and the models differentiated by using current inflation against realized inflation one year ahead.

Conclusion: The results showed that none of the asset prices or currency strength was found significant, implying that the Riksbank does not react to changes in the augmented variables. The inflation- and GDP-gap was significant in all the backward-looking models, though not in any of the forward-looking models. Differences in the current and forecast-based models show that the Riksbank's inflation forecast is insufficient.

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1. Introduction

In this chapter we will start by presenting the background to our thesis and then we will discuss the purpose.

1.1 Background

More than twenty years has passed since Sweden first introduced a floating exchange rate from having its currency fixed to the European currency unit ECU (Riksbanken 2011a). As Sweden transitioned, the Swedish central bank began using the repurchase agreement as the primary tool to regulate the monetary policy, with the intent to keep the inflation at a low and stable level without creating a greater fluctuation in the real economy (Palmqvist 2007).

In 1993, John. B. Taylor published a paper, "*Discretion versus policy rules in practice*" which highlights how central banks can use the prime rate as an instrument to regulate the inflation via monetary policy. Since the introduction of the Taylor Rule, it has been modified several times and extended with more variables in attempt to strengthen the model.

The Swedish central bank's target is to keep the inflation at 2% with a margin of error of one percentage point.[1] The repurchase rate has an effect on the lending rate i.e. the rate which banks borrow money from the central bank (e.g., see Fregert and Jonung 2010). By offering a low, or even a negative, rate the central bank stimulates the economy with the intent of increasing consumption. The inflation rate in Sweden is currently at 0.1% (Statistiska centralbyrån 2015) which is significantly lower than the target of 2 percent. On the 18th of February 2015 the Riksbank decided, for the first time in Swedish history, to lower the short term interest rate to a negative level in order to reach the inflation target of 2%. The Riksbank has, since February, lowered the rate further to a new record low level of -0.35% (Riksbanken 2015). According to the Riksbank (2011b) the value of the currency will be affected by a change in the interest rate. They further state that an increase in the interest rate will result in a strengthening of the currency, and the change in the currency's exchange rate will affect the import and export (Riksbanken 2011c). The current negative rate should have depreciated the value of the Swedish krona and therefore affected the export and the real economy. This economic chain reaction suggests that it is important to consider the currency's strength when regulating the rate.

The purpose of this paper is to examine how asset prices and the strength of the Swedish currency affect the Riksbank's interest rate decision. We are going to use backward- and forward-looking Taylor models and augment them with additional variables, which take asset prices and the strength of the currency into consideration. Differences in real time models versus forecast-based

[1] Generally, for goods and services measured by Consumer price index; the measurement of inflation that is commonly used by the official bank.

will be examined to see how well the Central bank of Sweden have forecasted the inflation for a reasonable time ahead. According to Chadha, Sarno and Valente (2003) and Taylor (2001), small economies should consider using a variable that captures the currency exchange rate when setting the monetary policy, since they argue that the central banks might respond to a change in exchange rates. As Sweden's export in 2014 was nearly 45 percent of GDP (SCB 2015), the effect on trade from monetary policy is relevant to the Swedish economy. We will use the Total Competitiveness Weights-index since it is a geometric index, a bundle which contains 21 different currencies, against the Swedish krona. The index is considering the import and exports to the countries in the bundle and is weighted subsequently.

In addition, the fact that housing- and asset prices grew more rapidly than the consumer price index would indicate that these markets do not react to changes in the interest rate to the same extent as the consumer price index. Mishkin (2001) found that fluctuations of the asset market influence the aggregated economy, through its impact on the transmission mechanism. This makes it noteworthy to see if the Swedish Riksbank takes these aspects into consideration in their decision making, and to what extent.

1.2 Previous research

There exist a number of empirical studies if asset prices are targeted by the central banks; with various results, no conclusive results have been observed.

Taylor (1993) outlines how the central bank can use a reaction function to control the inflation and economic output by changes in the nominal interest rate. The equation, known as the Taylor Rule, is generally accepted and applied within the economic community. It is a monetary policy rule focusing on long-term price stability through predictable actions by the official bank and therefore reduced uncertainty vis-à-vis a discretionary policy where the official bank take decisions from case-to-case (Orphanides, 2007). The Taylor Rule has since then been modified to include a forecast of the inflation by Orphanides (2001), Clarida, Gali & Gertler (1998a), among others, to create a better reaction function for the central banks.

Fisher (1911) highlights a relationship between movement in asset prices and inflation. He argues that asset prices can be used to forecast the inflation. Several recent studies have been focused on the subject of whether asset prices should be considered in the monetary policy. For instance, Bernanke & Gertler (1999) and Hilberg & Hollmayr (2011) argue that asset prices should not be included in the monetary policy rule because of undesired side effects; however, Bernanke & Gertler (1999), and later Siklos, Werner & Bohl (2004), found that asset prices could be relevant indicators for forthcoming inflation.

Sutherland (2015) investigates whether the interest rate is affected by changes in the exchange rate and the price of houses and assets. He used the currency pair SEK/EUR with the motivation that Sweden exports a large amount of goods to the Eurozone and therefore it would be valid to take the exchange rate into account in the Riksbank's monetary policy making. He did not find any evidence that the Swedish central bank reacted to deviations of asset- or house prices from their trend level, nor the exchange rate.

2. Theory

This chapter highlights the roll of the central bank in Sweden and how the central bank uses the interest rate as a tool to regulate the inflation; thereafter, both backward-looking and forward-looking Taylor rules will be presented.

2.1 The roll of the central bank of Sweden

The main purpose of the central bank of Sweden is to regulate the monetary policy in Sweden. Their principal instruments are the adjustment of the short-term interest rate (also known as the repurchase agreement), through altering the monetary base (Fregert & Jonung 2010). The Riksbank's inflation target is to keep the inflation in Sweden at a stable level of 2 percent. The interest rate does not only affect the inflation but also affects the economic growth in the country.

