What can the Taylor Rule say about Malaysia?

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DECLARATION

We hereby declare that:

(1) This undergraduate research project is the end result of our own work and that due acknowledgement has been given in the references to ALL sources of information be they printed, electronic, or personal.

(2) No portion of this research project has been submitted in support of any application for any other degree or qualification of this or any other university, or other institutes of learning.

(3) Equal contribution has been made by each group member in completing the research project.

(4) The word count of this research report is 18,331.

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ABSTRACT

This study empirically investigates the method to conduct monetary policy in Malaysia with respect to changes in price level and output gap. Secondly, this research intends to analyze the behavior of Bank Negara Malaysia based on Taylor rule's perspective including backward-looking, current, and forward-looking Taylor rule perspectives. More specifically, this paper examines the types of inflation rates that are significantly targeted by BNM when adjusting the monetary policy such as Consumer Price Index (CPI), Producer Price Index (PPI) and GDP deflator. The empirical results of this study show that backward-looking, current, and forward-looking Taylor rules are essential to monetary decision making of BNM. This indicated that BNM has taken past, current, and expected inflation and output gap into consideration. Lastly, we found that the BNM responded significantly to the past movement of inflation while adjusting its interest rate. Meanwhile, the responses of BNM become sensitive towards the current inflations and more aggressive to the expected inflations.

CHAPTER 1: INTRODUCTION

1.0 Introduction

This chapter mainly discusses about the background of the study, problem statements, research objectives and questions together with the significance of study.

1.1 Research Background

It is known that monetary policy will be imposed by central banks to overcome the economic problems such as unemployment, inflation, and so on. Majority of the policymakers conduct contractionary or expansionary monetary policy to solve the economic problems. There are two components in the monetary policy, which are the money supply and interest rate. In the early stage of development for monetary policy, monetary policy used to target on money supply to solve economic problems. However, the central of monetary policy has shifted to target interest rate in the latest development.

Interest rate is considered as an effective tool to overcome the economic problems instead of money supply. By using the interest rate as monetary policy tool, central bank able to promote economic growth, maintain price stability and overcome the economic problems. As time goes by, interest rate had become one of the popular monetary policy tool imposed by central bank thus this had raised the researchers' interest towards the research of monetary policy rule, which was also known as interest rate rules.

In the 1990s, a famous researcher, John B. Taylor has attracted public attention with the empirical results from his research. He discovered that central bank adjusted the interest rate based on the inflation rate and output gap. He computed a simple equation named Taylor rule to represent the behaviour of central bank. The estimated values generated from the equation fitted well with the actual interest rate.

Since then, many researchers started to examine the behaviours of central bank through the perspective of Taylor rule. Most of them discovered that central banks in different countries are setting the interest rate under the Taylor rule principle. Taylor rule is a principle which indicates that central banks set the interest rate by considering both important variables-inflation rate and output of the country. Taylor rule reduces the trade-off between inflation and output to achieve optimal solution for the country.

As Taylor rule had proven to be a optimal rule to economic development, so our main concern is ‘Does Malaysia follow the Taylor rule principle in setting interest rate?’. Let us review back to the historical development of the monetary policy framework in Malaysia. In the 1970s and 1980s, Bank Negara Malaysia (central bank of Malaysia) has used the monetary policy to target on money supply such as M1, M2 and M3. From the 1990s onwards, BNM started to shift the direction of the monetary policy and targeted on interest rate. At present, BNM is still emphasizing the monetary policy with the interest rate targeting. As BNM targets on interest rate, there might be a high possibility that BNM is following the Taylor rule principle to set the interest rate.

For Malaysia, economic downturn and high inflation will draw the attention of BNM to adjust the nominal interest rate in order to overcome those economic problems. Therefore, tracking the monetary policy behaviour of BNM towards the changes in price level, output gap and other economic conditions is essential for the researchers. This is because BNM may not impose the same adjustment of interest rate to deal with the same economic problems over the years, therefore it is important for researchers to formulate a suitable Taylor rule for Malaysia in order to describe the behaviour of BNM when adjusting the interest rate with respect to the changes in price level, output gap as well as the other macroeconomic variables.

1.1.1 The Adjustment of Monetary Policy during Crisis

According to fundamentalist view, Asian financial crisis that happened in 1997 was due to structural weaknesses widespread in the domestic financial institutions together with unsound macroeconomic policies and the issues of moral hazard. On the other hand, financial panic view suggested that the crisis was due to over-adjustment in both foreign and domestic investor expectations. Asian financial crisis was different with the other crisis because there are no conventional early warning indicators. However, there are some signs of vulnerability such as current account deficits, overvalued of exchange rate, and slowdown in export growth.

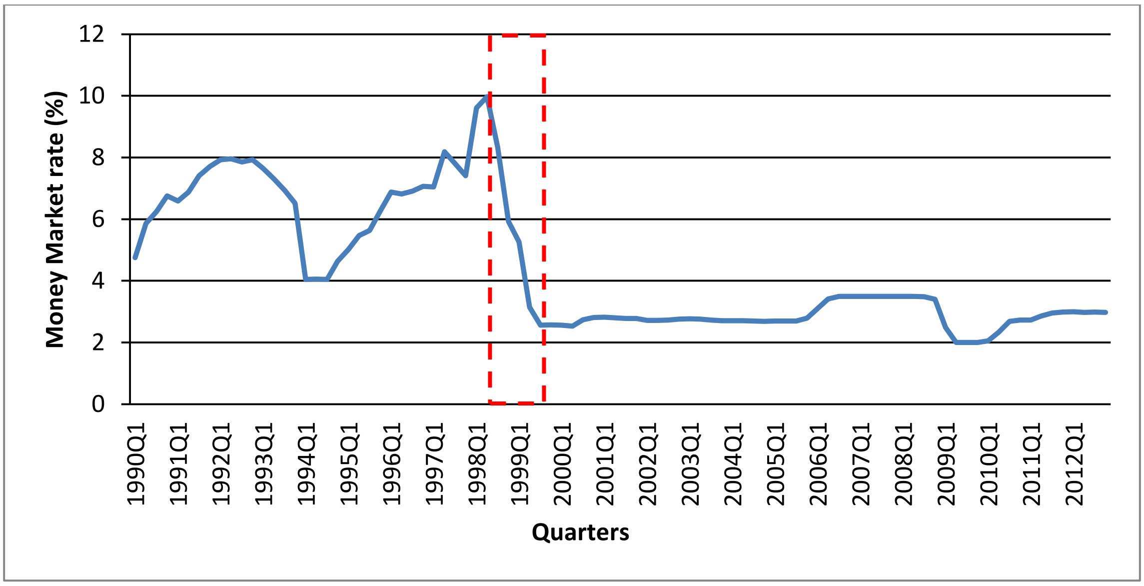
Malaysia was in recession by August 1998. The output declined by 6% and the unemployment rate increased by 1.3% in 1998. According to official BNM estimation, there was massive increase in non-performing loans by 10% in 1998 due to the combination effect of economic downturn and property market crash.

There were two alternatives for the Malaysia government to bring the economy back on the recovery track. The first option was to seek help from IMF and the second was to adopt capital controls to support reflationary monetary policies. The reason for Malaysia government to reject the help from IMF was due to IMF policy package imposed on government in the initial stage would end up facing even deeper recession. The policy package include fiscal tightening which cut government spending by 18% and monetary tightening by BNM which increase the inter-bank lending rate from 7.5% in 1997 to 11% in 1998. At the end, Malaysian economy faced the contraction approximately 7.4% in 1998.

In 1998, Malaysian government adopted capital and currency controls which Ringgit Malaysia was fixed at RM3.80 to the US Dollar. This is because government chose to disconnect the domestic capital market with the global economy in order to carry out its stimulatory policies, such as expansionary policies. When the economy was in deep recession, expansionary fiscal and monetary policy should be implemented rather than contractionary policy as recommended by IMF.

The expansionary macroeconomic policy intends to increase the spending by reducing interest rates. With lower interest rate, firms and consumers are encouraged to increase their consumption levels. Besides that, borrowers would not suffer from the higher cost of borrowings which can help to overcome their financial problems. Thus, this shows that expansionary monetary policy is normally used by policymakers during the crisis as reduction of interest rate can stimulate both the consumptions and investments in the economy.

Figure 1.1: Malaysia's Money Market Rate from 1980 First Quarter to 2011 Fourth Quarter.



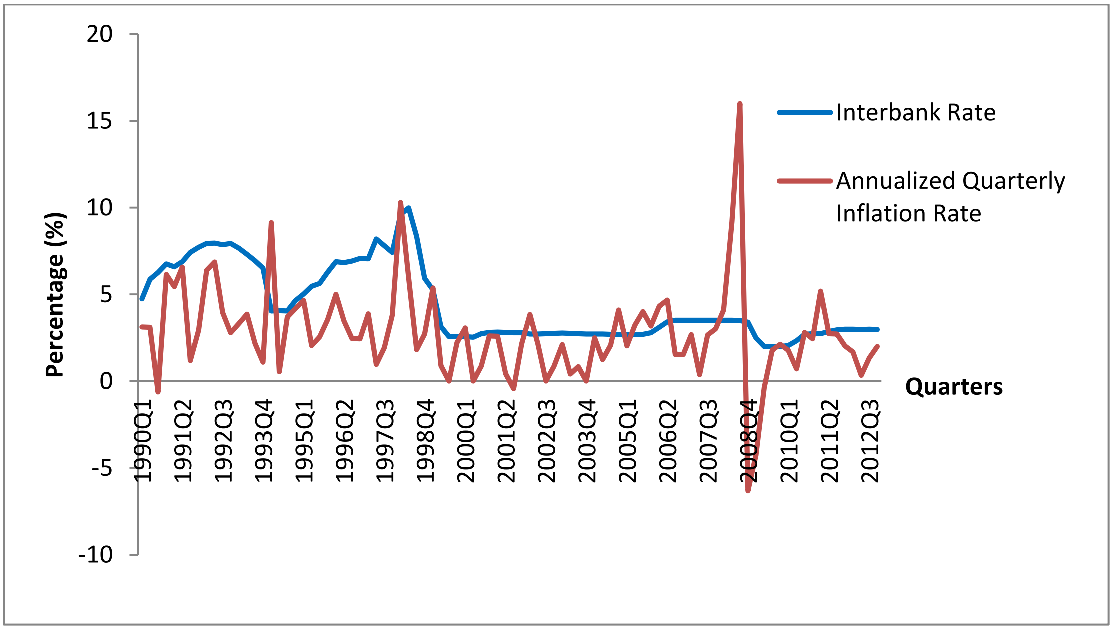
Based on the **Figure 1.1**, it shows that there was a huge decline in interest rate of Malaysia during 1998. This raises several questions which are (1) What happened in the economy that cause the interest rate to be reduced by such huge percentage? (2) What is the degree adjustment of interest rate by policymakers to overcome the economic problem?

1.1.2 The Adjustment of Monetary Policy under Inflation Movement

According to **Figure 1.2**, the monetary behaviour of BNM reacted differently between the period before and after 1999. The fluctuation of inflation rate before 1999 is more volatile compared to after 1999. Therefore, we can observe that interbank rate movements accommodated with the volatile movement of inflation rate before 1999. This indicates that BNM has placed more weight in setting interest rate to deal with inflation. As a result, interbank rate has the pattern which is comply with original Taylor Rule finding that central bank has set the interest rate regarding to the inflation.

However, we observed that there is strong evidence of interest smoothing behaviour discovered in Malaysia's interbank rate after 1999. The inflation rate fluctuation after 1999 is smaller compare to before 1999. Therefore, BNM has smaller degree of movement in adjusting the interest rate to deal with the inflation. The interbank rate after 1999 is smooth and stable for each quarter. It is coincidently matched with expansion of Taylor Rule research with interest rate smoothing behaviour proposed during 2000s.

Figure 1.2 Interbank rate and Annualized Quarterly Inflation Rate of Malaysia.



Based on **Figure 1.2**, this raises various questions which are (1) Does BNM follow Taylor Rule principle regarding to Malaysia's economic situations? (2) If BNM did follow the Taylor Rule principle, what is the degree of responsiveness of BNM towards the inflation rate and output gap? (3) If BNM has interest rate smoothing behaviour, what is the degree of interest rate smoothing?

Based on **Figure 1.1** and **Figure 1.2**, we observed that BNM may follow Taylor Rule principle in adjusting the interest rate. In order to have a better understanding about the monetary policy strategies imposed by BNM over the years, we would like to conduct the Taylor rule research to know how BNM would adjust the nominal interest rate with respect to the changes in price level, changes in output gap and interest rate smoothing behaviour.

1.1.3 The Story behind Taylor rule

Taylor rule is the basic monetary policy rule that describes how the central bank should adjust the interest rate in response to changes in inflation, output and other economic variables. The original Taylor rule was conducted by Stanford economist **John B. Taylor** in year 1993. The main aspect of this policy rule is to act as guidance for the central banks to manipulate the interest rate with respect to changes in price level or changes in real GDP so that it can maintain long-term economic growth. The Taylor rule draws an equation as below:

$$i_t = 2 + \pi_t + a(\pi_t - \pi^*) + b(y_t - y^*) \qquad (1.1)$$

Where a denotes the responsiveness to inflation deviation and b denotes the responsiveness to output gap fluctuation, it is the instrument rate in period t, i_t is the nominal interest rate, 2 represents the real interest rate which was assumed by John B. Taylor himself; $(\pi_t - \pi^*)$ is the deviation of the actual inflation rate π_t from its targeted inflation, π^*; $(y_t - y^*)$ is the deviation of the actual real output y_t from the potential output, y^*. The empirical results found that the US Federal Reserve Bank (Fed) would adjust the interest rate if the inflation rate deviates from 2% of its targeted or if the real gross domestic product (GDP) deviates from the potential GDP, which performed a monetary policy rule that was well fitted with the federal funds rate from 1987 to 1992.

Based on the results of **Taylor (1993)**, researchers were intrigued to investigate on monetary policy rules and central bank behaviour. Other researchers started to evaluate the monetary policy by using the original Taylor principal as foundation and reform the traditional Taylor rule by including additional economic variables.

In 2000, the forward-looking Taylor rule had been conducted in the study of **Clarida, Gali and Gertler (2000)** in order to investigate the monetary policy applications for US pre- and post-Paul Volker's tenure in 1979. Their results indicated that the interest rate policy react sensitively to the changes in expected inflation in the Volker-Greenspan term compared to pre-Volker period.

The backward-looking Taylor rule was first conducted by **Fair and Howney (1996)**. They found that backward-looking Taylor rule was fitted to explain central bank behaviour. However, the empirical results of **William (1999)** showed that the monetary policy applications of policymakers based on the backward-looking Taylor rule will cause significant poor performance.

Recently, some researchers have changed their focus towards Taylor rule specifications in order to find out the specifications of Taylor rule that better describe central bank behaviour. The study of **Qin and Enders (2008)** used the real-time US data to indicate the in-sample and out-of-sample properties of linear and non-linear Taylor rules in terms of five Taylor rule variants and two federal fund rates univariate models. They found that there are differences in the form of Taylor rule between the pre- and post-Greenspan sample periods.

The research done by **Cukierman and Muscatelli (2008)** mainly focused on the nonlinearities of Taylor rule due to the asymmetrical preferences of central bank. They used the new Keynesian framework to examine the relationships between the form of nonlinearities in Taylor rules and asymmetry of monetary policy objectives in both United Kingdom (UK) and United States (US). The empirical results showed that the Fed was more aggressive towards positive than negative inflation gaps during William Martin's chairmanship and more aggressive towards negative than positive output gaps under Greenspan's period.