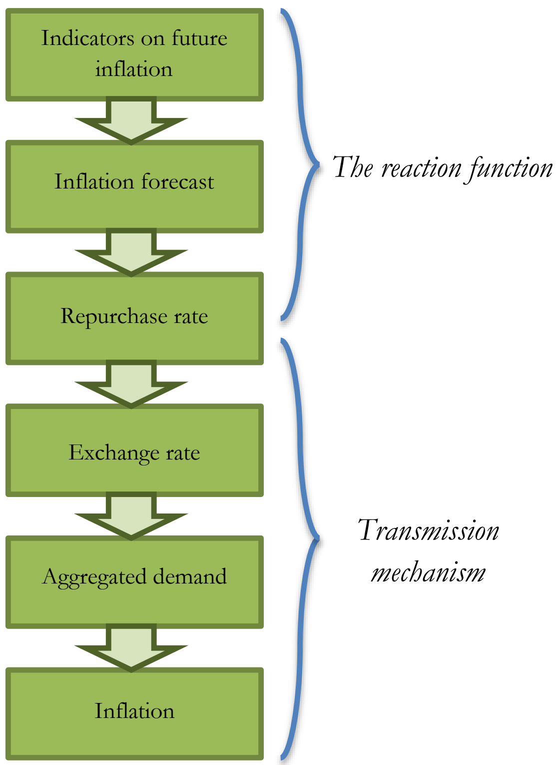

Figure 2.1: The Riksbank's structure of the monetary policy in Sweden

The effect that a change in the interest rate causes on inflation is known as the transmission mechanism. Figure 2.1 illustrates six important stages which the Riksbank are taking into account when trying to adjust the inflation level in Sweden. There are many processes to consider and every step of the chain reaction results in a lag between a change in the interest rate and the full effect of the alteration. Fregert & Jonung (2010) and Riksbanken (2011b) explain that the time between a change in the interest rate and the effect on the inflation is named the transmission mechanism and is considered to show an effect one to two years after the initial change. Further, Fregert & Jonung (2010) and Crockett (2000) argues that a change in the interest rate will not always have the desired outcome on the inflation. This is because of external disturbences, which can be somewhat troublesome and hence difficult to predict. The transmission mechanism contains of three different channels which are: the credit channel, the interest rate channel and the exchange rate channel. The Mundell-Fleming modell emphasises that the exchange rate channel have a greater impact on the inflation and GDP than the other two channels, since a change in the value of a currency will affect the import and export (see Fregert and Jonung 2010).

2.1.1 The credit channel

The central bank uses the credit channel to regulate the lending interest rate to banks. An increase in the lending rate will decrease the lending from banks, i.e. it will affect the banks customers willingness to take a loan. This will generally result in lower activity in the economy since potentiall lenders will postpone their investments (Riksbanken 2011b).

2.1.2 The interest rate channel

The centralbank uses the interest rate channel to regulate the household consumption by adjusting the interst rate to either make it attractive to save money or to consume. If the goal is to surpress consumption, the Central bank raises the interest rates to make it more appealing to save money (Riksbanken 2011b).

2.1.3 The exchange rate channel

The centralbank can use the exchange rate channel to regulate the inflow and the demand of capital to a country. If the central bank wants to increase the strenght of the currency, they need to make the currency attractive. An increase in the interest rate result in higher willingness of investing in the country's assets rather than a third country. This will normally result in higher demand for the currency and implicitly, an appreciation of the currency itself. Furthermore, this will have an affect on the trade, import and export, since a change in the currency alter the attractiveness of the trade flows from the country. If the currency appreciates, the currency becomes more expensive which implies that the demand for domestic good will decrease since it becomes more expensive to consume abroad, hence the inflation will be surpressed (Riksbanken 2011b). Research conducted by Crockett (2000) highlights the importance of the the exchange rate channel and emphasises that it can have great effects in small economies, since a change in the price of the currency will affect the countrys trade. Further, the general theory (e.g see Fregert & Jonung 2010) describes that for a small economy the monetary policy is primarly exercised by changes in the exchange rate. Sweden is a small and open economy thus the exchange rate is the Riksbank's primary monetary policy tool. Figure 2.2 illustrates the effects on the GDP when a small open economy uses expansive monetary policy, sustaining a floating exchange rate. When applying expansive monetary policy, the increase in the monetary base will shift the LM-curve[1] downwards which will temporary decrease the interest rate. Further this will result in a depreciation of the currency, which will lead to an increase in net export and shift the IS-curve[2] to the right until the LM-, IS- and foreign interest rate interects. As can be observed, this results in an increase in GDP and a new equlibrium.

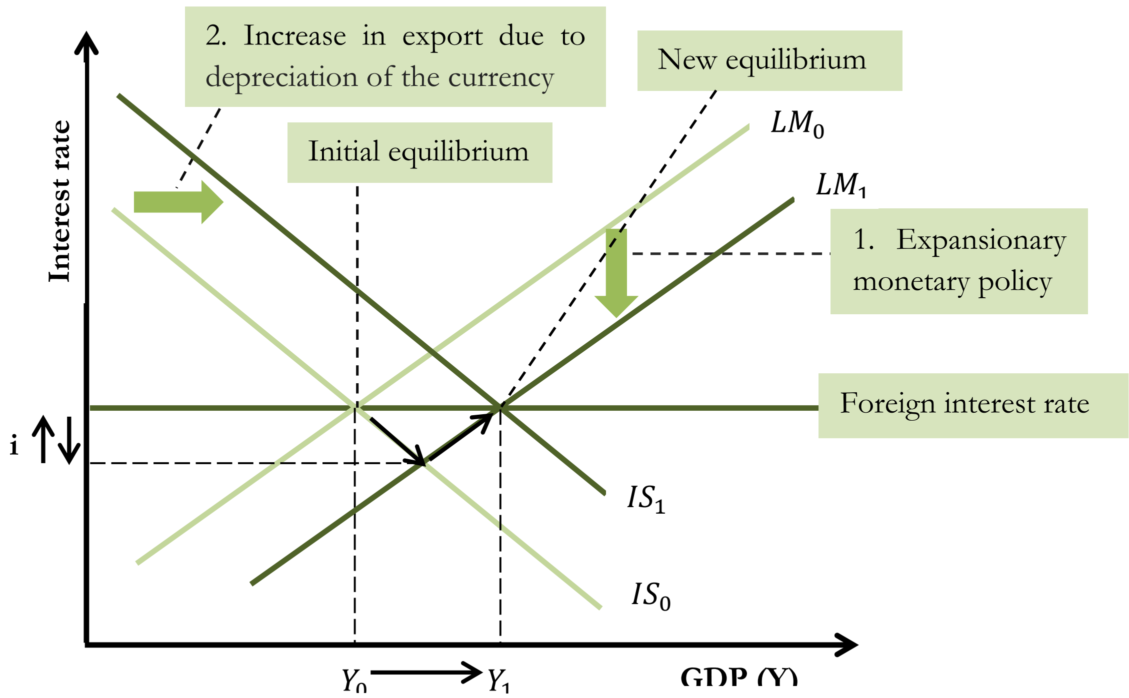

Figure 2.2 Illustrates Expansive monetary policy in a small open economy with a floating exchange rate (Fregert & Jonung, 2010)

Taylor (1993) emphasized how a monetary policy can be conducted and pointed out two important target variables; the inflation and the GDP. This will be presented further in the next section.