Therefore, the classical Taylor rule has then been evolved into many different versions such as forward-looking rules, backward-looking rules, modified Taylor rule with other macroeconomic variables and Taylor rule model with asymmetrical preferences concerning on inflation and output gap.

1.2 Problem Statement

It is important for researchers to consider the types of inflation rate targeted by policymakers and how it may change as the time goes by. This is because analyzing policymakers' decisions from this perspective will be useful when conducting the specific monetary policy rule for a particular country. However, it is difficult to measure or evaluate the different types of inflation which include Consumer Price Index (CPI), Producer Price Index (PPI), and GDP deflator in practice. Thus, this becomes one of the issues for the research.

Besides that, the previous researchers found that the backward-looking Taylor rule is not essential for Malaysia which means that the monetary behaviour of BNM is not based on the past information of price level and output gap. However, most policymakers will make their monetary policy strategies by depending on the previous movements of inflation rates and output gap, but the results found by previous researchers are contradict to this concept.

Last but not least, the previous researchers had further raised the issues when estimating the Taylor rule. They suggested that the researchers should consider the use of backward-looking, contemporaneous and forward-looking Taylor rules in order to identify which of these would be able to capture the movements of the nominal interest rate more precisely and provide a better understanding of historical monetary policy in Malaysia.

1.3 Research Objectives

The purpose of this paper is to investigate the method to conduct monetary policy in Malaysia with respect to the changes in price level and output gap.

1.3.1 General Objective

Our aim is to analyze the behaviour of central bank in Malaysia based on the Taylor rule's perspective. Previous researchers had expanded their research to many countries and their results indicated that most of the central bank behaviours are comply with Taylor rule principle. Therefore, our general objective is to identify whether the simple Taylor rule can be applied for Malaysia.

In this study, we will examine through different types of Taylor rules such as contemporaneous Taylor rule, backward-looking Taylor rule, and forward-looking Taylor rule. Our main objective is to examine the behaviour of BNM from all the three types of Taylor rule perspectives.

In addition, inflation can be represented by Consumer Price Index (CPI), Producer Price Index (PPI), and GDP deflator. The monetary policy behaviour of BNM would change when dealing with different inflations. Therefore, this had become our second main objective which is to identify the types of inflation rates that has targeted by BNM.

1.3.2 Specific Objective

The specific objectives are clarified from the general objectives above. There are several specific objectives as shown below:

(i) To examine the relationship between inflation rate and nominal interest rate imposed by policymakers in Malaysia.

(ii) To examine the relationship between output gap and nominal interest rate imposed by policymakers in Malaysia.

1.4 Research Questions

The research questions formulated in this research are shown as below:

(i) What can the Taylor rule say about Malaysia?

(ii) How monetary policy be conducted in Malaysia?

(iii) What is the degree of adjustment by BNM in response to the changes in price level?

(iv) What is the degree of adjustment by BNM in respond to the changes in output gap?

1.5 Significant of Study

This undergraduate project is to investigate an appropriate interest rate rule for Malaysia in order to contribute to the literature by examining the relationship between nominal interest rate, price level, and output gap.

The findings of our research project are able to contribute new findings related to this particular topic of study. Previous researcher, **Mohamad Hasni Shaari (2008)** found that backward-looking Taylor rule is not essential to BNM in Malaysia. However, our findings show that backward-looking Taylor rule is relevant to central bank in Malaysia. Our empirical results provide evidence that BNM respond to previous movements of inflation rate when making monetary decision which can be used as contribution to literature.

In addition, our findings intend to figure out the types of inflation rates that are targeted by BNM such as Consumer Price Index (CPI), Producer Price Index (PPI) and GDP deflator. Our empirical results show that BNM respond to CPI based inflation when conducting the monetary policy in Malaysia. This means that CPI based inflation is the most relevant type of inflations in determining the nominal interest rates adjustment which can be used as one of the contribution to literature.

The contemporaneous Taylor rule, backward-looking Taylor rule and forward-looking Taylor rule was conducted in this study. The empirical results of these Taylor rules will be compared and the significant types of Taylor rule will be recorded at the end of this study. The contribution to literature of this study is mainly about BNM has taken past, current and expected inflation and output gap into their consideration.

The findings also show that BNM respond significantly to the past movement of inflation while adjusting its interest rate. Meanwhile, the responses of BNM become sensitive towards the current inflations and more aggressive to the expected inflations. This shows that the previous inflation, current inflation and expected inflation are essential to the monetary decision making of BNM.

1.6 Chapter Layout

In the next section, literature review will be provided in Chapter 2 about the existing relevant studies on Taylor rules. In Chapter 3, it will present the data collections, econometric methodologies, theoretical framework, analysis of models and several econometric tests. The findings and empirical results of this study will be provided in Chapter 4 as well as the interpretation of results. In Chapter 5, it is part of concluding remarks of this study which including the summarization of results and policy implication of the findings.

1.7 Conclusion

Background of the study, problem statements, research objectives, research questions and significant of study was provided in this chapter. The next Chapter is about the relevant literature review of this study.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

After briefly discussed the background of study, problem statement, research questions, research objectives and significant of study in Chapter 1, we proceed to Chapter 2 to provide the relevant literature review including theoretical framework and relevant theoretical models.

2.1 Review of Relevant Theoretical Models

2.1.1 The Origin of Taylor rule

Economists often wonder about how much the central bank should change the nominal interest rate in response to changes in economic variables such as gross domestic product (GDP), inflation, output and other economic variable. One of the big name in the economic field, **John B Taylor**, in his journal "Discretion versus policy rules in practice" he found that his own forecasted policy rule fitted very well with the federal funds rate from 1984 first quarter to 1992 third quarter. In another words, this rule can actually predict how much the central bank should change the nominal interest rate in respond to changes in economic variables. This rule is also known as Taylor rule.

$$i_t = 2 + \pi_t + a(\pi_t - \pi^*) + b(y_t - y^*) \tag{2.1}$$

The equation above was the original Taylor rule equation proposed by John B Taylor, where $\mathrm{i_t}$ represents the short-term nominal interest, $\mathrm{\pi_t}$ represents the rate of inflation, π^* represents the inflation targeting rate, $\mathrm{y_t}$ represents the real gross domestic product and y^* represents the potential output. Taylor assumed that the inflation targeting, π^* is equal to 2%. His Taylor rule model indicated that when the inflation rate increases by one percentage point from targeting rate, the interest rate should increase more than one percentage point. This equation had become one of the major discoveries in the economic history.

In the recent years, the Taylor rule equation had been evolved into many different versions such as contemporaneous Taylor rule, forward-looking Taylor rule and backward-looking Taylor rule. The different between the contemporaneous Taylor rule and backward-looking Taylor rule is that backward-looking Taylor rule includes lag in their model to assume central bank is using past information to construct interest rate policy. As for forward-looking Taylor rule, it includes the expectation elements in the model to assume that central bank accommodate public expectation in setting the interest rate. In addition, contemporaneous Taylor rule assumes central bank uses the current information to set interest rate.

2.2 Review of the Literature

2.2.1 Choices of Variables

There are different types of inflation measurement that can be used in estimating Taylor rule equation such as consumer price index (CPI), producer price index (PPI), GDP deflator and so on. According to **Taylor (1993)**, inflation measurement can be defined as CPI, PPI and employment cost index. **Seyfried and Bremmer (2001)** also included different inflation measurements which are CPI, personal consumption deflator and GDP deflator. Besides that, two expected inflations source from University of Michigan survey of consumers and Philadelphia survey of professional economists also have been used as inflation measurement.

Similar as inflation rate, output gap also has different types of measurement. According to **Taylor (1993)**, potential output can be represented by productivity, labor-force participation and changes in the natural rate of unemployment. To obtain the output gap is by computing the different between real GDP and potential output.

2.2.2 The Importance of Output Gap, Inflation Rate and Other Variables

According to **Clarida, Gali and Gertler (1998),** central bank will adjust the interest rate based on their expectation towards the inflation. If the central bank expects that inflation rate is above the targeted, they will increase their nominal interest rate in order to reduce the inflation rate. In another words, there is a positive relationship between the expected inflation rate and the nominal interest rate.

Smets (2002) highlighted the importance of output gap as it is one of the crucial determinants in monetary policy strategy because error of output gaps measurement may affect the estimation results of Taylor rule. Besides that, the efficiency of Taylor rule parameter may be reduced as the measurement error of output gaps become bigger. The empirical results found that there is a positive relationship between the interest rate and output gap. **Bunzel and Enders (2010)** also indicated that when output is positive, central bank will increase the interest rate.

In addition, the research of **Moura and Carvalho (2010)** showed that output gap plays an important role in monetary policy for several emerging countries, such as Chile, Colombia and Venezuela. **Smets and Gerlach (1999)** found that European Central Bank (ECB) responds to output gaps while making monetary policy strategy in Economic and Monetary Union (EMU) area.

On the other hand, some other researchers also considered other variables which they believe will affect the monetary policy behaviour of central bank. The empirical results of **Moura and Carvalho (2010)** and **Lubik and Schorfheide (2007)** showed that exchange rate was one of the relevant variables in Mexico, Canada and England because the central banks of those countries will change the interest rate in response to exchange rate movements.

According to **Frommel, Garabedian and Schobert (2011)** and **Aizenman, Hutchison and Noy (2011)**, their findings showed that real exchange rate is one of the important determinants of monetary policy for those emerging market economies even though their main target is not based on the exchange rate.

They also found that policymakers respond more sensitively to real exchange rate movements in those countries which are following inflation targeting policies.

Besides that, the research of **Cermeño, Villagómez and Polo (2012)** showed that central bank considers the movement of the real exchange rate in its monetary policy. In the small open economy, the exchange rate significantly responses to the changes in monetary policy.

In addition, **Leitemo and Soderstrom (2005)** indicated that adding exchange rate into the estimation of Taylor rule is able to improve the empirical results in term of economic stability. **Galimberti and Moura (2013)** found that there was a significant evidence of exchange rate predictability under forward-looking Taylor rule based on their out-of-sample performances.

Another variable that researcher also included in Taylor rule equation is the stock price. According to **Castro (2011)**, European Central Bank (ECB) also sets their monetary policy towards financial conditions. The empirical finding also showed that an increase in the interest rate able to stabilize the financial condition in the Euro area.

2.2.3 What are the ways to estimate the Taylor rule?

Ordinal Least Square (OLS) is one of the popular estimation method used by researchers in estimating their Taylor rule model. The reason is because the original equation created by **Taylor (1993)** is in the form of simple linear equation. **Judd and Rudebusch (1998)** used OLS to explain how the Federal Reserve reaction function changes for each time period. However, researchers often encountered problems when estimating Taylor rule using OLS.

For instance, the estimation model must be in stationary form. Otherwise, we can no longer proceed with the method of OLS. **Sulaiman D Muhammad, Adnan Hussain, Muhammad Ahsanuddn, Shazia Kazmi and Irlan Lal (2012)** indicated that their variables are non stationary variables and thus unable to continue their research by using OLS method. Furthermore, researchers also faced autocorrelation problems because the inflation rate and output gap tend to be correlated. According to **Michaelides and Milios (2009)**, there is a strong relationship between inflation and output gap. However, the autocorrelation problem can be solved by using Newey-West variance matrix based on the research done by **Hutchison, Sengupta, and Singh (2013)**. The most problematic issue faced by researchers in estimating Taylor rule with OLS method is the endogeneity problem. Endogeneity problem occurred when the residuals and the exogenous variables are correlated. According to **Khan (2011)**, estimating Taylor rule by using OLS would often lead to endogeneity problem.

Due to this limitation, researchers tend to shift from using OLS method to generalized method of moments (GMM). Researchers who conducted their research using forward-looking Taylor rule often apply GMM. According to **Newey and West (1987)**, GMM is used specifically to deal with expectation. This statement proven that GMM is applicable for forward-looking Taylor rule since forward-looking Taylor rule are based on inflation expectation and output gap expectation. Researchers need to obtain the correct form of instrument variables when using GMM. The reason is because according to **Yau (2011)** the parameters of the expectation terms can be estimated only by using a correct form of instrument variables. **Bueno (2008)** stated that estimating a forward-looking Taylor rule using GMM able to explain the monetary policy in Brazil. **Umezaki (2007)** also used GMM since his Taylor rule equation was found to be nonlinear in Malaysia.

We are going to run all different types of Taylor rule models by using OLS estimation to see whether our result can match with the actual policy performances as well as indentifying the best fitting Taylor rule for Malaysia case.

2.3 Proposed Theoretical/ Conceptual Framework

2.3.1 Contemporaneous Taylor rule

Since the discovery of Taylor rule, contemporaneous Taylor rule is widely used by macroeconomists to forecast the behaviour of central bank. Contemporaneous Taylor rule is estimated by using current inflation and current output gap. There are few researchers who found significant results when studying the contemporaneous Taylor rule. According to **Moons and Van Poeck (2008)**, contemporaneous Taylor rule is capable to forecast the monetary behaviour of European Central Bank. **Osterholm (2005)** also found similar result where monetary behaviour of Federal Reserve can be explained by contemporaneous Taylor rule.

Furthermore, **Bhattarai (2008)** concluded that contemporaneous Taylor rule is significant for Germany, France, Japan United Kingdom and United State. **Judd and Rudebush (1998)** found that contemporaneous Taylor rule forecast performs the best in the Greenspan period compared to Volcker and Burn's period. However, in some cases, contemporaneous Taylor rule is unable to describe the monetary policy behaviour of central bank. According to **Sulaiman D Muhammad, Adnan Hussain, Muhammad Ahsanuddn, Shazia Kazmi and Irlan Lal (2012)**, contemporaneous Taylor rule is unable to predict the behaviour of State Bank of Pakistan.

Contemporaneous Taylor rule will be included in our equation for estimating the monetary policy of Central bank in Malaysia. We want to see whether contemporaneous Taylor rule is able to explain the behaviour of central bank in Malaysia.

2.3.2 Backward-looking Taylor rule

Backward-looking Taylor rule is a principle where central bank set the nominal interest rate according to past inflation and past output gap. According to **Taylor (1999),** historical information taught Fed how to improve their monetary policy.

The backward-looking Taylor rule was first developed by **Fair and Howrey (1996)** and their empirical results indicated that backward-looking Taylor rule was fitted well with Fed rate. However, most researchers found insignificant results for backward-looking Taylor rule. This is because central bank no longer set the nominal interest rate based on the past movements of inflation and output gap. According to **Bullard and Mitra (2002),** they argued that estimating the monetary policy based on lagged inflation might not be able to capture the monetary behaviour of central bank. In addition, **William (1999)** also indicated that backward-looking Taylor rule might perform poorly when monetary behaviour of central bank is based on expectation.

There are many criticisms about backward-looking Taylor rule but we managed to study Malaysia case from its perspective. There might be a possibility that backward-looking Taylor rule is suitable for Malaysia case and able to capture the monetary behaviour of BNM in Malaysia. Therefore, backward-looking Taylor rule will be included in our study.

2.3.3 Forward-looking Taylor rule

Macroeconomists started to have doubt about the central bank behaviour towards rational expectation proposed by **Taylor (1993)**. As a result, they raised an issue to indicate that future expectation is more accurate than rational expectation to explain central bank behaviour. According to **Yau (2010)**, macroeconomists had raised econometric issues related to the estimation of Taylor rule models should include future expectation. Due to these issues, forward-looking variables have used to estimate the Taylor rule. This is known as forward-looking Taylor rule by macroeconomists today.