[1] Liquidity and Money curve
[2] Investment- and savings curve

2.2 Taylor rule

The backward-looking Taylor rule – the standard Taylor rule – is based on historical data and the reaction function gives a historical relationship between the targeted and tangible inflation, the output gap and the interest rate. The relationship of the variables yields a short term approach to determine the level of the interest rate, as well as long term market stability through the inflation target. The model, described by Taylor (1993), are the following:

$$\boldsymbol{r^*{}_t = p_t + 0,5(p_t - 2) + 0,5y_t + 2} \tag{2.1}$$

where

r^* is the optimal short term interest rate at time *t*

p_t is the inflation rate

y_t is the percent deviation of real GDP from the GDP target (GDP gap) at time *t*.

$y = 100(Y - Y^*)/Y^*$ where Y is the real GDP and Y^* is the real GDP linear trend (estimated by a Hodrick-Prescott-filter).

Taylor suggest that the coefficient of the inflation gap(*h*) and the GDP gap(*g*) should be weighted equally at 0.5[1], giving the same response for inflation and GDP deviation in the reaction function. The inflation target was set at 2 percent, which is used in several countries (e.g. Sweden, USA). The term $(p_t\text{-}2)$ is the inflation deviation from its targeted level. Suppose the output gap and the inflation deviation would be zero, the optimal short run interest rate would be set at 2 percent plus the level of inflation[2]. In other terms, the real interest rate would be set at 4 percent if no discrepancy exists between the GDP trend and the inflation target. Later Taylor (1999) suggested that a coefficient for the inflation gap should be greater than one, renown as the Taylor principle. The purpose of the Taylor principle is to help the official bank to better react to fluctuation; a coefficient of $1 + h$ would better stabilize the macro economy (Troy & Leeper 2007).

A problem for the policymakers, discussed by McCullum (1993), was the inability to observe the current GDP, and subsequently optimize with the actions available (tighten/not tighten). Critique was also aimed at the original rule for lacking a smooth, progressive change in the interest rate.
The wish for a more subtle change of the interest rate was expressed by Bob Bernanke, the former head of the Federal Reserve: "But if we do agree with that inflation outlook, then at least based on

[1] Taylor calibrated that parameters, set to 0.5, followed the U.S fund rate between 1987-1992 with a good fit (Taylor, 1993).
[2] To obtain the inflation gap at zero, the inflation would by default be 2 percent.

this estimated rule our policy tightening should be slower and more gradual than suggested by historical relationships…" (FOMC, October 2003, p72). In other words, the forward-looking rule advised a smaller change, whilst the backward-looking rule suggested larger changes more rapidly. Forward-looking models use lagged interest rate on the right side; the coefficients are known as smoothing parameters. The lagged variable gives the interest rate a slower speed of adjustment and does not stipulate larger direct change, contrary the backward-looking rule, instead intermittently change the rate towards its desired level. This is named interest rate smoothing: a change in the interest rate is believed to have a delayed effect of one to two years and the lagged variables take these effects in to consideration.

A forward-looking Taylor (1999) rule can be expressed as:

$$\boldsymbol{r^*}_{\boldsymbol{t}} = \boldsymbol{p_t} + \mathbf{0,5}\left(\boldsymbol{E}[\boldsymbol{p_{t+j}} \mid \boldsymbol{\Omega_t}] - \mathbf{2}\right) + \mathbf{0,5}\boldsymbol{E}[\boldsymbol{y_{t+j}} \mid \boldsymbol{\Omega_t}] + \mathbf{2} \tag{2.2}$$

A forward-looking model for the central bank will be based on expected inflation deviation from target $\boldsymbol{E}[(\boldsymbol{\pi_{t+4}} - \boldsymbol{\pi^*}) \mid \boldsymbol{\Omega_t}]$, and the expected GDP gap $\boldsymbol{E}[\boldsymbol{\gamma_t} \mid \boldsymbol{\Omega_t}]$. $\mathbf{\Omega_t}$ is the information set available to the Riksbank at time *t*.

The difference between the backward- and forward-looking rules is the marginal change in the short-term interest rate and the greater weight put on the inflation expectancies by the forward-looking rule (FOMC, October 2003, p72). The Federal Open Market Committee (1997) found through simulations that it is more costly to not tighten (lower the rate/unchanged rate) when the real situation required a tighter policy than to tighten (increase the rate) when the actual response would be not to tighten. Therefore, including lagged interest rate is more forgiving than the original rule if the central bank's decision on the interest rate is erroneous.

2.3 The Riksbank's two percent target and forecasted inflation

The Riksbank's target of two percent has not been reached with any greater success.
The National institute of economic research (Konjunkturinstitutet, 2013) published a rapport on how the Riksbank has systematically misjudged the prediction of inflation. On average, the Riksbank's inflation forecast has been overestimated with approximately one percent points on a two year term. The poorly predicted inflation, and the changes in the interest rate that follows, will cause further pressure on the actual inflation. Aggregated, this will push the inflation down and not allow it to recover to the desired level.

3. Data and Method

This chapter starts with a brief presentation of the variables used in our modified Taylor model, the chapter continues with presenting the execution of the model.

3.1 Discussion of variables

The foundation of the empirical models constructed in this paper is based on the Taylor rule. We will extend the Taylor rule model by adding additional dependent variables that we believe can have an effect on the interest rate, and widen the central bank's information set when determining the interest rate. The key findings in Taylors (1993) paper are that the interest rate tends to be driven by two main factors, the inflation and the difference between GDP and potential GDP. Further the Taylor model emphasizes that the difference between actual inflation and the inflation target together with the GDP gap is a function of the interest rate, set by the central bank. We collected data from the first quarter in 1995 to the third quarter in 2015. Augmented Dickey Fuller unit root tests were performed on all the variables to check the data for stationarity[1]. The test indicated non-stationary series on OmxSpi, housing prices, TCW-index and commodities. The variables were transformed to stationary by taking the difference of the variables.

Inflation

The data of the inflation were collected from Statistiska Centralbyrån in quarterly form. The inflation gap is obtained by taking the difference of the inflation and its targeted level (for The Riksbank; 2 percent). The data for the interest rate were collected from the Riksbank in quarterly form.

[1] Tests attached in appendix; A

GDP gap

The GDP gap, also known as the output gap, is the difference between real GDP and potential GDP. The percentage changes in real GDP were collected from OECD, in quarterly data. By using a Hodrick–Prescott filter on the real GDP we were able to calculate the potential GDP. The Hodrick–Prescott filter is used for estimating trends by smoothing the time series data and is proposed in the relevant literature (Taylor 1999). This approximation of trends will be used on the subsequent variables. It is suggested in Hodrick & Prescott (1980) that the smoothing parameter should be set to λ=1600 for quarterly data, and were applied to the concerned variables.