Forward-looking Taylor rule is a rule that central bank make adjustment for the interest rate according to the expected inflation from targeting rate and expected output gap. Forward-looking Taylor rule seem to generate better result compared to contemporaneous Taylor rule and backward-looking Taylor rule. **Clarida, Gali and Gertler (2000)** argued that forward-looking Taylor rule is more suitable to explain the objective of central banks. They indicated that Fed adjusts the interest rate based on the expectation towards inflation instead of past inflation. When the inflation rate is above the targeting level, Fed will adjust the nominal interest rate to control the inflation level. If a country adopted inflation targeting as its policy instrument, inflation forecast is essential for good policy rules (**Rudebusch and Svensson, 1999)**.

The study of **Batini, Harrison and Millard (2003)** showed that inflation forecast based (IFB) rule is the best rule among all the other rules because inflation forecast based (IFB) rule is quite robust when react to different shocks. This proved that forward-looking Taylor rule outstand other rules in the study of central bank behaviour.

Furthermore, macroeconomists found significant results when using forward-looking Taylor rule. Empirical results also showed strong evidence that financial market participants have applied forward-looking Taylor rule in the forecasts of short term interest rates (**Fendel, Frenkel and Rulke, 2011a)**. This proved that forward-looking Taylor rule is applicable in predicting the behaviour of the central bank.

In addition, according to **Mehra and Minton (2007)**, forward-looking Taylor rule best explain the monetary policy implemented by Greenspan Fed during Greenspan Era. The reason is because Greenspan Fed concentrated on expected inflation and interest rate smoothing. Furthermore, **Martins, Machado and Esteves (2003)** found that forward-looking Taylor rule can forecast the better results compared to other Taylor rule. Besides that, **Qin and Enders (2008)** found similar result that forward-looking Taylor rule forecasts with better results compared to other models. In addition, **Mehra and Mintion (2007)** also proved that forward-looking inertial Taylor rule with core CPI forecasts and congressional budget estimates of the output gap performs the best forecast with the lowest RMSE. As a result, forward-looking Taylor rule will be more preferable compared to contemporaneous and backward-looking Taylor rule.

2.3.4 Nonlinear Reaction of Central Bank – Nonlinear Taylor rule

Simple Taylor rule is able to explain the central bank behaviour in setting the interest rate assumed that central bank follows the principle of Taylor rule to set interest rate for the following period. However, simple Taylor rule might not be efficient to explain the monetary policy process when central bank has asymmetric behaviour. The asymmetric behaviour happened when central bank reacts differently to different situations. For example, central bank might react aggressively to push down the inflation rate when inflation rate is above targeting rate. However, central bank might not react so much or even chose not to react when the inflation rate is below the targeting level. The same goes to output gaps where central bank tends to react more towards negative output gap compared to positive output gap. The researches done by **Bunzel and Enders (2010); Cukierman and Muscatelli (2008); Surico (2004)** indicated that central bank responds more to output contractions than output expansions and more sensitive to positive than negative inflation gaps (inflation gap is the deviation of inflation rate from its targeting rate). Therefore, asymmetric preference of central bank will form non-linear reaction behaviour.

In previous studies, Taylor rule is considered as a linear rule because the quadratic loss function is minimized by central bank (**Khan 2011)**. However, central bank might not do so due to the asymmetric preference exists in central bank behaviour. **Moura and Carvalho (2010)** studied asymmetric behaviour of central banks from Latin America. The empirical results showed that the nominal interest rate react sensitively with response to inflation fluctuation in Mexico and Brazil which also known as ‘tough’ monetary policy. For Chile and Peru, they adopt ‘mild’ monetary policy against inflation whereas Argentina, Colombia and Venezuela impose ‘lax’ monetary policy to deal with inflation fluctuations. In addition, **Castelnuovo (2003)** also found significant results that asymmetric preference exists in Federal Reserve behaviour when setting the monetary policy in United State.

As a result, central bank might follow a nonlinear Taylor rule. **Castro (2011)** indicated that Bank of England and Europe Central Bank monetary behaviour fit well by a nonlinear Taylor rule. **Umezaki (2007)** also found similar results which indicated that Malaysia’s central bank follows a nonlinear Taylor rule.

2.3.5 Criticism on Taylor rule

Taylor rule is really useful to study central bank behaviour in the sense that many researchers discovered significant result based on the Taylor rule principle.

However, Taylor rule principle may not applicable in some situations as well. **Kazanas, Philippopoulos and Tzavalis (2011)** research showed that central bank refuses to use Taylor rule principle and imposed a no-state contingent policy which focused on smoothing interest rate during economic downturn.

Osterholm (2005) also criticized on the Taylor rule result. He indicated that Taylor rule estimation requires long time period. Besides that, his other findings showed that the Taylor rule was not the best measurement for the behaviour of the central bank due to the rule was misspecified no matter which data was used. In addition, **Fendel, Frenkel and Rulke (2011b)** results indicated that Taylor rule hold in countries that aimed for inflation targeting. They found that those countries that do not set targeting inflation rate are not follow Taylor principle.

2.3.6 Monetary Policy Reaction Function in Malaysia

Above we mentioned a brief review of Taylor rule that being conducted by previous researchers. To the best of our knowledge, there are three researchers, who had investigated the Bank Negara Malaysia (BNM) behaviour under Taylor rule principle. The first Malaysia case was conducted by **Umezaki (2007)**. He used monthly data from January 1988 to August 1998 to investigate the reaction function of BNM. He found that forward-looking Taylor rule is fit to explain the behaviour of BNM.

The second and third Malaysia researches were conducted by **Ramayandi (2008)** and **Mohamad Hasni Shaari (2008)**. According to **Ramayandi (2009)**, he found that contemporaneous Taylor rule is unable to explain the monetary behaviour of central bank in Malaysia. In addition, **Mohamad Hasni Shaari (2008)** had conducted contemporaneous, backward-looking and forward-looking Taylor rule for Malaysia case. His empirical result found that BNM did not comply with backward-looking behaviour. Instead, he found that contemporaneous and forward-looking Taylor rule are capable to explain BNM behaviour. His finding contradicted with **Ramayandi (2009)** results as

Ramayandi (2009) found that contemporaneous Taylor rule does not explain BNM behaviour.

By discovering the conflicts and different findings from those researchers, we would prefer to re-examine BNM behaviour from three types of Taylor rule from 1990 Q1 to 2012Q4. The reason we chose to start our research from 1990 is because Malaysia started interest rate targeting from 1990s. We are also interested on one question: Which types of inflation targeted by BNM? This is the topic has not cover by previous researchers. All three researchers had only covered CPI-based inflation for Malaysia **(Umezaki, 2007; Mohamad Hasni Shaari, 2008; Ramanyandi, 2009)**. In our research, we will cover CPI based inflation, GDP deflator based inflation and PPI based inflation to identify which types of inflation targeted by BNM.

2.4 Conclusion

In this chapter we review the past studies of Taylor rule. We found that there are three different types of Taylor rule being studied by previous researchers. From the past studies, we will be able to develop our research model. We will further our discussion on our research methodology in chapter 3.

CHAPTER 3: METHODOLOGY

3.0 Introduction

In chapter 3, we will discuss about the methodology of our research. This chapter will cover the data description, theoretical framework for Taylor rule model, stationary test, ordinary least square (OLS) estimation, diagnostic checking for ordinary least square (OLS), estimation method for two-stage least square (TSLS) and diagnostic checking for two-stage least square (TSLS) estimation includes Hausman test (Endogeneity test), weak instrument test and instrument validity test (Sargan Test).

3.1 Data

All of our data were obtained from the DataStream. According to the information from DataStream, the historical data of interbank rate, Consumer Price Index (CPI), Producer Price Index (PPI), GDP deflator and nominal Gross Domestic Product (GDP) are sourced from International Monetary Fund (IMF). Historical data CPI, PPI, and GDP deflators are price index based on 2005 as their base year. Nominal GDP is based on Ringgit Malaysia.

The forecast CPI, forecast GDP Deflator, forecast PPI, forecast RGDP (Real Gross Domestic Product) are sourced from Oxford Economics. Forecast CPI is price index based on 2010 as base year. We converted forecast CPI to base year with 2005 by applying the formula (all index numbers divide by the index number of 2005 quarter 4 and times 100). The reason that we converted forecast CPI to base year 2005 is to standardize our data. On other sides, forecast GDP deflator is obtained with price index based on 2005 as base year. Forecast RGDP is inflation adjustment based on 2005 as base year. Forecast RGDP is measured based on Ringgit Malaysia.

We use the quarterly data in our research. Historical data- nominal GDP and GDP deflator are started from the first quarter of 1991 to the fourth quarter of 2012, whereas other data are started from the first quarter of year 1990 to the fourth quarter of 2012.

In overview, we used the historical data to compute inflation rate, past inflation rate, output gap and past output gap to study contemporaneous and backward-looking Taylor rule model. On the other hand, we used the forecast data as the proxy to compute expected inflation and expected output gap to study forward-looking Taylor rule model. Interbank rate used as proxy for interest rate to study all types of Taylor rule model.

3.2 Processing of Data

In order to estimate Taylor rule, we have processed the raw data of CPI, PPI, and GDP deflator into inflation rate. Firstly, we log the variables and then we computed the inflation rate by using the log (CPI, PPI, GDP deflator) minus the lag one value and times with 100 and 4 to get annualized quarterly inflation rate.

- The annualized quarterly inflation rate computation as shown:

$$[\log(CPI, PPI, GDP\ deflator)_{\mathrm{t}} - \log(CPI, PPI, GDP\ deflator)_{t-1}] \times 100 \times 4$$

- The equation we compute RGDP:

$$(\ nominal\ GDP\ \div gdp\ deflator\ )\ \times 100$$

- There are several steps taken to transform RGDP to output gap. First step is we log the RGDP. Second step is we applied a method called Hodrick-Prescott (HP) Filter on log RGDP. Previous researchers who studied Taylor rule have applied HP Filter to compute output gap. We applied cyclical component with smoothing parameter = 1600. HP Filter detects the trend of the log RGDP and calculates deviation from the trend. The last step is we times 100 on the data computed by HP Filter. Then we will get the percentage deviation from the long run trend of RGDP, which is the output gap. Figure 3.1 and figure 3.2 in next page are the output gap data we obtained from HP filter.

Figure 3.1: Output gap from 1991Q1 to 2012Q4:

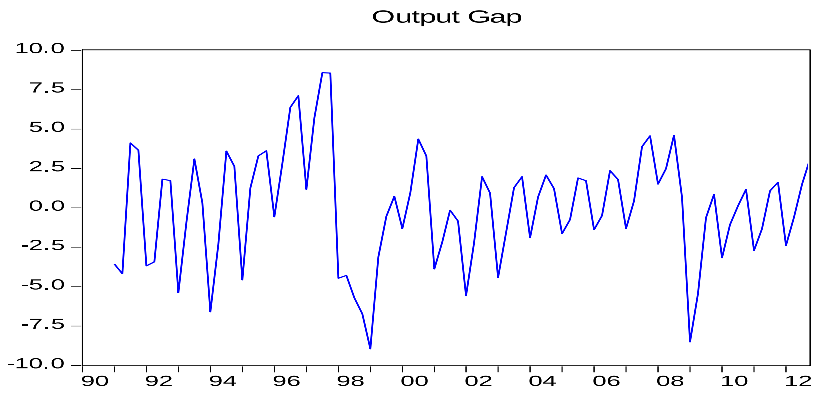
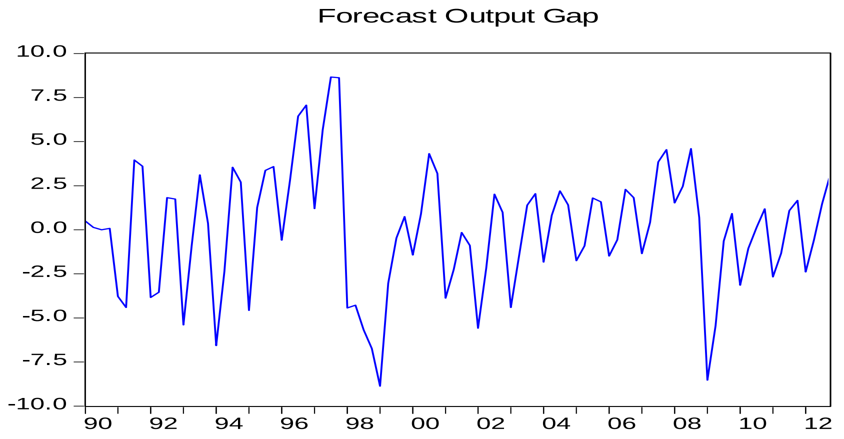


Figure 3.2 Forecast output gap from 1990Q1 to 2012Q4:



3.3 Theoretical Framework and Taylor rule Model

The original Taylor rule proposed by Taylor (1993) is shown as below:

$$i_t = r + \pi_t + a(\pi_t - \pi^*) + by_t^* \quad (3.1)$$

Where r represents real interest rate; π_t represents inflation rate; π^* represents inflation target rate and y_t^* represents the percentage deviation of the output from its trend (output gap). **Taylor (1993)** assumed that Federal Reserve set the Federal Fund rate according to the deviation of inflation rate from the inflation target $(\pi_t - \pi^*)$ and output gap.

In the further studies of Taylor rule, researchers have realised the interest rate smoothing behaviour of central bank. Researchers discovered that central bank intend to smoothen the interest rate movement in the long run. Original Taylor equation assumes that central bank place all the weight to inflation and output gap. Original Taylor rule does not assume central bank has taken past interest rate into consideration to form the current interest rate. To capture interest rate smoothing behaviour of central bank, researchers modified the original Taylor rule. We adopted the Taylor rule model from **Mehran & Minton (2007)** as our Taylor rule model. The equations are shown below:

$$i_t = \rho i_{t-1} + (1-\rho)[\beta_a + \beta_\pi \pi_t + \beta_\gamma y_t^*] \quad (3.2)$$

$$i_t = \rho i_{t-1} + (1-\rho)[\beta_a + \beta_\pi \pi_{t-1} + \beta_\gamma y_{t-1}^*] \quad (3.3)$$

$$i_t = \rho i_{t-1} + (1-\rho)[\beta_a + \beta_\pi \pi_{t+1} + \beta_\gamma y_{t+1}^*] \quad (3.4)$$

For all the above three equations, we do not add in targeted inflation rate because BNM does not have the official long run targeting inflation rate.

Equation 3.2 is the contemporaneous Taylor rule model. The lag one of interest rate (i_{t-1}) has been added into the equation to justify the interest rate smoothing behaviour. Interest rate smoothing behaviour occurred when BNM review back to past inflation rate in setting interest rate. Coefficient ρ is the weight we assume BNM place for the interest rate smoothing in the long run. The coefficient $(1-\rho)$ allocated for $[\beta_a + \beta_\pi \pi_t + \beta_\gamma y_t^*]$ is to indicate the weight BNM places to other macroeconomic variables such as inflation rate and output gap. β_a is the constant terms. β_π is the coefficient for current inflation rate (π_t) . β_γ is the coefficient for the current output gap (y_t^*).

Equation 3.3 is the backward-looking Taylor rule model. Except from interest rate smoothing behaviour specification, we assume that BNM responds to the previous inflation rate (π_{t-1}) and previous output gap (y_{t-1}^*) when they set the current interest rate. **Equation 3.4** is forward-looking Taylor rule model. Except from interest rate smoothing behaviour specification, we assume that BNM responds to the expected inflation rate (π_{t+1}) and expected output gap (y_{t+1}^*) when they set the current interest rate.

According to Taylor rule principle, the expected sign for inflation rate is positive and the coefficient for inflation rate should be more than one. The rationale is central bank should adjust the interest rate more than one percentage point for each percentage point increase of inflation rate in order to lower down the inflation rate. If central bank adjusts less than one percentage point for each percentage point increase of inflation rate, this will not lower down the inflation rate and even end up with higher inflation rate. This is because if central bank adjusts less than one for each percentage point increase of inflation rate, it will lower down the real interest rate which will encourage consumer to spend more and thus to end up with higher inflation rate. Therefore, the coefficient of inflation rate should be more than one.

The expected sign for output gap should be positive. According to Taylor rule principle, central bank should adjust higher the interest rate when there is positive output gap and lower down interest rate when there is negative output gap (recession). As conclusion, the expected sign for inflation rate and output gap should be positive and coefficient of inflation rate should be more than one if Taylor rule principle holds.

3.4 Stationary Test

Data stationary is very important for economic data estimation. Before we start our estimation, we must ensure that the stationary status has been achieved. This is because non-stationary data will cause a common econometric problem to happen: spurious regression result. This happens when we regress a set of non-stationary data on another set of stationary or non-stationary data. Unless the sets of non-stationary data are cointegrated on the same integration or else this would cause the spurious regression problem. Spurious regression symptoms include high R-Square and high F-statistic as well as low Durbin-Watson value. The serious problem for spurious regression is it will mislead us to believe that there are highly significant relationships between the independent and dependant variables (high R-Square) when there is none.

To prevent spurious regression problem, it is necessary to conduct diagnostic check on stationary and integration of the data we used. In our research, we applied both ADF test and KPSS to complement each other. The reason that we chose KPSS to compliment ADF test is to cover the weakness of ADF test. ADF test has the weakness of low power of test. ADF's power of test will be affected when there is a small sample size and inclusive of intercept or trend. Below are the hypothesis testing of ADF and KPSS.

ADF		KPSS	
$H_0 : Y_t$ I(1)	(Non-Stationary)	$H_0 : Y_t$ I(0)	(Stationary)
$H_1 : Y_t$ I(0)	(Stationary)	$H_1 : Y_t$ I(1)	(Non-Stationary)

For ADF test, rejection of the null hypothesis means the data set is stationary. For KPSS, rejection of the null hypothesis mean the data set is non-stationary. If the test result is non-stationary for the set of data, then we need to proceed the testing for first difference, second difference and so on in order to identify that at which integration the set of data is stationary. As conclusion, we must ensure that our data is cointegrated on the same level either stationary or non-stationary for all independent and dependent variables in order to prevent spurious regression problem.

3.5 OLS Estimation

We are using OLS as our preliminary estimation method for Taylor rule. OLS is widely and commonly used by previous researchers. This is because Taylor rule assumes central bank will adjust the interest rate with constant changes regarding to the deviation of inflation rate from targeting rate and output gap. Therefore, OLS is suitable to be used to estimate the Taylor rule.

When using the OLS estimation, researcher will apply the Newey-West HAC procedure to adjust the standard error. This is because Taylor rule estimation potentially consists of heteroscedascity problem. Heteroscedascity problem will lead the standard error to be biased and T-statistic become unreliable. Therefore, application of Newey-West HAC procedure is necessary in order to converge the biased standard error close to its true value and make the hypothesis testing become valid.

3.6 Diagnostic Checking for OLS

To ensure validity of our estimation result, we run several diagnostic checking to examine three major problems that may occur in OLS estimation. They are normality, autocorrelation and heteroscedasticity problems.

Non-normality distribution will cause the OLS estimation not able to fulfil the CLRM assumptions. As rule of thumb, we must ensure that the error terms in our estimation are normally distributed. Subsequently, autocorrelation problem happened when error terms are correlated with each other. Autocorrelation problem will cause the estimator to be unbiased and consistent if OLS estimation fulfils the normality assumption. However, the standard error is no longer to be efficient because it does not achieve minimum variance under autocorrelation problem. We need to apply Newey-West HAC procedure to converge the standard error to its true value.

Heteroscedasticity problem is one of the common problems that occurred in the OLS estimation. Heteroscedasticity problem happened when the variance of the error terms are not consistent over time. Variance of error terms may become larger or smaller when time goes by. Heteroscedasticity will cause the hypothesis testing becomes invalid. Therefore, we need to apply Newey-West HAC procedure to converge the biased standard error to its true value so that hypothesis testing is valid.

For the diagnostic checking, we applied Jarque-Bera test to test for the normality of the error terms with null hypothesis: There is normality distribution of the errors terms. Besides that, we introduced Breush-Godfrey Serial Correlation Lagrange Multiplier (LM) test to detect the autocorrelation problem with null hypothesis: There is no autocorrelation problem. Lastly, we applied Autoregressive Conditional Heteroscedascity (ARCH) test to detect the heteroscedascity problem with null hypothesis: There is no heteroscedascity problem. We robust the results of LM test and ARCH test through different lags to ensure the consistency of the testing results.

3.7 Instrument Variable (IV) Estimation Method-Two-Stage Least Square (TSLS)

OLS estimation sometimes may not successfully estimate the Taylor rule model. The reason is that Taylor rule model may potentially suffer from endogeneity problem. Endogeneity problem happened when exogenous variables correlated with error terms. For example:

$$\hat{y}_t = \hat{\beta}_0 + \hat{\beta}_1 x_t + u_t \tag{3.5}$$

$$cov(x, u) \neq 0$$

The above example is a simple simultaneous equation which estimates Y variable with X variable. If x_t and u_t are correlated with each other, this will make the OLS estimation to become biased and inconsistent. The estimated coefficient $\hat{\beta}_1$ will converge far away from the true β_1. Therefore, OLS estimation will suffer from the problem we called as 'endogeneity problem'.

To solve this problem, we need to apply the two-stage least square (TSLS) method. So, how the TSLS work to solve the endogeneity problem? Basically, researchers need to identify the instrument variables (IV) that are exogenous to x_t . The set of instrument lists must be theoretically correlated with x_t , but not correlated with u_t. For taking Z_t as an instrument example:

$$\hat{x}_t = \widehat{\emptyset}_0 + \widehat{\emptyset}_1 Z_t + V_t \qquad (3.6)$$

We use Z_t as exogenous variable and form a reduced form equation as shown above to estimate x_t . Then we use forecast to obtain expected value $\hat{x}_t$ and plug into the original equation:

$$\hat{y}_t = \hat{\beta}_0 + \hat{\beta}_1 \hat{x}_t + u_t \qquad (3.7)$$

$$cov(\hat{x}_t, u_t) = 0$$

After plugged $\hat{x}_t$ into original equation and if $\hat{x}_t$ is not correlated with u_t, then the estimation will be free from endogeneity problem. The coefficient will become unbiased and consistent. However, there are several issues regarding to the instrument lists selection that need to be aware of. In order to use the appropriate instrument lists, we need to proceed to several diagnostic checking to ensure the validity of the instrument lists. This will be further discussed in the next section.

3.8 Diagnostic Checking of TSLS

There are three types of diagnostic checking that must be carried out to check for the endogeneity problem and validity of instrument lists. They are Hausman Test, weak instrument test and Sargan Test.

3.8.1 Endogeneity Test (Hausman Test)

For the case of Taylor rule, inflation rate and output gap may determine endogenously with the interest rate itself. There are previous researchers who discovered endogeneity problem in Taylor rule research before. We suspect that estimating Taylor model with OLS method may not be efficient and biased due to the endogeneity problem. There are several steps need to be taken to test for the endogeneity problem.

Firstly, we need to identify the instrument lists we want to use and then we formed a reduced form equation. The reduced form equation consists of X_i from original model as dependent variable and the selected instrument lists as independent variables. To illustrate better understanding, we will use our contemporaneous Taylor rule model as example. We selected three different combinations of instrument lists to robust the endogeneity problem. The first group consists of lag 1 to 4 of all independent variables and dependant variable from original model as instrument lists. The second group consists of lag 1 to lag 5. The third group is lag 1 to 6.

To illustrate understanding for endogeneity test, we take our contemporaneous Taylor rule model as example:

$$i_t = \hat{\rho} i_{t-1} + (1 - \hat{\rho})\left[\hat{\beta}_a + \hat{\beta}_\pi \pi_t + \hat{\beta}_\gamma {y_t}^*\right] + u_t \qquad (3.8)$$

$$cov(\pi_t,\, u_t) \neq 0$$

$$cov({y_t}^*,\, u_t) \neq 0$$

If either one or both independent variables π_t and ${y_t}^*$ are correlate with error terms, this would cause endogeneity problem to happen. Then, we need to select the instrument lists to test for endogeneity problem. In our research, we chose to use the lags of the independent variables and dependent variables as our instrument lists. By using lag 1 to lag 4 instrument lists as example, we formed the reduced form equation for π_t and ${y_t}^*$ as shown below to test for endogeneity problem in both variables:

$$\pi_t = \hat{\beta}_0 + \hat{\beta}_1 i_{t-1} + \hat{\beta}_2 i_{t-2} + \hat{\beta}_3 i_{t-3} + \hat{\beta}_4 i_{t-4} + \hat{\beta}_5 \pi_{t-1} + \hat{\beta}_6 \pi_{t-2} + \hat{\beta}_7 \pi_{t-3} + \hat{\beta}_8 \pi_{t-4} + \hat{\beta}_9 y^*_{t-1} + \hat{\beta}_{10} y^*_{t-2} + \hat{\beta}_{11} y^*_{t-3} + \hat{\beta}_{12} y^*_{t-4} + \hat{\partial}_1 Resid_\pi \quad (3.9)$$

$$y_t{}^* = \hat{\beta}_0 + \hat{\beta}_1 i_{t-1} + \hat{\beta}_2 i_{t-2} + \hat{\beta}_3 i_{t-3} + \hat{\beta}_4 i_{t-4} + \hat{\beta}_5 \pi_{t-1} + \hat{\beta}_6 \pi_{t-2} + \hat{\beta}_7 \pi_{t-3} + \hat{\beta}_8 \pi_{t-4} + \hat{\beta}_9 y^*_{t-1} + \hat{\beta}_{10} y^*_{t-2} + \hat{\beta}_{11} y^*_{t-3} + \hat{\beta}_{12} y^*_{t-4} + \hat{\partial}_2 Resid_y \quad (3.10)$$

At first, we regress two reduced form of equation of π_t and $y_t{}^*$ with the lag variables as instrument lists. Secondly, we obtain residuals from both equations and insert it into original model as shown below:

$$i_t = \hat{\rho} i_{t-1} + (1 - \hat{\rho})\left[\hat{\beta}_a + \hat{\beta}_\pi \pi_t + \hat{\beta}_\gamma y_t{}^* + \hat{\partial}_1 Resid_\pi + \hat{\partial}_2 Resid_y\right] + u_t \quad (3.11)$$

$Resid_\pi$ and $Resid_y$ are the residual values computed from the two reduced form equations. Last step is to carry out the T-test and F-test. The hypothesis testing as shown below:

$H_0: \partial\ = 0\ (There\ is\ no\ correlation\ between\ X_i\ and\ u_t)$

$H_1: \partial\ \neq 0\ (There\ is\ correlation\ between\ X_i\ and\ u_t)$

If we only test for one independent variable for the endogeneity problem, we should obtain t-statistic from the residual variables. If the t-statistic of the residual variable is significant, it means there is endogeneity problem. If we want to test for more than one variable for the endogeneity problem, we need to compute F-statistic to carry out joint hypothesis of significance.

3.8.2 Weak Instrument Test

Weak instrument problem is one of the important issues encountered by researchers who are using Instrumental Variable (IV) estimation. We need to avoid weak instrument problem in order to prove the TSLS estimation is valid. There are few methods to perform weak instrument test:

- First, is to examine the t-statistic of the instruments that we used in the reduced form equation. If it is significant at 5% and 1%, it means that is a strong instrument.
- If we are using more than one instrument, then we need to check the F-test of the all the coefficients in reduced form by using Wald-test. We need to test with null hypothesis: At least one of the coefficients of instrument is not zero. Even though we may get the result to reject the p-value at 1% or 5%, it is still not enough to convince that they are strong instrument. According to rule of thumb, the F test-statistic need to be greater than 10 to show that the there is no weak instrument problem.
- Lastly, even F test-statistic is greater than 10, but it is not absolutely shows that there is no weak instrument problem. We need to ensure that standard error from IV estimation smaller than the standard error from OLS estimation to further convince that there is no weak instrument problem.

3.8.3 Testing Instrument Validity (Sargan Test)

For TSLS estimation, we need to ensure the instrument lists are not correlated with error terms, which is $(z_i, e_i) = 0$. If instrument lists are correlated with error terms in the TSLS estimation, it means that the endogeneity problem remain unsolved. Therefore, it is appropriate to test the validity of the instrument lists. Validity test of instrument lists is also known as Sargan test.

There are several procedures we need to follow in Sargan test.

- First, we need to regress the TSLS equation with the selected instrument lists. Then, we obtain the residuals from the TSLS estimation result.
- Second is to regress the residuals as dependent variable with instrument lists as independant variables. We use back the lag 1 to 4 instruments in the previous example and assume v_t is the residuals obtained from TSLS model:

$$v_t = \hat{\beta}_0 + \hat{\beta}_1 i_{t-1} + \hat{\beta}_2 i_{t-2} + \hat{\beta}_3 i_{t-3} + \hat{\beta}_4 i_{t-4} + \hat{\beta}_5 \pi_{t-1} + \hat{\beta}_6 \pi_{t-2} + \hat{\beta}_7 \pi_{t-3} + \hat{\beta}_8 \pi_{t-4} + \hat{\beta}_9 y^*_{t-1} + \hat{\beta}_{10} y^*_{t-2} + \hat{\beta}_{11} y^*_{t-3} + \hat{\beta}_{12} y^*_{t-4} + e_t \quad (3.12)$$

- Third is to obtain the R^2 from the above reduced form equation and compute NR^2 (N is the sample size)
- Then we compare with chi-square $x^2_{0.01,0.05,0.1}$ with degree of freedom $(m - k)$, where m is number of instruments; k is number of endogenous variables. Reject null hypothesis means $cov(z_i , e_i) \neq 0$, which indicates that the instrument lists are invalid. z_i represents the instrument lists, while e_i represents residuals. Hypothesis testing of Sargan test as shown below:

  H_0: *Instrument lists are valid.*
  H_1: *Instrument lists are overidentifying*
  (*Instrument lists are invalid*)

3.9 Conclusion

In overall, we have shown our data sources and procedures in estimating our data with OLS and TSLS. We also introduced the appropriate diagnostic checking for both OLS and TSLS estimation. Next, the empirical results of our research will be further discussed in chapter 4.

CHAPTER 4: RESULT

4.0 Introduction

This chapter discusses about our overall empirical results. First, we performed the stationary tests which are Augmented Dickey Fuller (ADF) and Kwiatkowski-Philips-Schmidt-Shin (KPSS) tests to identify the stationary status of all data. Then we proceed to OLS estimations for our research in the preliminary stage. Next, we carried out endogeneity test to check for the endogeneity problem that may potentially happen in studying Taylor rule. After endogeneity problem discovered, we proceed to TSLS estimation to deal with the endogeneity problem. Lastly, we plotted the graph to compare the forecast value from the three types Taylor rule with actual interbank rate to know the tendency of fitness.