Asset prices and exchange rate

Stock prices

OmxSpi is an all share-index containing all the stocks that are listed on the Stockholm stock exchange. The OmxSpi data were collected from NASDAQ OMX Nordic in daily observations. The data were recalculated to quarterly form by taking an average of the three months included in each quarter. The unit root test indicated that the data was non-stationary; the solution to this problem was to take the 1st difference in the data.

House prices

Housing prices represent the average price for permanent houses in Sweden. The house prices were collected from Statistiska Centralbyrån in quarterly data. The unit root test indicated that the data was non-stationary; the solution to this problem was to take the 2st difference in the data.

Commodity prices

The commodities index used is an all commodity price index. The data was collected from the International Monetary Fund in monthly form; recalculated the data to get it in to quarterly form by taking an average of the three months. The unit root test indicated that the data was non-stationary and also here, the 1st difference of the series made it stationary.

TCW-index

The TCW-index consists of different currencies, weighted with respect to size of the trade to the third part country. The quarterly data for the Total Competitiveness Weights-index were collected from the Riksbank.

3.2 Regressions

To make the Taylor reaction function possible to regress, it must be transformed. Thus, the model in regression form based on the original Taylor rule, is given by:

$$\boldsymbol{i_t = \alpha + \beta_\pi(\pi_t - \pi^*) + \beta_\gamma \gamma_t + \varepsilon_t} \tag{3.1}$$

Where *i* is the interest rate at time t, α is an intercept, π is the current inflation at time t, π^* is the inflation target. Combined, $(\pi_t - \pi^*)$ represent the current inflation deviation from its targeted two percent, also known as the inflation gap. The GDP-gap is represented by γ and ε_t is the error term.

Regressing the model with Ordinary Least Squares (OLS) gives a linear relationship between the dependent and non-dependent variables. The residuals from this regression display autocorrelation, which is confirmed by a Breusch-Godfrey LM test.

Later studies on the Taylor rule suggest that previous periods of the interest rate should be incorporated in the equation to capture the interest smoothing factor from previous lagged effects of the short-term interest rate. Bob Bernanke expressed that in both the backward- and the forward-looking rule, lagged interest rate is sufficient in the equation as an error correction term (FOMC, Oct 2003, p71). Thus, variables of lagged interest rate can be incorporated in the models, not just in the forecast-based model. By adding two variables of lagged interest rate, the null hypothesis of the Breusch-Godfrey LM test was rejected and our problem with the correlated residuals was fixed. With the correction for autocorrelation, we end up with the following model:

$$\boldsymbol{i_t = \alpha + \beta_\pi(\pi_t - \pi^*) + \beta_\gamma \gamma_t + \rho_1 i_{t-1} + \rho_2 i_{t-2} + \varepsilon_t} \tag{3.2}$$

Where $i_{t-1,2}$ is the interest rate lagged one or two periods back and $\rho_{1,2}$ is the smoothing parameter.

3.2.1 Forward-looking Taylor rule

The Riksbank's change of the short-term interest rate will not have a direct effect on the market and the policy makers cannot observe numerous variables in the time of the decision making, therefore a forward-looking model would be more viable to use. Furthermore, Svensson (1997), Batini & Haldane (1999) and the general theory (e.g. in Fregert & Jonung 2010) argues that the Taylor rule should be forecast-based as several central bank's conduct their policy with the help of forecast-based models. Batini & Haldane (1999) reasons that inflation forecast is to be approached by π_{t+j}. The value of *j* implies the degree of smoothing of the interest rate by the number of periods before inflation reach its targeted level. The choice of *j* is based on the optimal forecast horizons in Batini & Haldane (1999), who advocate a number of *j* between three to six quarters. Our choice of *j* is four quarters, supported by Batini & Haldane as well as similar regressions (Sutherland 2015; Clarida et al 1998b).

The forward-looking Taylor rule can be written in this way:

$$\boldsymbol{i_t = \alpha + \beta_\pi(\pi_{t+4} - \pi^*) + \beta_\gamma \gamma_t + \rho_1 i_{t-1} + \rho_2 i_{t-2} + \varepsilon_t} \quad (3.3)$$

We do observe two problems with regressing model (3.3). Models, just like this one, are using realized inflation for *j* periods ahead; commonly used in relevant literature such as Bernanke & Gertler (1999) and Cecchetti, Genberg & Wadhwani (2002). This choice is based on the assumption that the forecast model is unbiased and that the Central bank can predict the behavior of future inflation without any significant inaccuracies.

Further, the forecast model for the central bank will be based on expected inflation deviation from target and the expected GDP gap, written as $\boldsymbol{E[(\pi_{t+4} - \pi^*) \mid \Omega_t]}$ and $\boldsymbol{E[\gamma_t \mid \Omega_t]}$ where $\boldsymbol{E}$ is the expected value of the inflation gap and the GDP gap. In addition, $\boldsymbol{\Omega_t}$ is the information available to the Riksbank at time *t*. The inflation deviation and output gap are conditional on the information, hence highly uncertain.

The expectations cannot be regressed and will therefore be captured as a linear combination in the error term, causing endogeneity between the regressors and the error term. A regular OLS-estimation will be inconsistent and another type of method that allows instruments to cope with the correlations must be used. By using instrument variables, the endogeneity problem could be solved if the instruments are uncorrelated with the dependent variable, but correlated with the independent endogenous variables. In this paper we will use Two-stage least squares (TSLS). Literature suggests that usage of lagged inflation- and GDP gap is sufficient as instruments (Bernanke & Gertler 1999; Clarida et al 1998b). Clarida et al (1998b) also propose to use a world commodity index and its lags of one to four periods as instruments.

3.2.2 The augmented model

We add our variables of interest to examine if they affect the interest rate, i.e. if the Riksbank has taken these variables into consideration when determining the short term interest rate. Our added terms for asset prices (*a* and *h*) is expressed in terms of the changes in the previous period deviation from its trend level, based on similar studies from Cecchetti et al (2002) and Bernanke & Gertler (1999). The exchange rate is modeled in a similar way, through lagged deviation from its average. The augmented model with our variables:

$$\boldsymbol{i_t = \alpha + \beta_\pi(\pi_{t+4} - \pi^*) + \beta_\gamma \gamma_t + \rho_1 i_{t-1} + \rho_2 i_{t-2} + \beta_a(a_{t-1} - \hat{a}) + \beta_h\left(h_{t-1} - \hat{h}\right) + \beta_e(e_{t-1} - \bar{e}) + \varepsilon_t} \quad (3.4)$$

Where $\boldsymbol{(a_{t-1} - \hat{a})}$ is the lagged deviation of asset prices from its trend level, $\boldsymbol{\left(h_{t-1} - \hat{h}\right)}$ is the lagged deviation of house prices from its trend level and $\boldsymbol{(e_{t-1} - \bar{e})}$ is the lagged deviation of the TCW-Index from the periods average value.

As instruments for asset prices and the competitive exchange rate index, the terms as its own will function as instruments. This is valid since the observed deviation of the variable in period *t-1* will not be correlated with the error term in period *t*, i.e. the covariance of the lagged deviations and $\boldsymbol{\varepsilon_t}$ is zero.

We will initially regress and compare model (3.2) and (3.3) with OLS to see potential differences in the backward- and forward-looking models. We will then compare the augmented model (3.4) with a similar model, called model (3.4*).[1] The model (3.4*) is an augmented model of (3.2); we use the backward-looking Taylor rule and add our variables of interest. Model (3.4) and (3.4*) will be estimated with OLS and later with TSLS. When using TSLS, the models are estimated with the aforementioned instruments (constant included). All models are estimated with HAC standard errors to correct for possible heteroscedasticity and/or autocorrelation

[1] The model (3.4*) is given by: $\boldsymbol{i_t = \alpha + \beta_\pi(\pi_t - \pi^*) + \beta_\gamma \gamma_t + \rho_1 i_{t-1} + \rho_2 i_{t-2} + \beta_a(a_{t-1} - \hat{a}) + \beta_h\left(h_{t-1} - \hat{h}\right) + \beta_e(e_{t-1} - \bar{e}) + \varepsilon_t}$

4. Results & Analysis

This section will present the outcome of our regressions and comment on the significance of the explanatory variables.

4.1 Ordinary least square regressions

Table 4.1 contains the results from the OLS regression of model (3.2) and (3.3). From the results we can observe that the inflation gap and the GDP gap are significant at a five percent level in the backward-looking model, though these significances cannot be observed when using a forward-looking estimation. The lagged interest rates are, as expected, significant at a one percent level for both models. This is because of the causality between the dependent variable and its lags.

Table 4.1: OLS

Explanatory Variable	**Estimates (3.2)**	**P-Value**	**Estimates (3.3)**	**P-Value**
$\boldsymbol{\beta_\pi}$ Inflation gap	0,0675* [0,0261]	0.011	0,0303 [0,0266]	0,258
$\boldsymbol{\beta_\gamma}$ GDP gap	0,1718* [0,0749]	0.024	0,1471 [0,0800]	0,070
$\boldsymbol{\rho_1}$ i_{t-1}	1,4559** [0.0692]	0.000	1,5496** [0,0614]	0,000
$\boldsymbol{\rho_2}$ i_{t-2}	-0,5078** [0.0668]	0.000	-0,5935** [0,0622]	0,000
$\boldsymbol{N}$	81		77	
$\boldsymbol{R^2}$	0.979		0,976	

Notes: (1) Standard errors given in parentheses; (2) * p< 0.05; (3) ** p< 0.01; (4) *N* is the number of observations

As mentioned in the methodology part, a LM-test was performed that confirmed that we had problem with autocorrelation. By adding two lagged interest rate variables this issue was solved. It is noteworthy to mention that the R^2 is affects by the lagged variables of the interest rate, giving the model an undeserved high explanatory power. When we observed the correlation between variables, it showed that the correlation value for the interest rate and its lags were high (>0.90)[1].

[1] See table B in appendix.

This suggests that the model might suffer from multicollinearity, hence the high R^2 (Kennedy 2008). By deducting the lagged interest variables our problem with multicollinearity disappeared, but the model would suffer from autocorrelation.[1] We continued including the two lagged interest rate variables in our model, and accept the fact of multicollinearity.

Table 4.2: OLS regression on (3.4*) and (3.4)

Explanatory Variable	**Estimates (3.4*)**	**P-Value**	**Estimates (3.4)**	**P-Value**
$\boldsymbol{\beta_\pi}$ Inflation gap	0,0995**	0,002	0,0331	0,202
	[0,0312]		[0,0257]	
$\boldsymbol{\beta_\gamma}$ GDP gap	0,1341*	0,040	0,1148	0,106
	[0,0644]		[0,0701]	
$\boldsymbol{\rho_1}$ i_{t-1}	1,3880**	0,000	1,5370**	0,000
	[0,0699]		[0,0590]	
$\boldsymbol{\rho_2}$ i_{t-2}	-0,4516**	0,000	-0,5877**	0,000
	[0,0692]		[0,0585]	
$\boldsymbol{\beta_a}$ Asset prices	0,2319	0,059	0,1434	0,288
	[0,1210]		[0,1340]	
$\boldsymbol{\beta_h}$ House prices	0,7304	0,470	0,7908	0,506
	[1,0056]		[1,1841]	
$\boldsymbol{\beta_e}$ TCW-index	-0,4335	0,456	-0,1209	0,820
	[0,5795]		[0,5321]	
$\boldsymbol{N}$	80		76	
$\boldsymbol{R^2}$	0,979		0,974	

Notes: (1) Standard errors given in parentheses; (2) * p< 0.05; (3) ** p< 0.01; (4) *N* is the number of observations

[1] When faced with a choice of autocorrelation or multicollinearity, we find that the latter is more favorable for our regressions since autocorrelation gives greater errors over time, while multicollinearity affects the size of the coefficients for the concerned variables. Kennedy (2008) states that multicollinearity is not a problem if the R^2 of the regression exceed the R^2 of any two independent variables. See table C in appendix.

Table 4.2 shows the result from the regression of the Taylor model with additional variables. From the results in the backward-looking model we conclude that the inflation gap is significant at a one percent level; the GDP gap is significant at a five percent level. The interpretation of the results shows that the Riksbank would raise the interest rate by 0,09 percent points if the inflation deviation from its target increased with one percent point. An increase in interest rate by 0,13 percent points would be the response on a one percent increase in the GDP deviation from its trend. None of the asset prices or TCW variables in the augmented model is significant at a five percent level. Also, the interest rate smoothing are the only significant variables in the forward looking model.

4.2 Two stage least square regressions

We assumed that the OLS would not give us the best linear unbiased estimation (BLUE) since the expectancies in our forecasted model would be captured in the error terms[1] causing bias of the error term. Therefore the models (3.4*) and (3.4) were estimated with TSLS, as in previous research.