4.1 Introduction of Stationary Checking

Before we start our estimation, we would like to check about stationary status of all sets of data. We will check on the inflation, output gap, forecast inflation, forecast output gap, interbank rate level form and interbank rate of first difference. **Table 4.1** in next page shows all the stationary test results that we performed based on ADF and KPSS.

Table 4.1 Unit Root Test Results

	Augmented Dickey-Fuller		Kwiatkowski-Phillips-Schmidt-Shin	
	Intercept	Trend + Intercept	Intercept	Trend + Intercept
π_t (CPI)	-7.6527***	-7.5808***	0.4076*	0.0891
π_t (Deflator)	-7.3042***	-7.2720***	0.0642	0.0621
π_t (PPI)	-7.2799***	-7.2302***	0.0491	0.0509
Output Gap	-6.2925***	-6.2646***	0.0507	0.0507
Forecast π_t (CPI)	-7.2929***	-7.5495***	0.4159*	0.0893
Forecast π_t (GDP Deflator)	-7.5773***	-7.5489***	0.0781	0.0565
Forecast π_t (PPI)	-6.5655***	-6.5278***	0.0323	0.0300
Forecast Output Gap	-6.2925***	-6.2646***	0.0507	0.0507
Interbank Rate	-1.9563	-2.8365	0.8331***	0.1034
Interbank Rate (First Difference)	-6.7010***	-6.6543***	0.0611	0.0599

Note 1: The asterisks, ***, makes indicate rejection of the null hypothesis at 10%, 5% and 1% level of significance respectively in parentheses.
Note 2: ADF test applied with 30 maximum lags length with automatic AIC selection; KPSS test applied with automatic selection based on Newey-West Bandwidth.

4.1.1 Evaluation on Stationary Test

According to ADF and KPSS results in **Table 4.1**, mostly all the annualized quarterly inflation rate, forecast annualized quarterly inflation rate, output gap and forecast output gap are stationary at 1% and 5% significant level. This indicated that those variables are stationary at their level form with I(0).

On the other side, ADF and KPSS test showed that interbank rate is not stationary at I(0). Interbank rate achieved stationary at its first difference, I(1). Even though interbank rate is not stationary at I(0), it does not cause spurious result in our research. Review back our Taylor rule model as shown below:

$$i_t = i_{t-1} + c + \pi_t + \ y_t^* \qquad (4.1)$$

Our Taylor rule model consists lag one of interbank rate, constant term, inflation rate and output gap. When we moved the lag one of interbank rate to the left hand side of the equation, it achieved stationary at first difference:

$$i_t - i_{t-1} = c + \pi_t + \ y_t^* \qquad (4.2)$$

$$\Delta i_t = c + \pi_t + \ y_t^* \qquad (4.3)$$

Thus, by adding the lag one of interbank rate to our equation, it could help our Taylor rule equation to achieve stationary and prevent spurious regression result. As conclusion, all of our data is stationary at I(0).

4.2 Why not OLS Estimations?

4.2.1 Introduction

In the preliminary stage of our research, we have run contemporaneous Taylor rule model, backward-looking Taylor rule model and forward-looking Taylor rule. Taylor rule researchers applied OLS estimation since OLS estimations fit Taylor rule equation well in the early stage of Taylor rule development. Nevertheless, there are some Taylor rule researchers still chose to use OLS estimations in their recent research. Their OLS estimation results also fit well with the Taylor rule principle which indicated that the OLS estimation is suitable to estimate Taylor rule model.

Therefore, we are interested in one question: Would OLS estimation be able to fit with Taylor rule principle for Malaysia from 1990s until 2010s (interest rate targeting policy started at 1990s)? To answer this question, we used OLS to estimate for three types Taylor rule with different types of inflation such as CPI, GDP deflator and PPI. The next three pages are the display of our OLS estimation result tables. **Table 4.2** shows the OLS estimation result of contemporaneous Taylor rule model. **Table 4.3** shows the OLS estimation result of backward-looking Taylor rule model. **Table 4.4** shows the OLS estimation result of forward-looking Taylor rule model.

Table 4.2: Contemporaneous Taylor rule Model (OLS Estimation Result)

$$i_t = \hat{\rho} i_{t-1} + (1 - \hat{\rho})[\hat{\beta}_a + \hat{\beta}_\pi \pi_t + \hat{\beta}_\gamma y_t^*] + u_t$$

Equation	CPI	GDP	PPI
Sample Period	1991:1 2012:4	1991:2 2012:4	1991:1 2012:4
$\hat{\rho}$	0.9414** (0.0356)	0.9568** (0.0365)	0.9609*** (0.0338)
$\hat{\beta}_a$	1.5756 (1.5253)	3.6371*** (1.1282)	2.5948** (1.1810)
$\hat{\beta}_\pi$	0.7534 (0.7449)	-0.0834 (0.1547)	0.2212 (0.2872)
$\hat{\beta}_\gamma$	0.9707** (0.4256)	1.3458* (0.6864)	1.3503* (0.7756)
Adjusted R^2	0.9349	0.9312	0.9331
D.W Test-Statistic	1.6526	1.5594	1.6361
RMSE	0.5354	0.5501	0.5430
Diagnostic Checking (P-Value)			
LM Test (1)	0.0919	0.0388	0.0745
LM Test (2)	0.2210	0.0777	0.1244
LM Test (3)	0.2761	0.1205	0.1074
ARCH (1)	0.5635	0.4700	0.2533
ARCH (2)	0.2264	0.1270	0.0649
ARCH (3)	0.0173	0.0042	0.0028
Jacque-Bera	0.0000	0.0000	0.0000

Note 1: The asterisks, ***, makes indicate rejection of the null hypothesis at 10%, 5% and 1% level of significance respectively, t-statistic in parentheses.
Note 2: Newey-West HAC procedure applied since the most OLS estimation results potentially consist of autocorrelation and heteroscedascity problem.
Note 3: [LM Test, Arch Test] (1), (2), (3) indicate lag one to lag 3 results

Table 4.3: Backward-Looking Taylor rule Model (OLS Estimation)

$$i_t = \hat{\rho} i_{t-1} + (1-\hat{\rho})\left[\hat{\beta}_a + \hat{\beta}_\pi \pi_{t-1} + \hat{\beta}_\gamma y^*_{t-1}\right] + u_t$$

Equation	CPI	GDP	PPI
Sample Period	1991:2 2012:4	1991:3 2012:4	1991:2 2012:4
$\hat{\rho}$	0.9259*** (0.0437)	0.9471*** (0.0385)	0.9538*** (0.0385)
$\hat{\beta}_a$	1.9564*** (0.6834)	2.3555** (1.1805)	1.6667 (1.4569)
$\hat{\beta}_\pi$	0.6770* (0.3907)	0.3075 (0.3016)	0.5521 (0.4307)
$\hat{\beta}_\gamma$	0.9102** (0.4105)	1.0465* (0.5880)	1.2015 (0.7630)
Adjusted R^2	0.9378	0.9375	0.9441
D.W Test-Statistic	1.5389	1.5977	1.5381
RMSE	0.5232	0.5229	0.4957
Diagnostic Checking (P-value)			
LM Test (1)	0.0302	0.0883	0.0339
LM Test (2)	0.0571	0.1830	0.0999
LM Test (3)	0.0384	0.1072	0.1458
ARCH (1)	0.5882	0.6454	0.7025
ARCH (2)	0.3124	0.4013	0.7058
ARCH (3)	0.0467	0.0936	0.3767
Jacque-Bera	0.0000	0.0000	0.0000

Note 1: The asterisks, ***, makes indicate rejection of the null hypothesis at 10%, 5% and 1% level of significance respectively, t-statistic in parentheses.
Note 2: Newey-West HAC procedure applied since the most OLS estimation results potentially consist of autocorrelation and heteroscedascity problem.
Note 3: [LM Test, Arch Test] (1), (2), (3) indicate lag one to lag 3 results

Table 4.4: Forward-Looking Taylor rule Model (OLS Estimation)

$$i_t = \hat{\rho} i_{t-1} + (1 - \hat{\rho})[\hat{\beta}_a + \hat{\beta}_\pi \pi_{t+1} + \hat{\beta}_\gamma y^*_{t+1}] + u_t$$

Equation	CPI	GDP	PPI
Sample Period	1990:2 2012:4	1990:2 2012:4	1990:2 2012:4
$\hat{\rho}$	0.9442*** (0.0375)	0.9638*** (0.0348)	0.9647*** (0.0330)
$\hat{\beta}_a$	1.5521 (1.4818)	4.1915** (1.6667)	2.6919** (1.3510)
$\hat{\beta}_\pi$	0.9149 (0.7484)	-0.0852 (0.1839)	0.3617 (0.4161)
$\hat{\beta}_\gamma$	0.9934** (0.4811)	1.5608 (0.9826)	1.3705 (0.9254)
Adjusted R^2	0.9327	0.9289	0.9309
D.W Test-Statistic	1.5393	1.4828	1.5604
RMSE	0.5434	0.5583	0.5504
Diagnostic Checking (P-value)			
LM Test (1)	0.0405	0.0191	0.0507
LM Test (2)	0.1206	0.0559	0.1201
LM Test (3)	0.1362	0.0769	0.0752
ARCH (1)	0.4903	0.4429	0.2762
ARCH (2)	0.1402	0.0649	0.0521
ARCH (3)	0.0090	0.0018	0.0033
Jacque-Bera	0.0000	0.0000	0.0000

Note 1: The asterisks, ***, makes indicate rejection of the null hypothesis at 10%, 5% and 1% level of significance respectively, t-statistic in parentheses.
Note 2: Newey-West HAC procedure applied since the most OLS estimation results potentially consist of autocorrelation and heteroscedascity problem.
Note 3: [LM Test, Arch Test] (1), (2), (3) indicate lag one to lag 3 results.

4.2.2 Evaluation of OLS Estimation

We discovered there are three problems according to OLS estimation result based on **Table 4.2, Table 4.3** and **Table 4.4**. First problem is regardless contemporaneous, backward or forward-looking estimation results, all of them are not normally distributed. Second problem is most of them consist of autocorrelation and heteroscedascity problem at 5% significant level. We applied Newey-West HAC procedure to adjust the standard error in our OLS estimation result. However, Newey-West HAC procedure does not provide much help because non-normality problem will make the estimator to be biased and inconsistent. Even though standard error converged to true value under Newey-West HAC procedure, the estimation result is not valid as estimator is biased and inconsistent when normality assumption is violated.

The third problem we discovered is all the estimated coefficients of inflation have violated Taylor rule principle. All the estimated coefficients of inflation have the values which are less than one. According to Taylor rule principle, central bank should adjust the degree of coefficient more than one in order to lower down the inflation rate. If central bank adjusts the coefficient less than one, this would worsen the inflation because it could lower the real interest rate and end up with higher inflation rate.

Therefore, we have raised one question: Do the estimation results indicate there is endogeneity problem? If yes, endogeneity problem will cause the OLS coefficients to become biased and inconsistent. Therefore, the result will become unreliable. We need to perform TSLS estimation to solve endogeneity problem if endogeneity problem exists.

What if there is no endogeneity problem exists in the estimation results? There are two issues will arise. First issue is the estimation results may indicate that BNM does not follow Taylor rule principles in setting interest rate. If the BNM does not follow Taylor rule principle in setting interest rate, we will not able to find the estimation results that comply with Taylor rule principle which the coefficient of inflation rate is more than one.

Second issue is it may possible to indicate that BNM does not target on those types of inflation (CPI, GDP deflator and PPI) since estimation results do not comply with Taylor rule principle which the coefficient is less than one. Lastly, before we finalize conclusion for the two issues we mentioned, we will perform the endogeneity test to confirm the existence of endogeneity problem.

4.3 Endogeneity Test

4.3.1 Introduction

We have selected three groups of instrument lists to test for endogeneity problem. We used lag 1 to lag 4, lag 1 to lag 5 and lag 1 to lag 6 of all independent variables and dependent variables for contemporaneous and forward-looking Taylor rule model. On the other hand, we used lag 2 to lag 5, lag 2 to lag 6 and lag 2 to lag 7 as three groups of instrument lists for backward-looking Taylor rule model.

At first, we regress the reduced form equations of inflation rate and output gap with the three groups of instrument lists. Then we obtained the residuals from those reduced form estimation results and inserted them into the original model. If the t test-statistic of the residual significant, it indicated that there is endogeneity problem on that particular independent variables in our original model. We also performed F test-statistic to test whether both inflation rate and output gap showed joint endogeneity problem.

Table 4.5, **Table 4.6** and **Table 4.7** in the next three pages show the endogeneity test estimation results for contemporaneous Taylor rule, backward-looking Taylor rule and forward-looking Taylor rule.

Table 4.5: Endogeneity Test for Contemporaneous Taylor rule Model

$$i_t = \hat{\rho} i_{t-1} + (1-\hat{\rho})\left[\hat{\beta}_a + \hat{\beta}_\pi \pi_t + \hat{\beta}_\gamma y_t{}^* + \hat{\partial}_1 Resid_\pi + \hat{\partial}_2 Resid_y\right] + v_t$$

Equation	$\hat{\rho}$	$\hat{\beta}_a$	$\hat{\beta}_\pi$	$\hat{\beta}_\gamma$	$\hat{\partial}_1$	$\hat{\partial}_2$	F-test $(\hat{\partial}_1 + \hat{\partial}_2)$
CPI (a)	0.8665*** (0.0349)	-0.4713 (1.0947)	1.5999*** (0.4879)	0.3723** (0.1779)	-1.6431*** (0.4127)	-0.1051 (0.3210)	0.0002
CPI (b)	0.8746*** (0.0406)	-0.2278 (1.1508)	1.4901*** (0.5179)	0.5302*** (0.1479)	-1.5364*** (0.4141)	-0.2937 (0.4208)	0.0001
CPI (c)	0.8766*** (0.0406)	-0.1673 (1.2551)	1.4632** (0.5692)	0.5527*** (0.1597)	-1.5258*** (0.4500)	-0.3370 (0.4330)	0.0011
GDP Deflator (a)	0.9426*** (0.0366)	2.1724 (1.4308)	0.2616 (0.4343)	1.1270 (0.7038)	-0.4122 (0.4657)	-0.4662 (1.2023)	0.6343
GDP Deflator (b)	0.9364*** (0.0376)	2.2079* (1.1876)	0.2490 (0.3559)	1.0065** (0.3888)	-0.3644 (0.3702)	-0.7286 (1.4010)	0.6178
GDP Deflator (c)	0.9359*** (0.0393)	2.0346 (1.3032)	0.2953 (0.3702)	0.9397** (0.3666)	-0.4459 (0.4085)	-0.5373 (1.3033)	0.5017
PPI (a)	0.9574*** (0.0302)	-0.5635 (3.2031)	1.0514 (0.9024)	1.3335* (0.7873)	-1.2313 (1.0406)	-0.5857 (1.1507)	0.4490
PPI (b)	0.9492*** (0.0319)	0.1819 (2.4829)	0.8325 (0.6835)	1.1323** (0.5257)	-0.9795 (0.7879)	-0.4825 (1.2062)	0.3811
PPI (c)	0.9431*** (0.0340)	0.6615 (2.1291)	0.6951 (0.5934)	0.9868** (0.4305)	-0.8210 (0.6862)	-0.1221 (1.0281)	0.3737