Table 4.3 illustrates the results from the two least square regressions. In the backward-looking regression we find that the inflation gap and the GDP gap are significant at their attributed levels. This infers that the Swedish central bank reacts to changes in inflation and gross domestic product. An increase in inflation by one percent point will result in an increase of 0.11 percent points of the interest rate, slightly higher than table 4.2 (OLS). If the GDP gap changes by one percent point, it will result in a change of the interest rate by 0.18 percent points. The regressed models do not find the OMX, TCW-index or the house prices significant.

[1] $\boldsymbol{\varepsilon_t = \alpha + \beta_\pi\{(\pi_{t+4} - \pi^*) - E[(\pi_{t+4} - \pi^*) \mid \Omega_t]\} + \beta_\gamma(\gamma_t - E[\gamma_t \mid \Omega_t]) + v_t}$

Table 4.3: TSLS regression on (3.4*) and (3.4)

Explanatory Variable	Estimates (3.4*)	P-Value	Estimates (3.4)	P-Value
$\boldsymbol{\beta_\pi}$ Inflation gap	0,1138**	0,0005	0,0049	0,942
	[0,0313]		[0,0677]	
$\boldsymbol{\beta_\gamma}$ GDP-gap	0,1822*	0,015	0,1567	0,176
	[0,0733]		[0,1148]	
$\boldsymbol{\rho_1}$ i_{t-1}	1,3549**	0,000	1,5571**	0,000
	[0,0749]		[0,0933]	
$\boldsymbol{\rho_2}$ i_{t-2}	-0,4159**	0,000	-0,5980**	0,000
	[0,0681]		[0,0771]	
$\boldsymbol{\beta_a}$ Asset prices	0,1751	0,248	0,1200	0,480
	[0,1506]		[0,1690]	
$\boldsymbol{\beta_h}$ House prices	0,7290	0,477	0,7353	0,509
	[1,0212]		[1,1094]	
$\boldsymbol{\beta_e}$ TCW-index	-0,6363	0,272	0,1066	0,894
	[0,5757]		[0,8045]	
$\boldsymbol{N}$	78		74	
$\boldsymbol{R^2}$	0,971		0,962	

Notes: (1) Standard errors given in parentheses; (2) * p< 0.05; (3) ** p< 0.01; (4) *N* is the number of observations; (5) instruments: $\boldsymbol{\pi_{t-1\ldots4} - \pi^*}$, $\boldsymbol{\gamma_{t-1\ldots4}}$, $\boldsymbol{i_{t-1}}$, $\boldsymbol{i_{t-2}}$, $\boldsymbol{commodity_{t,t-1\ldots4}}$, $\boldsymbol{a_{t-1} - \hat{a}}$, $\boldsymbol{h_{t-1} - \hat{h}}$, $\boldsymbol{e_{t-1} - \bar{e}}$

Although, when comparing table 4.2 and 4.3 (the augmented model regressed first with OLS and then with TSLS), the coefficient and p-values do not change as much as expected.

We have used instruments proposed in the earlier research for our TSLS-regression[1], however we did not know their validity in our regressions. We performed a Durbin-Wu-Hausman test to see if the inflation gap and GDP gap are in fact endogenous as we presumed. For the Durbin-Wu-Hausman test, the null hypothesis is that the Inflation gap and GDP gap are endogenous.

[1] See Clarida (1998b); Sutherland (2015)

Table 4.4: Regressor endogeneity test – Inflation gap and GDP gap

	Durbin score	**p-Value**
Model (3.4*) Current inflation	1.527651	0.4659
Model (3.4) Inflation forecast	0.653858	0.7211

As seen in table 4.4, we cannot reject the null hypothesis and therefore we conclude that the regressors are exogenous. A TSLS is therefore not necessary to use since our OLS model in table 4.2 give us the best linear unbiased estimators.

We also tested the models (3.4*) and (3.4), with the minor change of using the difference in the interest rate, **Δ**(interest rate). The coefficients and p-values were similar to table 4.2.[1] There were no major changes in the significance of the variables or coefficients. This reinforces our robustness of the original OLS estimation.

[1] See table D.1 and D.2 in appendix for comparison

5. Discussion

This chapter will start of by a brief discussion of our findings. The chapter will continue by a deeper discussion of the TCW-index and asset price, followed by a discussion of the results regarding the back- and forward looking models regressed.

In this paper we have investigated whether or not the Swedish central bank reacts to asset prices and the strength of the native currency when regulating the monetary policy. We have also compared the inflation and the predicted inflation four quarters ahead. As anticipated, our regression models found the inflation-gap and the GDP gap significant to the interest rate when estimated in the backward looking model. However, estimations of the forward-looking model showed no significance for the inflation-gap nor the GDP gap. This would suggest that the interest rate do not react to them, which seems odd since the main purpose of the monetary policy is to regulate the inflation. Another noteworthy finding is that neither model found asset prices nor the TCW-index significant.

5.1 TCW and asset prices

Since the results of the regression show that asset prices and the TCW-index are insignificant, in both the forward- and backward looking models, we can state that the Swedish central bank do not react to changes in neither of the three variables. Our results align with previous research made on large open economies as well as the results from Sutherland (2015) based on the Swedish official bank, concluding that asset prices do not belong in the reaction function. However, Bernanke & Getler (1999) and Siklos et al. (2004), debated in their findings that asset prices can be used as an instrument to help forecast the inflation.

The TCW-index consists of different currencies, weighted with respect to the size of the trade to the specific country. The insignificant result of the TCW-index we obtain is interesting, since the exchange rate channel in the transmission mechanism is said to have a great impact on the inflation and affect the import and export, according to the Mundell Fleming model. However we cannot observe the impact on the interest rate from the exchange rate nor the export in the reaction function. Although, the TCW-index most likely have an indirect effect on the interest rate through the inflation and GDP, since the monetary base is said to be used as a tool to conduct monetary policy in small open economies (see Fregert & Jonung 2010). As illustrated in in Figure 2.2, an increase the monetary base will initially lower the interest rate. Further, the currency will depreciate and increase the net export. Based on this theoretical reaction, it is remarkable that we find the

TCW-index insignificant in our regressions. Furthermore, regarding the house prices, we find it odd that the variable is insignificant in all of our regressions. When the central bank want to increase consumption they can decrease the interest rate; hence make it more attractive to take loans. Mishkin (2001) argues that a decrease in the interest rate will result in lowering of the cost associated with financing a house, further suggesting that there is a relationship between the interest rate and house prices; however we cannot observe this in our regressions.