Note 1: The asterisks, ***, makes indicate rejection of the null hypothesis at 10%, 5% and 1% level of significance respectively, t-statistic in parentheses.
Note 2: (a) indicates instrument lists $[i_t, \pi_t, y_t^*]$[lag1 to lag4] (b) indicates instrument lists $[i_t, \pi_t, y_t^*]$[lag1 to lag5] (c) indicates instrument lists $[i_t, \pi_t, y_t^*]$[lag1 to lag6]
Note 3: F-test is based on P-value

Table 4.6 Endogeneity Test for Backward-Looking Taylor rule Model

$$i_t = \hat{\rho} i_{t-1} + (1-\hat{\rho})\left[\hat{\beta}_a + \hat{\beta}_\pi \pi_{t-1} + \hat{\beta}_\gamma y_{t-1}{}^* + \hat{\partial}_1 Resid_\pi + \hat{\partial}_2 Resid_y\right] + v_t$$

Equation	$\hat{\rho}$	$\hat{\beta}_a$	$\hat{\beta}_\pi$	$\hat{\beta}_\gamma$	$\hat{\partial}_1$	$\hat{\partial}_2$	F test ($\hat{\partial}_1 + \hat{\partial}_2$)
CPI (a)	0.8773*** (0.0495)	1.0065 (0.8020)	1.0146*** (0.3558)	0.3733 (0.2503)	-0.7331* (0.3712)	0.3980* (0.2097)	0.0231
CPI (b)	0.8942*** (0.0516)	1.7603** (0.8304)	0.6912* (0.3986)	0.6872* (0.3710)	-0.3403 (0.3922)	0.0639 (0.5174)	0.6865
CPI (c)	0.8949*** (0.0508)	2.0079** (0.8964)	0.5807 (0.4300)	0.7260* (0.3904)	-0.2164 (0.4233)	-0.0362 (0.5985)	0.8664
GDP Deflator (a)	0.9307*** (0.0341)	0.6039 (1.5747)	0.7206 (0.4417)	0.2593 (0.4313)	-0.5536 (0.3669)	0.7952 (0.5527)	0.2946
GDP Deflator (b)	0.9208*** (0.0379)	1.4494 (1.0083)	0.4984* (0.2721)	0.6971* (0.4171)	-0.3468* (0.1830)	-0.1160 (0.6251)	0.1683
GDP Deflator (c)	0.9167*** (0.0405)	1.8710** (0.9035)	0.3835* (0.2275)	0.7136 (0.4310)	-0.2218 (0.1464)	-0.1694 (0.6437)	0.3227
PPI (a)	0.9347*** (0.0302)	0.4482 (1.5802)	0.8143** (0.3979)	0.6180 (0.4295)	-0.5716* (0.3139)	0.4390 (0.4222)	0.1916
PPI (b)	0.9252*** (0.0339)	1.0261 (1.1203)	0.6497** (0.2816)	0.8471* (0.4485)	-0.4319** (0.2010)	-0.1403 (0.6530)	0.0813
PPI (c)	0.9188*** (0.0339)	1.2214 (1.0167)	0.5886** (0.2473)	0.8517** (0.4220)	-0.3882** (0.1855)	-0.3235 (0.6231)	0.1127

Note 1: The asterisks, ***, makes indicate rejection of the null hypothesis at 10%, 5% and 1% level of significance respectively, t-statistic in parentheses.
Note 2: (a) indicates instrument lists [i_t , π_t , y_t^*][lag2 to lag5] (b) indicates instrument lists [i_t , π_t , y_t^*][lag2 to lag6] (c) indicates instrument lists [i_t , π_t , y_t^*][lag2 to lag7]
Note 3: F-test is based on P-value.

Table 4.7 Endogeneity Test for Forward-Looking Taylor rule Model

$$i_t = \hat{\rho} i_{t-1} + (1-\hat{\rho})\left[\hat{\beta}_a + \hat{\beta}_\pi \pi_{t+1} + \hat{\beta}_\gamma y^*_{t+1} + \hat{\partial}_1 Resid_\pi + \hat{\partial}_2 Resid_y\right] + v_t$$

Equation	$\hat{\rho}$	$\hat{\beta}_a$	$\hat{\beta}_\pi$	$\hat{\beta}_\gamma$	$\hat{\partial}_1$	$\hat{\partial}_2$	F test $(\hat{\partial}_1 + \hat{\partial}_2)$
CPI (a)	0.8782***	-0.7160	1.7307***	0.3564*	-1.6441***	0.0482	0.0017
	(0.0430)	(1.1992)	(0.5411)	(0.1837)	(0.4782)	(0.3252)	
CPI (b)	0.8851***	-0.5326	1.6468***	0.5057**	-1.6058***	-0.1288	0.0027
	(0.0449)	(1.2458)	(0.5669)	(0.1920)	(0.4877)	(0.3887)	
CPI (c)	0.8792***	-0.3917	1.5701***	0.5225***	-1.5194***	-0.4020	0.0032
	(0.0444)	(1.1436)	(0.5171)	(0.1710)	(0.4393)	(0.4335)	
GDP Deflator (a)	0.9586***	1.9481	0.4013	1.2167	-0.6428	-0.0914	0.6749
	(0.0347)	(1.8890)	(0.6525)	(0.9494)	(0.7363)	(1.4100)	
GDP Deflator (b)	0.9536***	2.2502	0.2820	1.2747**	-0.4467	-0.5154	0.6469
	(0.0349)	(1.3647)	(0.4488)	(0.6274)	(0.4776)	(1.4278)	
GDP Deflator (c)	0.9503***	2.0540	0.3238	1.2320**	-0.5137	-1.1375	0.5662
	(0.0334)	(1.3921)	(0.4233)	(0.5416)	(0.4802)	(1.7442)	
PPI (a)	0.9636***	-0.1411	1.0826	0.9278	-1.2397	0.4249	0.5673
	(0.0324)	(3.4372)	(1.1327)	(0.6609)	(1.2493)	(0.9679)	
PPI (b)	0.9584***	0.1563	0.9478	1.0630	-1.0798	0.1674	0.4167
	(0.0270)	(3.2328)	(0.7002)	(0.8234)	(0.8139)	(0.9244)	
PPI (c)	0.9544***	0.2750	0.8910	1.0043**	-1.0292	-0.3124	0.4475
	(0.0309)	(2.5022)	(0.7746)	(0.5045)	(0.8632)	(1.2555)	

Note 1: The asterisks, ***, makes indicate rejection of the null hypothesis at 10%, 5% and 1% level of significance respectively, t-statistic in parentheses.

Note 2: (a) indicates instrument lists $[i_t, \pi_{t+1}, y^*_{t+1}]$[lag1 to lag4] (b) indicates instrument lists $[i_t, \pi_{t+1}, y^*_{t+1}]$[lag1 to lag5] (c) indicates instrument lists $[i_t, \pi_{t+1}, y^*_{t+1}]$[lag1 to lag6]

Note 3: F-test is based on P-value.

4.3.2 Evaluation of Endogeneity Problem

At first, we evaluate endogeneity test result for the contemporaneous Taylor rule. We found that there is evidence showed that estimation of CPI based inflation suffered with endogeneity problem because results showed significant at 1% significant level under three groups of instrument lists: lag 1 to lag 4, lag 1 to lag 5 and lag 1 to lag 6. On the other hand, output gap did not correlate with error terms. This is because the residual from reduced form equation of output gap is not significant at 10% significant level. However, when we jointed these two residuals to test for joint endogeneity test, we found that there is also evidence to show that both variables contribute endogenous problem for estimations of CPI based inflation. However, the endogeneity test did not show any evidences that the estimations of GDP deflator based inflation and PPI based inflation suffered with endogeneity problem since the residual variables are insignificant under the three groups of instrument lists.

For backward-looking Taylor rule, we found that there is evidence to show the estimation of CPI based inflation has endogenous problem which was detected by lag 2 to lag 5 instrument lists. The residual from reduced form equation of CPI based inflation is significant at 10% significant level. The residual from reduced form equation of output gap also showed significant at 10% significant level. F test-statistic further proved that both variables contribute endogenous problem at 5% significant level. Besides that, we also detected endogenous problem for the estimation of GDP deflator based inflation with lag 2 to lag 6 instrument lists. The residual from reduced form equation of GDP deflator based inflation is significant at 10% significant level. Lastly, we detected that the estimation of PPI based inflation suffered with endogenous problem under three groups of instrument lists: lag 2 to lag 5, lag 2 to lag 6 and lag 2 to lag 7.

For forward-looking model, we found that there is strong evidence to show that the estimation of CPI-based inflation suffered with endogeneity problem because the results showed significant at 1% significant level under three groups of instrument lists: lag 1 to lag 4, lag 1 to lag 5 and lag 1 to lag 6. The residual from reduced form CPI equation is significant at 1% significant level. Joint significant test for both residuals from reduced form equation of CPI inflation and output gap also showed significant at 1% significant level. On the other hand, we did not discover the endogeneity problem for the estimations of GDP deflator and PPI based inflation under three groups of instrument lists.

As conclusion, we will proceed to two-stage least square (TSLS) estimations for those estimations that detected endogeneity problem with the relevant group of instrument lists. TSLS estimation is capable of solving the endogeneity problem. We would like to know how Taylor rule estimations perform with TSLS after we remove the endogeneity problem.

4.4 Two Stage Least Square (TSLS)

4.4.1 Introduction

Endogeneity problem is very common in econometric problem, thus TSLS was introduced to tackle off endogeneity problem. It has been applied widely by previous researchers to deal with endogeneity problem. Even though researchers can use TSLS to deal with the endogeneity problem, they need to perform few diagnostic checking in order to prove that their TSLS estimations are valid.

At first, they need to prove that there is endogeneity problem with endogeneity test. After that, they need to carry out another two diagnostic checking which are the weak instrument test and Sargan-test. Weak instrument test requires researchers to use Wald-coefficient test to compute F test-statistic to find out significance of the coefficients of instruments in the reduced form equation of inflation rate and output gap. As rule of thumb, we must get F-test statistic which is greater than 10 to indicate there is no weak instrument problem. However, F-test statistic greater than 10 sometimes may not be enough to convince us that there is no weak instrument problem. For further confirmation, we need to check for the standard error of the TSLS with the OLS estimations. If standard error of TSLS is smaller than OLS estimation, this will further confirm that there is no weak instrument problem.

Besides that, we also need to obtain the residual from TSLS estimations and regress it with instrument lists as reduced form equation. Then we obtain the R^2 from the equation and compute NR^2 to carry out Sargan-test. If the hypothesis testing do not reject H_0, this indicates that our instrument lists are valid.

If TSLS estimation is able to fulfil those diagnostic checking, then TSLS estimation is asymptotically normally distributed. We also will proceed to Lagrange mulitiplier test and Autoregressive conditional heteroscedascity test to check for the heteroscedascity and autocorrelation problem. Newey-West HAC procedure will be applied if we found that heteroscedascity and autocorrelation problems are significant at 5% significant level. This will help the standard error converge to its true value. **Table 4.8, Table 4.9** and **Table 4.10** show our TSLS estimations result.

Table 4.8 Contemporaneous Taylor rule Model (TSLS Estimation)

$$i_t = \hat{\rho} i_{t-1} + (1 - \hat{\rho})[\hat{\beta}_a + \hat{\beta}_\pi \pi_t + \hat{\beta}_\gamma y_t^*] + u_t$$

Equation	CPI(a)	CPI(b)	CPI(c)
Sample Period	1992Q1 2012Q4	1992Q2 2012Q4	1992Q3 2012Q4
$\hat{\rho}$	0.8665*** (0.0446)	0.8746*** (0.0409)	0.8766*** (0.0403)
$\hat{\beta}_a$	-0.4713 (1.5040)	-0.2278 (1.4754)	-0.1673 (1.5014)
$\hat{\beta}_\pi$	1.5999*** (0.4827)	1.4901*** (0.4723)	1.4632*** (0.4876)
$\hat{\beta}_\gamma$	0.3723 (0.2766)	0.5302** (0.2562)	0.5527** (0.2599)
Diagnostic Checking			
Wald test-statistic Reduced Form Eq. (π_t)	9.0912	10.1999	16.5173
Wald test-statistic Reduced Form Eq. (y_t^*)	15.7651	23.4672	23.6101
Sargan test-statistic (NR^2)	5.3441	6.9876	8.6919
DW test-statistic	1.8502	1.8572	1.8568
LM(1)	0.4784	0.5022	0.5040
LM(2)	0.7277	0.7020	0.7001
LM(3)	0.8880	0.8712	0.8701
ARCH (1)	0.0579	0.0904	0.1111
ARCH (2)	0.1697	0.2466	0.2879
ARCH (3)	0.3104	0.4291	0.4832
RMSE	0.6995	0.6553	0.6462

Note 1: (a) indicates instrument lists $[i_t, \pi_t, y_t^*]$[lag1 to lag4] (b) indicates instrument lists $[i_t, \pi_t, y_t^*]$[lag1 to lag5] (c) indicates instrument lists $[i_t, \pi_t, y_t^*]$[lag1 to lag6]

Note 2: Wald test-statistic of Reduced Form Equations (π_t) and (y_t^*) are used to conduct weak instrument test. F >10 means there is no weak instrument problem.

Note 3: Sargan test-statistic is computed for instrument validity test. H_0: Instrument lists are valid.

Note 4: LM test, ARCH test, JB test are based on P-value.

Note 5: [LM Test, Arch Test] (1), (2), (3) indicate lag one to lag 3 results.

Note 6: The asterisks, ***, makes indicate rejection of the null hypothesis at 10%, 5% and 1% level of significance respectively, t-statistic in parentheses.

4.4.2 Evaluation of Contemporaneous Taylor rule Model (TSLS Estimation)

Since endogeneity problem discovered for estimation of CPI-based inflation under all 3 groups of instrument lists, we proceed them with the TSLS estimation. **Table 4.8** above shows our TSLS estimation result of contemporaneous Taylor rule model. Before we confirm the validity of TSLS estimation result, we perform several diagnostic checking.

As first, we discovered that there is no weak instrument problem since almost all the F test-statistics from reduced form equations are greater than 10. Furthermore, all the standard errors of the inflation rate and output gap coefficient are smaller than standard errors in OLS estimation further convinced that there is no weak instrument problem. Besides that, all Sargan test-statistics do not show significant at 10% significant level. Therefore, instrument lists are proved to be valid. Since the instrument lists are valid and there is no weak instrument problem, we concluded that our TSLS estimations are asymptotically normally distributed. On the other hand, we did not find heteroscedascity and autocorrelation problem at 5% significant level.

By looking on our TSLS estimation, it shows improvement compare to OLS estimations that suffered from endogeneity problem. From TSLS estimation, we observed that the inflation rate coefficients have become larger and output gap coefficients have become smaller. Inflation rate coefficients have fulfilled Taylor rule principle which is more than one. The output gap coefficients have the positive sign and thus comply with Taylor rule principle. Furthermore, all the coefficients of the three estimation results are close to each other. This indicates that our TSLS estimations are quite stable and robust.

We would like to pick the estimation of CPI-based inflation with group (C) instrument lists as the best contemporaneous Taylor rule estimation results out of the three estimation results. That estimation result is free from heteroscedascity and autocorrelation at even 10% significant level. It also has the lowest RMSE among all the three estimations. Lowest RMSE indicates that estimation can perform the best forecast. We will use this estimation as benchmark when we want to make comparison with backward-looking and forward-looking Taylor rule model.

From our best TSLS estimation result, we observed that BNM has responded to the current inflation and current output gap. The inflation rate coefficient is significant at 1% significant level. Output gap coefficient is significant at 5% significant level. On the other sides, coefficient of lag one interbank rate is also significant at 1% significant level. This indicates that BNM has interest rate smoothing behaviour and complies with the findings from previous Taylor rule researchers from 2000s. It also matches with the **Figure 1.2** that we proposed in chapter one: Introduction. From **Figure 1.2**, we are able to find the interest rate smoothing pattern through visual analysis. The TSLS estimation results have proven the existence of interest rate smoothing behaviour.

By reviewing both OLS and TSLS estimation results, we concluded that BNM has followed Taylor rule principle in setting interest rate. We also further discovered that BNM has only targeted at CPI based inflation rather than GDP based inflation and PPI based inflation. From the contemporaneous Taylor rule perspective, it shows strong evidence that BNM has adjusted the interest rate regarding to current economic situation. Here is another question we would be eager to know: Does BNM concern towards the past information of our macroeconomic variables in setting interest rate? To know for it, we will proceed to next section to study the behaviour of BNM from the perspective of backward-looking Taylor rule model.

Table 4.9 Backward-Looking Taylor rule Model (Estimation-TSLS)

$$i_t = \hat{\rho} i_{t-1} + (1-\hat{\rho})[\hat{\beta}_a + \hat{\beta}_\pi \pi_{t-1} + \hat{\beta}_\gamma y^*_{t-1}] + u_t$$

Equation	CPI (a)	GDP (b)	PPI (a)	PPI (b)	PPI (c)
Sample Period	1992Q2 2012Q4	1992Q4 2012Q4	1992Q2 2012Q4	1992Q3 2012Q4	1992Q4 2012Q4
$\hat{\rho}$	0.8623*** (0.0692)	0.9175*** (0.0312)	0.9306*** (0.0415)	0.9207*** (0.0285)	0.9128*** (0.0291)
$\hat{\beta}_a$	1.0888 (0.7410)	1.5582 (1.4439)	0.6729 (1.9851)	1.2010 (1.3817)	1.4182 (1.2011)
$\hat{\beta}_\pi$	1.0030*** (0.3477)	0.4780* (0.2708)	0.7657 (0.4756)	0.6136** (0.2599)	0.5488** (0.2200)
$\hat{\beta}_\gamma$	0.3300 (0.2757)	0.6735* (0.3434)	0.5857 (0.4696)	0.8041** (0.3528)	0.7998** (0.3187)
Diagnostic Checking					
Wald test-statistic Reduced Form Eq. (π_{t-1})	9.0718	9.1758	5.0383	8.2107	7.4168
Wald test-statistic Reduced Form Eq. (y^*_{t-1})	15.5095	37.1897	18.6417	17.4448	30.1603
Sargan test-stat.	10.7541	23.0168**	7.7254	10.9299	11.2315
DW test	1.4166	1.6894	1.4794	1.5755	1.6022
LM(1)	0.0067	0.1613	0.0220	0.0595	0.0702
LM(2)	0.0194	0.2166	0.0651	0.1661	0.1929
LM(3)	0.0270	0.1737	0.0857	0.2259	0.2406
ARCH (1)	0.8904	0.7111	0.9391	0.9205	0.9224
ARCH (2)	0.6614	0.7763	0.9956	0.9728	0.9671
ARCH (3)	0.1995	0.4227	0.9703	0.9405	0.9121
RMSE	0.5836	0.5605	0.5522	0.5428	0.5462

Note 1: (a) indicates instrument lists $[i_t, \pi_t, y^*_t]$[lag2 to lag5] (b) indicates instrument lists $[i_t, \pi_t, y^*_t]$[lag2 to lag6] (c) indicates instrument lists $[i_t, \pi_t, y^*_t]$[lag2 to lag7]

Note 2: Wald test-statistic of Reduced Form Equations (π_t) and (y^*_t) are used to conduct weak instrument test. F >10 means there is no weak instrument problem.

Note 3: Sargan test-statistic is computed for instrument validity test. H_0: Instrument lists are valid.

Note 4: LM test, ARCH test, JB test are based on P-value.

Note 5: [LM Test, Arch Test] (1), (2), (3) indicate lag one to lag three results.

Note 6: The asterisks, ***, makes indicate rejection of the null hypothesis at 10%, 5% and 1% level of significance respectively, t-statistic in parentheses.

Note 7: Newey-West HAC procedure applied when we discovered autocorrelation and hetereoscedascity at 5% significant level.

4.4.3 Evaluation of Backward-Looking Taylor rule Model (TSLS Estimation)

Referring to the **Table 4.6**, we found that backward-looking Taylor rule estimations also suffered from endogeneity problem. Then, we proceed to TSLS method with the relevant groups of instrument lists that detected endogeneity problem. **Table 4.9** shows the complete picture for our TSLS estimations of backward-looking Taylor rule model.

Before we start to examine the TSLS result, we proceed to diagnostic checking to ensure the validity of TSLS estimation result first. The F-test statistics of some reduced form equations are not more than 10 indicate there is potentially weak instrument problem. After we compared the standard error of coefficient of inflation and output gap between TSLS and OLS estimations, we further confirmed that there is no weak instrument as standard error of inflation and output gap's coefficient of TSLS are smaller than OLS. All Sargan test-statistics are not significant at 1% significant level indicate that the instrument lists are valid. TSLS estimations are asymptotically normally distributed after fulfilled no weak instruments problem and valid of instrument lists.

Besides that, almost all TSLS estimation results are not suffered from heteroscedascity problem at 10% significant level and autocorrelation problem at 1% significant level. However, TSLS estimation with CPI based inflation has suffered autocorrelation at 1% significant level. Even though it is suffered from autocorrelation problem, the coefficient is unbiased under normality distribution. The only concern is autocorrelation problem will violate the minimum variance properties. Therefore, we applied Newey-West HAC procedure to converge the standard error to its true value so that the hypothesis testing is valid.

By examining the TSLS estimation results, we discovered important information that the estimation results with GDP based inflation and PPI based inflation do not comply with Taylor rule principle. This is because the coefficients of inflation from all those estimation results do not have the value which is greater than one. This indicates that BNM does not refer to GDP based inflation and PPI based inflation when setting interest rate. This is consistent with the results we discovered from contemporaneous Taylor rule estimation.

On the other hand, we surprisingly discovered that backward-looking estimation with CPI-based inflation complies with the Taylor rule principle. The coefficient of inflation rate is more than one, which is 1.0030 and significant at 1% significant level. This provides strong evidence that BNM has responded to the past inflation when setting interest rate.

Another important thing is we discovered that the coefficients of CPI-based inflation rate in backward-looking models have smaller value (1.0030) compared to our best TSLS contemporaneous Taylor rule estimation (1.4632). This indicates that BNM has weaker response to the past information and stronger response to the current economic situations. This assumption matched with economic principle that central bank is more concerned about adjusting the short term interest rate based on current economic situations even though past economic information will be taken into consideration.

Besides that, the coefficient of output gap from CPI-based inflation estimation result does not show significant at even 10% significant level. This indicates that BNM does not take past output gap into consideration when setting interest rate. On the other hand, we also found strong evidences that BNM has interest rate smoothing behaviour from backward-looking Taylor rule model. The coefficient of lag one interbank rate is significant at 1% significant level.

By reviewing back the OLS and TSLS estimation from backward Taylor rule model, we concluded that BNM does not target on GDP based inflation and PPI based inflation. Instead, BNM targets on CPI based inflation.

Lastly, we would interest on another question: Does the central bank respond to the expectation of inflation and expectation of output gap? To answer this question, we will proceed to forward-looking Taylor rule estimation in next section.

Table 4.10 Forward-looking Taylor rule Model (TSLS Estimation)

$$i_t = \hat{\rho} i_{t-1} + (1-\hat{\rho})\left[\hat{\beta}_a + \hat{\beta}_\pi \pi_{t+1} + \hat{\beta}_\gamma y^*_{t+1}\right] + u_t$$

Equation	CPI (a)	CPI (b)	CPI (c)
Sample Period	1991Q2 2012Q4	1991Q3 2012Q4	1991Q4 2012Q4
$\hat{\rho}$	0.8782*** (0.0514)	0.8851*** (0.0488)	0.8792*** (0.0471)
$\hat{\beta}_a$	-0.7160 (1.3412)	-0.5326 (1.3816)	-0.3917 (1.3316)
$\hat{\beta}_\pi$	1.7307*** (0.5449)	1.6468*** (0.5749)	1.5701*** (0.5437)
$\hat{\beta}_\gamma$	0.3564* (0.1814)	0.5057*** (0.1675)	0.5225*** (0.1723)
Diagnostic Checking			
Wald test-statistic Reduced Form Eq. (π_{t+1})	12.1802	10.8979	14.5517
Wald test-statistic Reduced Form Eq. (y^*_{t+1})	19.3240	26.4276	27.7689
Sargan test-statistic (NR^2)	5.8314	7.6070	9.1507
DW test-statistic	1.7425	1.7424	1.7742
LM(1)	0.2017	0.2489	0.2844
LM(2)	0.3896	0.4382	0.4393
LM(3)	0.5945	0.6479	0.6489
ARCH (1)	0.0220	0.0355	0.0271
ARCH (2)	0.0713	0.1105	0.0905
ARCH (3)	0.1474	0.2269	0.1935
RMSE	0.6820	0.6485	0.6503

Note 1: (a) indicates instrument lists [i_t , π_{t+1} , y^*_{t+1}][lag1 to lag4] (b) indicates instrument lists [i_t , π_{t+1} , y^*_{t+1}][lag1 to lag5] (c) indicates instrument lists [i_t , π_{t+1} , y^*_{t+1}][lag1 to lag6]

Note 2: Wald test-statistic of Reduced Form Equations (π_t) and (y^*_t) are used to conduct weak instrument test. F >10 means there is less likely to have weak instrument problem.

Note 3: Sargan test-statistic is computed for instrument validity test. H_0: Instrument lists are valid.

Note 4: LM test, ARCH test, JB test are based on P-value.

Note 5: [LM Test, Arch Test] (1), (2), (3) indicate lag one to lag three results.

Note 6: The asterisks, ***, makes indicate rejection of the null hypothesis at 10%, 5% and 1% level of significance respectively, t-statistic in parentheses.

Note 7: Newey-West HAC procedure applied when we discovered autocorrelation or hetereoscedascity at 5% significant level.

4.4.4 Evaluation of Forward-Looking Taylor rule Model (TSLS Estimation)

Referred to the **Table 4.7**, there is only estimation of CPI-based inflation suffered from endogeneity problem. We proceed to TSLS estimation to deal with the endogeneity problem. **Table 4.10** above showed the complete picture on our TSLS estimation results for forward-looking Taylor rule model.

Before we start to examine the TSLS result, we first proceed to diagnostic checking to ensure the validity of TSLS estimation result first. The F test-statistics of all reduced form equations more than 10 indicate that there is no weak instrument problem. We further confirmed that there is no weak instrument problem since standard error of inflation and output gap coefficient in TSLS are smaller than OLS. All Sargan test-statistics are insignificant at 10% significant level indicate that the instrument lists are valid. By fulfilled no weak instruments problem and valid of instrument lists, the TSLS estimations asymptotically normally distributed.

Besides that, all TSLS estimations do not suffered from heteroscedascity problem at 1% significant level and autocorrelation problem at 10% significant level. Even so, we still applied Newey-West HAC procedure when autocorrelation problem discovered at 5% significant level. This could make our hypothesis testing to be more robust.

By looking on our TSLS estimations, the results showed improvement compared to the previous OLS estimations that suffered from endogeneity problem. From TSLS estimations, we can observe that the inflation coefficients became larger and output gap coefficient became smaller. Inflation coefficients have fulfilled Taylor rule principle which is more than one. The coefficients for output gap are positive and statistically significant at 1% significant level. Therefore, coefficients for output gap are also complied with Taylor rule principle. After that, the coefficients for the three estimations results are close to each other. This indicates that our TSLS estimations are quite stable and robust.

Both expected inflation and expected output gap coefficients are significant at 1% significant level with group (b) and (c) instrument lists. In such situations, this proved that BNM has followed Taylor rule principle in setting the interest rate. It also shows that BNM has responded to expected CPI based inflation and expected output gap.

By examining the TSLS estimation, we found that the coefficient of lag one interbank rate is also significant at 1% significant level. Therefore, there is evidence to indicate that BNM has the interest rate smoothing behaviour as similar result we discovered in contemporaneous and backward-looking Taylor rule model. This shows interest rate smoothing is one of the important components when BNM make their decision in setting interest rate regardless of any types of Taylor rule model.

We would like to pick the CPI-based inflation with group (b) instrument lists as the best forward-looking Taylor rule model out of the three estimation results. It has the lowest RMSE among all three estimations. Lowest RMSE indicates that it can perform the best forecast. We will use it as benchmark when we want to make comparison with contemporaneous and backward-looking Taylor rule model.

The interesting part is we found the expected inflation coefficient has the highest value compared to the coefficient of current inflation (contemporaneous Taylor rule estimation) and coefficient of past inflation (backward-looking Taylor rule estimation). The expected inflation coefficient (1.6468) is slightly higher than current inflation coefficient (1.4632) and higher than past inflation coefficient (1.0030). This indicates that BNM has the strongest reaction when they respond to the expected inflation. This could be explained that BNM will respond the most to expectation since expectation could influence all the economic activities. It is probably that BNM want to accommodate the public expectation to be more effective in stabilizing the inflation.

On the other hand, we also found that there is strong evidence that BNM has responded towards expected output gap. We discovered another interesting fact when we compared to contemporaneous Taylor rule estimation. The both coefficients:

current output gap (0.5527) and expected output gap (0.5057) are close to each other. Therefore, this indicates that BNM has indifferent reaction when they respond to current output gap and expected output gap.

Reviewing both OLS estimation and TSLS estimation, we can conclude that BNM does not target on GDP based-inflation or PPI based-inflation from forward-looking Taylor rule perspective. Instead, we found BNM has only targeted CPI based-inflation. This is consistent with we found in contemporaneous and backward-looking Taylor rule estimations.