5.2 Measurement errors

As been noted in the results obtained from the regression of the backward- and forward-looking models, there is a great difference between them. We found all variables insignificant (with the exception of the lagged interest rate) in the forward-looking regressions, even the inflation gap and the GDP gap. Our interpretation is that the interest rate would not react to a change in those variables, which is highly unlikely. Previous research has found the inflation gap and GDP gap significant, confirming that the independent variables explain changes in the dependent variable (see Taylor 1993). The reason behind our unlikely result could be that the Swedish central bank are having difficulties forecasting the inflation outcome. Our calculations show that the mean of the inflation is 1.122 percent during the period 1995Q1 to 2015Q3. As seen in figure 2.3, the inflation is volatile and the mean confirm that it is not directly revolving around the target of two percent
To the count of observations on the inflation, 64 out of 83 observations lies beneath the target of

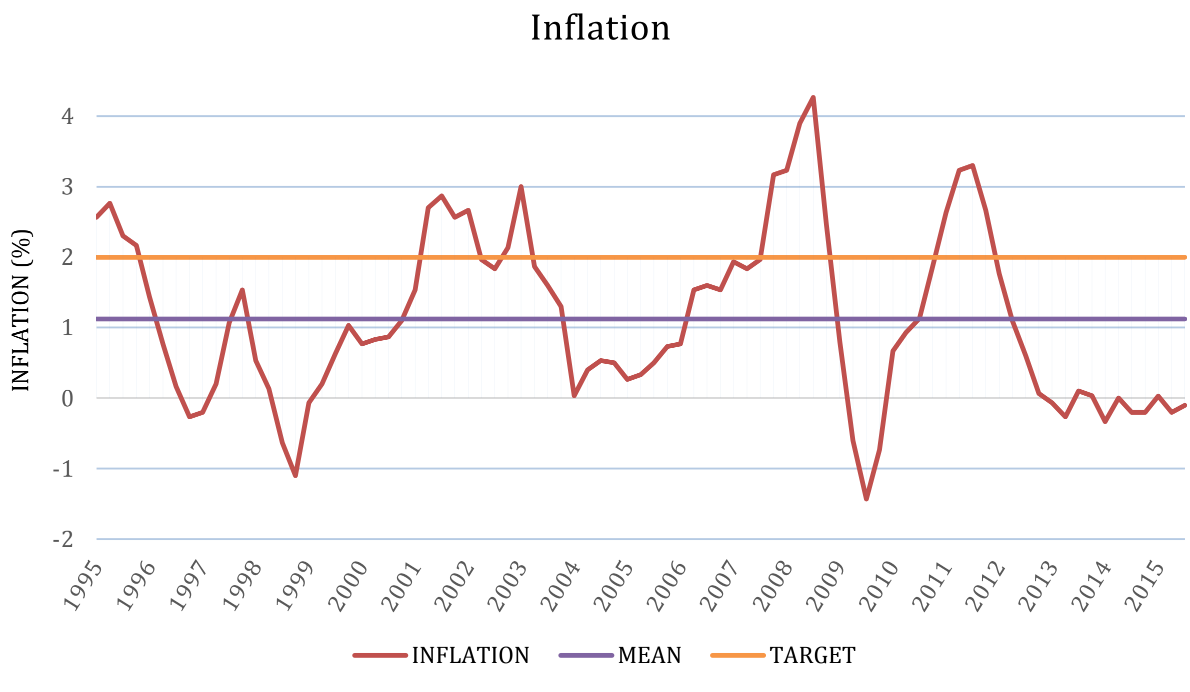

Figure 5.1 Inflation between 1995Q1-2015Q3, the mean of the inflation and the desirable target of two percent.

showing that deviation from the target has been stringent throughout the majority of the time period[1].

Comparisons of our backward- and forward-looking models show that the observed measurement errors in future inflation are quantifiable; concluding that The Riksbank's prediction of the inflation are biased. Surely, the ability to perfectly forecast inflation and further decide on the right level of interest rate can be seen as an impossible task. As Crockett (2000) reasoned, external disturbances affect the inflation, making predictions of the inflation difficult. This might be a reason why a change in the interest rate does not always result in the desired outcome. Supported by the rapport from Konjunkturinstitutet (2013), the Riksbank have had problems with their inflation forecasting. We argue that if the Riksbank's inflation forecast would have been accurate; their forecasted inflation would in average be the same as the future realized value of the inflation. The result we obtained with significant realized inflation in the current period versus the non-significant realized inflation four periods ahead consolidates the fact that the Riksbank has not been able to predict the inflationary direction without noteworthy errors. Since the current level of interest rate is negative, the maneuverability for the Riksbank is limited in case of any shock or great fluctuation in the real economy.

5.3 Further research

Previous research, conducted on large economies, found that asset prices can be used as an indicator of the direction for the inflation. Since Sweden is considered a small economy, it would be interesting to investigate whether the Swedish central bank can use the asset prices as an indicator of future inflation and better forecast the outcome.

Further research on asset price growth and its effect on the variance of GDP might help controlling economic fluctuations that in the long run affect the inflation and, in extent, the interest rate.

[1] See table E in appendix.

6. Conclusions

A summary of the findings in this paper will be presented.

The purpose of this paper was to investigate whether or not the Swedish central bank reacts to asset prices and the strength of the currency, and see if the predicted inflation forecast has been accurate. By using the Taylor rule as a foundation to conduct forward- and backward-looking models, we obtained different results for the similar augmented models. The findings presented shows that the Swedish central bank does not react to asset prices nor the TCW-index in either the backward- or forward-looking models i.e. the Riksbank does not view asset prices or the strength of the currency as valid indicators for changes in the short term interest rate.

Furthermore, the results of the backward- and forward-looking models showed a difference in the significance of the deviation of the inflation from its target and the GDP from its trend. The backward-looking model (uses current inflation) had significant inflation- and GDP gap. In the forward-looking model (using inflation one year ahead), neither the inflation gap nor the GDP gap was found significant, which we interpret that interest rate levels has not been optimally chosen by the Riksbank. Our interpretation of the different results is that the Swedish central bank is experiencing difficulties in forecasting the future inflation, and through erroneous interest rate adjustment, systematically pushed down the inflation below desired levels.

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Appendix

A. Unit root test

A.1 Initial Unit root tests

Interest rate

Augmented Dickey-Fuller Unit Root Test		t-Statistic	p-value
		-3,46955	0,0113
Test critical values:	1% level	-3,513344	
	5 % level	-2,897678	

Inflation

Augmented Dickey-Fuller Unit Root Test		t-Statistic	p-value
		-4,056729	0,0019
Test critical values:	1% level	-3,513344	
	5 % level	-2,897678	

GDP gap

Augmented Dickey-Fuller Unit Root Test		t-Statistic	p-value
		-6,925945	0,0000
Test critical values:	1% level	-3,51229	
	5 % level	-2,897223	

OmxSpi

Augmented Dickey-Fuller Unit Root Test		t-Statistic	p-value
		-3,003131	0,1378
Test critical values:	1% level	-4,07534	
	5 % level	-3,466248	

House prices

Augmented Dickey-Fuller Unit Root Test		t-Statistic	p-value
		-2,985669	0,1429
Test critical values:	1% level	-4,080021	
	5 % level	-3,468459	

TCW-Index

Augmented Dickey-Fuller Unit Root Test		t-Statistic	p-value
		-3,368741	0,0629
Test critical values:	1% level	-4,075340	
	5 % level	-3,466248	

Commodity

Augmented Dickey-Fuller Unit Root Test		t-Statistic	p-value
		-2,65271	0,2589
Test critical values:	1% level	-4,07534	
	5 % level	-3,466248	

A.2 Unit root tests on differentiated variables

ΔInterest rate

Augmented Dickey-Fuller Unit Root Test		**t-Statistic**	**p-value**
		-4,116332	0,0001
Test critical values:	1% level	-2,593824	
	5 % level	-1,944862	

ΔOmxSpi

Augmented Dickey-Fuller Unit Root Test		**t-Statistic**	**p-value**
		-6,268318	0,0000
Test critical values:	1% level	-3,514426	
	5 % level	-2,898145	

2ΔHouse prices

Augmented Dickey-Fuller Unit Root Test		**t-Statistic**	**p-value**
		-9,716707	0,0000
Test critical values:	1% level	-3,517847	
	5 % level	-2,899619	

ΔTCW-Index

Augmented Dickey-Fuller Unit Root Test		**t-Statistic**	**p-value**
		-3,344938	0,0000
Test critical values:	1% level	-3,513344	
	5 % level	-2,897678	

ΔCommodity

Augmented Dickey-Fuller Unit Root Test		**t-Statistic**	**p-value**
		-7,278871	0,0000
Test critical values:	1% level	-4,076860	
	5 % level	-3,466966	

B. Correlation table

Correlation	Repo	Repo(-1)
Repo(-1)	0,969210	1,000000
Repo(-2)	0,904307	0,972210

C. Augumented Taylor - no interest rate smoothing

Explanatory Variable	**Estimates (3.4*)**	**P-Value**	**Estimates (3.4)**	**P-Value**
$\boldsymbol{\beta_\pi}$ Inflation gap	0,5792* [0,2501]	0,023	0,0831 [0,2450]	0,735
$\boldsymbol{\beta_\gamma}$ GDP gap	-0,1828 [0,1993]	0,362	-0,1636 [0,2376]	0,493
$\boldsymbol{\beta_a}$ Asset prices	-0,4445 [0,6865]	0,519	-1,1841 [0,7260]	0,107
$\boldsymbol{\beta_h}$ House prices	2,7398 [2,3485]	0,247	1,4266 [2,9928]	0,635
$\boldsymbol{\beta_e}$ TCW-index	-9,1568 [5,7574]	0,116	-7,500 [6,6341]	0,262
$\boldsymbol{N}$	80		76	
$\boldsymbol{R^2}$	0,226		0,085	

Notes: (1) Standard errors given in parentheses; (2) * p< 0.05; (3) ** p< 0.01; (4) N is the number of observations

D. Regressions with Y=Interest rate and Y=ΔInterest rate

D.1 Backward-looking Taylor rule

	Y= Interest rate		Y= **Δ**(Interest rate)	
Explanatory Variable	**Estimates (3.4*)**	**P-Value**	**Estimates (3.4*)**	**P-Value**
$\boldsymbol{\beta_\pi}$ Inflation gap	0,0995** [0,0312]	0,002	0,0815** [0,0307]	0,009
$\boldsymbol{\beta_Y}$ GDP gap	0,1341* [0,0644]	0,040	0,1421* [0,0657]	0,034
$\boldsymbol{\rho_1}$ i_{t-1}	1,3880** [0,0699]	0,000	0,6345** [0,1339]	0,000
$\boldsymbol{\rho_2}$ i_{t-2}	-0,4516** [0,0692]	0,000	-0,2185* [0,0858]	0,013
$\boldsymbol{\beta_a}$ Asset prices	0,2319 [0,1210]	0,059	0,2486 [0,1342]	0,068
$\boldsymbol{\beta_h}$ House prices	0,7304 [1,0056]	0,470	0,3862 [0,8648]	0,656
$\boldsymbol{\beta_e}$ TCW-index	-0,4335 [0,5795]	0,456	0,0699 [0,6994]	0,920
$\boldsymbol{N}$	80		80	
$\boldsymbol{R^2}$	0,979		0,618	

Notes: (1) Standard errors given in parentheses; (2) * $p< 0.05$; (3) ** $p< 0.01$; (4) N is the number of observations

D.2 Forward-looking Taylor rule

	Y= Interest rate		Y= Δ(Interest rate)	
Explanatory Variable	**Estimates (3.4)**	**P-Value**	**Estimates (3.4)**	**P-Value**
$\boldsymbol{\beta_\pi}$ Inflation gap	0,0331 [0,0257]	0,202	0,0386 [0,0255]	0,135
$\boldsymbol{\beta_\gamma}$ GDP gap	0,1148 [0,0701]	0,106	0,1204 [0,0702]	0,090
$\boldsymbol{\rho_1}$ i_{t-1}	1,5370** [0,0590]	0,000	0,7041** [0,1240]	0,000
$\boldsymbol{\rho_2}$ i_{t-2}	-0,5877** [0,0585]	0,000	-0,1585 [0,0973]	0,107
$\boldsymbol{\beta_a}$ Asset prices	0,1434 [0,1340]	0,288	0,1716 [0,1484]	0,251
$\boldsymbol{\beta_h}$ House prices	0,7908 [1,1841]	0,506	0,5182 [1,1218]	0,645
$\boldsymbol{\beta_e}$ TCW-index	-0,1209 [0,5321]	0,820	0,1236 [0,6622]	0,852
$\boldsymbol{N}$	76		76	
$\boldsymbol{R^2}$	0,974		0,603	

Notes: (1) Standard errors given in parentheses; (2) * p< 0.05; (3) ** p< 0.01; (4) N is the number of observations

E. Inflation

Inflation	Mean	Std. Dev.	Observ.	Cumulative Observ.	Cumulative Percent
[-2, -1)	-1,266667	0,235702	2	2	2,41
[-1, 0)	-0,297436	0,220043	13	15	18,07
[0, 1)	0,442738	0,306056	28	43	51,81
[1, 2)	1,549206	0,321216	21	64	77,11
[2, 3)	2,541667	0,232303	12	76	91,57
[3, 4)	3,305556	0,308701	6	82	98,80
[4, 5)	4,266667	N/A	1	83	100,00
Total	1,122048	1,226420	83	83	100,00