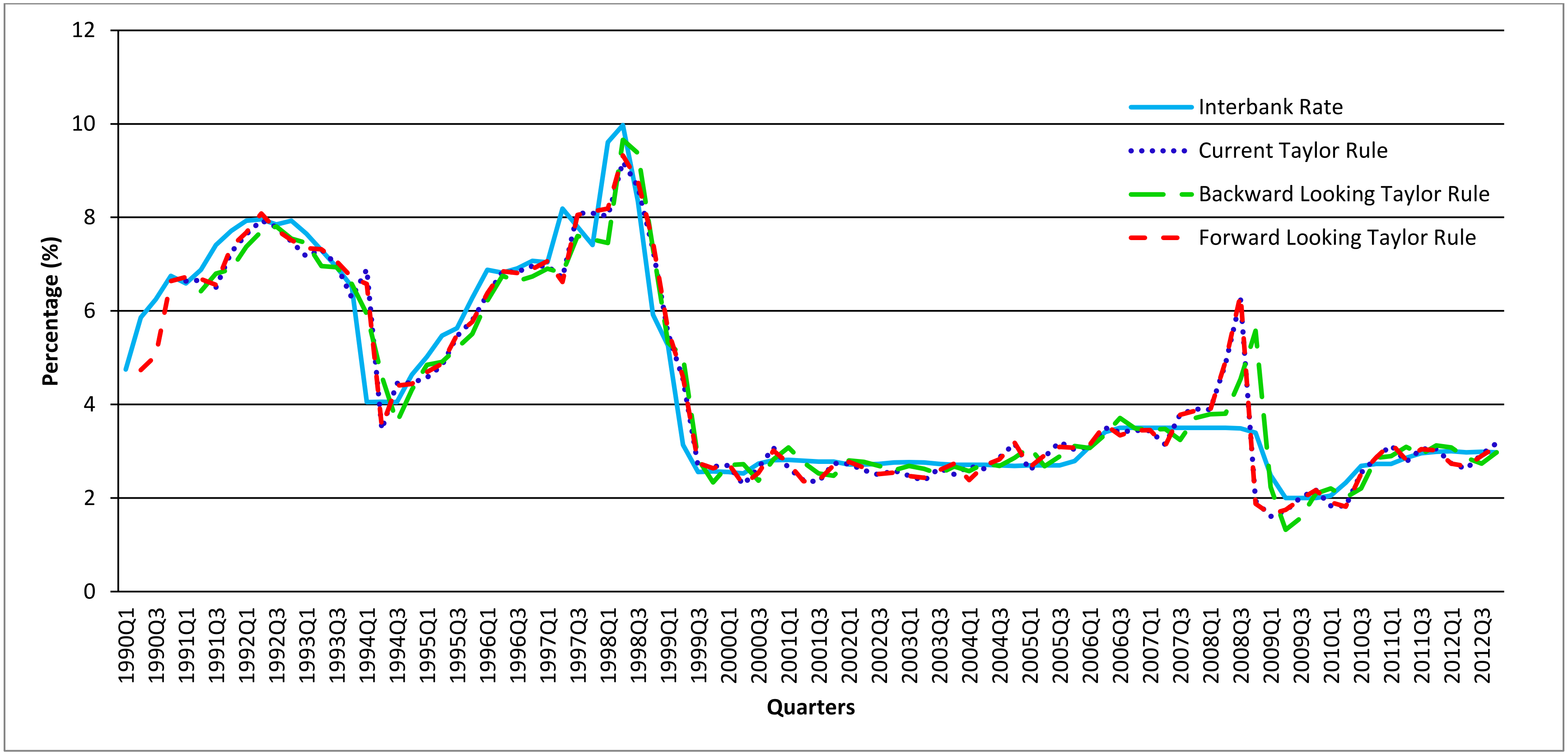
Lastly, there is one question that we would like to examine: which types of Taylor rule model give the best answer to explain the BNM behaviour? Through comparison, we found that the RMSE for each type of Taylor rules are close to each other. RMSE of contemporaneous (0.6462), backward-looking (0.5836) and forward-looking (0.6485) are close to each other. We are unable to identify which type of Taylor rules can explain the BNM behaviour solely. However, the estimation results give an insight to us that BNM's interest rate setting has taken past, current and expected inflation into consideration. The degree of responses also varies regarding to past, current and expected inflation. Besides that, BNM also take current and expected output gap into consideration.

In the next section, we will show and discuss further on the forecast performance of the three types of Taylor rule with the actual interbank rate.

4.5 Performance of Taylor rule Estimations

The estimated results of contemporaneous, backward-looking and forward-looking Taylor rules in our study are shown in **Figure 4.1.** We have plotted the estimated values with the actual values of interbank rate that started with different periods.

Figure 4.1: The Estimated and True Interbank Rate of Malaysia.



4.5.1 Evaluation of Taylor rule Performance

Referred to figure 4.0, interbank rate started from the first quarter of 1990. Estimated values of forward-looking Taylor rule began from the second quarter of 1990. Estimated values of contemporaneous Taylor rule started from first quarter of 1991. Estimated values of backward-looking Taylor rule began from second quarter of 1991.

The figure shows that the estimated values of interbank rate of contemporaneous, backward-looking and forward-looking Taylor rule are close to each others. All estimated interbank rate of three types of interbank rate are also have the same trend as the actual interbank rate in Malaysia over the years except from the fourth quarter of 2007 to the third quarter of 2008. In fact, we discovered that inflation rate from fourth quarter of 2007 started to rise sharply until third quarter of 2008. According to annualized CPI based inflation we computed, the inflation rate for 2007:4, 2008:1, 2008:2 and 2008:3 are 3.01%, 4.10%, 9.17% and 15.99% respectively.

The numbers showed that Malaysia inflation rate raise up sharply in those periods. The possible reason to explain why there was high inflation occurred for 2008 is due to rising oil price. By tracking oil price movement from 2007 to 2008, we can observe the rising trend for oil price. Oil price started to rise from 2007 and reached the peak at 2008. Theoretically, rising oil price will affect supply side and cause higher inflation. Therefore, this can explain that why Malaysia faced high inflation during 2008:1 and 2008:2. Under Taylor rule principle, BNM should adjust with higher interest rate in order to lower down the inflation rate. However, BNM maintained interest rate during that time. BNM did not follow Taylor rule principle to set interest rate during that time. The possible explanation is BNM might concern to other economic problems and made the decision to maintain interest rate.

4.6 Conclusion

Generally, the estimated interbank rate from contemporaneous, backward-looking and forward-looking Taylor rules are fitted well and follow the trend of the actual interbank rate over the years. It proved that BNM has followed Taylor rule principle in setting the interest rate regarding to past interest rate, inflation and output gap.

CHAPTER 5: CONCLUSION

5.0 Introduction

The objective of this study is to investigate monetary behaviour of BNM in conducting monetary policy in respond to the changes in price level and output gap. In order to have a deep study for the choices of inflation, we also examined the types of inflation rate targeted by BNM in Malaysia. This paper performed the empirical analysis of contemporaneous, backward-looking and forward-looking Taylor rules which were estimated by using Ordinary Least Square (OLS) and Two-Stage Least Square method (TSLS). In this chapter, we included the summarization and discussion of major findings, policy implications, limitations and recommendations that can be improved for future analysis.

5.1 Summary and Discussions of Major Findings

In the preliminary stage, we have applied OLS estimation which was commonly used by previous Taylor rule researchers for our research. However, we discovered there are econometrics problems such as non-normality distribution, autocorrelation and heteroscedascity problem. Furthermore, we also found that the coefficients of inflation rate do not match with Taylor rule principle because the coefficients of inflation rate are less than one. We have found invalid Taylor rule estimation result from OLS estimations.

We suspected that there is endogeneity problem, thus we chose to perform diagnostic checking on the endogeneity problem. It is very common to have endogeneity problem for Taylor rule model because inflation and output gap can be determined endogenously with interest rate. Endogeneity problem will cause the OLS estimation to be biased and inconsistent. We have selected three groups of lag values as instrument lists to detect the endogeneity problem. Lag values of independent variables and dependant variable are very commonly used as instrument lists to perform instrument variable estimation. Therefore, we used them to conduct the endogeneity test and proceed to instrument variables estimation if we detected endogeneity problem.

However, if there is no endogeneity problem exists for the estimation results, this may indicate that BNM did not follow Taylor rule principle or did not target on those types of inflation rate since estimation results do not comply with Taylor rule principle. Before we reach a conclusion, we proceed to endogeneity test to confirm the existence of endogeneity problem.

As expected, we found some equations in contemporaneous, backward-looking and forward-looking Taylor rule's OLS estimations suffered from endogeneity problem. Therefore, we proceed to TSLS estimation to tackle the endogeneity problem that was found in the relevant OLS estimations.

Regardless contemporaneous, backward-looking and forward-looking Taylor rule model, TSLS estimation results with CPI-based inflation have matched with Taylor rule principle. We obtained the results where the coefficient of inflation rate more than one and thus comply with Taylor rule principle. The TSLS estimation results of GDP based inflation and PPI based inflation from backward looking Taylor rule model do not comply with Taylor rule principle. By further reviewing both results from OLS and TSLS estimations for all types of Taylor rule, we concluded that BNM has only targeted on CPI-based inflation rather than GDP-based inflation and PPI-based inflation.

By evaluating the TSLS estimation results, we discovered several important findings. Firstly, there is strong evidence to prove that BNM has interest rate smoothing behaviour regardless contemporaneous, backward-looking and forward-looking Taylor rule TSLS estimations.

Secondly, we discovered the coefficient of current inflation is higher than past inflation and the coefficient of expected inflation has the highest coefficient value. This indicates that BNM has the weakest response towards the past inflation, stronger response to the current inflation and the strongest response towards to expected inflation.

Thirdly, we discovered that coefficient of past output gap is statistically insignificant. This indicates that BNM has not taken the past output gap into consideration in setting interest rate. Fourthly, we discovered that BNM has indifferent reaction towards current output gap and expected output gap because both coefficients' values are close to each other and statistically significant.

Lastly, by evaluating the performance of all three types of Taylor rule, we found that they have the same pattern as the trend of actual interbank rate. The only exception was happened during 2007 quarter 4 to 2008 quarter 3. We spotted huge difference between the Taylor rule estimated value and actual value of interbank rate during 2007 quarter 4 to 2008 quarter 3. This can be explained by rising in the world oil prices had led to the rising inflation from 2007 to 2008 in Malaysia. According to Taylor rule principle, BNM should increase the interest rate in order to lower down the inflation rate during that particular time. However, BNM did not follow Taylor rule principle to adjust the interest rate during that particular time. The possible explanation is BNM might concern to other economic problems and made the decision to maintain the interest rate.

As conclusion, we are unable identify which types of Taylor rule have the best explanation for the BNM behaviour. The three types of Taylor rule estimated value do not yield much different when we compared through their RMSE and **Figure 4.1**. However, the TSLS estimations give us an insight that BNM has considered past interest rate, past inflation, current inflation, expected inflation, current output gap and expected output gap in setting interest rate.

5.2 Policy Implications

Taylor rule can provide the good guidance for central bank to maximize the economic development by balancing the trade-off between inflation problem and output gap. In practical, central bank sometimes may place too much weight by setting interest rate to tackle either inflation problem or output development. For an example, if central bank places too much weight to the inflation problem, the adjustment of interest rate may not take into consideration of GDP development of the country. Trade-off problem occurs where setting high interest rate to deal with inflation problem can deteriorate GDP growth at the same time.

Since Taylor rule equation takes into consideration for both inflation and output gap issue, it is able to avoid the trade-off problem, provide optimal guidance to BNM for the development of Malaysia and serve as guidance for public to know how BNM set the interest rate policy.

5.3 Limitations and Recommendations

There are two major limitations for our study. Firstly, our scope of study is limit to simple Taylor rule model. We are only interested to examine how BNM responds towards changes in price level and output gap. Therefore, we do not include other macroeconomic variables to our model. Future researchers can further the scope of study by including other macroeconomic variables such as stock price, financial index, real exchange rate and so on.

Lastly, our research emphasized in identifying which types of inflation rate target by BNM. Our scope of study is limit to examine the types of inflation rate target by BNM. Therefore, our research is lack of comparison the choices of variables or proxies for output gap. Therefore, we suggest future researchers to further study by comparing proxies such as real output growth, industrial production index and unemployment rate with the output gap.

5.4 Conclusion

Although our study may suffer from various limitations, it can be served as a guideline or contribution of literature for future researchers who conduct similar area of interest. In addition, future researchers can consider the limitations that we mentioned in order to obtain a better empirical analysis of this study in the future.

REFERENCES

Aizenman, J., Hutchison, M. and Noy, I. (2011). Inflation targeting and real exchange rates in emerging markets. *World Development 39(5)*, 712-724.

Batini, N., Harrison, R. and Millard, S. P. (2003). Monetary policy rules for an open economy. *Journal of Economic Dynamics & Control 27*, 2059-2094.

Bhattarai, K. (2008). An empirical study of interest rate determination rules. *Applied Financial Economics 18*, 327-343.

BNM Administered Legislation. (2013). Retrieved April 21, 2013, from Central Bank of Malaysia Official Portal: http://www.bnm.gov.my/index.php?ch=en_legislation&pg=en_legislation_act&ac=858&full=1&lang=en

Bullard, J. and Mitra, K. (2002). Learning about monetary policy rules. *Journal of Monetary Economics 49(6)*, 1105-1129.

Bunzel, H., & Enders, W. (2010). The Taylor rule and "opportunistic" monetary policy. *Journal of Money, Credit and Banking 42(5)*, 931-949.

Carlstrom, C. T. and Fuerst, T. S. (2012, October 12). Gaps versus growth rates in the Taylor Rule. *Economic Commentary, Federal Reserve Bank of Cleveland*. Retrieved from https://www.clevelandfed.org/research/Commentary/2012/2012-17.pdf

Castelnuovo, E. (2003). Taylor rules, omitted variables, and interest rate smoothing in the US. *Economics Letters 81*, 55-59.

Castro, V. (2011). Can Central Banks' monetary policy be described by a linear (augmented) Taylor rule or by a nonlinear rule? *Journal of Financial Stability 7*, 228-246.

Cermeño, R., Villagómez, F. A. and Polo, J. O. (2012). Monetary policy rules in a small open economy: An application to Mexico. *Journal of Applied Economics 15(2)*, 259-286.

Clarida, R., GalÌ, J. and Gertler, M. (1998). Monetary policy rules in practice: Some international evidence. *European Economic Review 42*, 1033-1067.

Clarida, R., Gali, J. and Gertler, M. (2000). Monetary policy rules and macroeconomic stability: Evidence and some theory. *The Quarterly Journal of Economics 115 (1)*, 147-180.

Cukierman, A. and Muscatelli, A. (2008). Nonlinear Taylor rules and asymmetric preferences in central banking: Evidence from the United Kingdom and the United States. *The BE Journal of macroeconomics 8(1)*, 1935-1690.

da Silveira Bueno, R. D. (2011). *Essays on the Taylor Rule*. United States: ProQuest. Retrieved from http://books.google.com.my/books?hl=en&lr=&id=-EWeS7yQYY4C&oi=fnd&pg=PR4&dq=Essays+on+the+Taylor+Rule&ots=V-_YQESlNW&sig=Kxn1X3skvg7rfkg7sgSpxx-QwbM&redir_esc=y

Dr. Singh, S. (2011, April 12). *Monetary policy framework in Malaysia*. Retrieved May 21, 2013, from F Step: http://www.fstep.org.my/media/File/Overview%20Week%20Notes/Monetary%20Framework_Dr%20Sukhdave_120411_Slide%202_BNM.pdf

Fair, R. C., and Howrey, E. P. (1996). Evaluating alternative monetary policy rules. *Journal of Monetary Economics 38(2)*, 173-193.

Fendel, R., Frenkel, M. and Rülke, J. C. (2011a). 'Ex-ante' Taylor rules – Newly discovered evidence from the G7 countries. *Journal of Macroeconomics 33*, 224-232.

Fendel, R., Frenkel, M. and Rülke, J. C. (2011b). ''Ex-ante'' Taylor rules and expectation forming in emerging markets. *Journal of Comparative Economics 39*, 230-244.

Frömmel, M., Garabedian, G. and Schobert, F. (2011). Monetary policy rules in central and eastern European countries: Does the exchange rate matter? *Journal of Macroeconomics 33*, 807-818.

Galimberti, J. K. and Moura, M. L. (2013). Taylor rules and exchange rate predictability in emerging economies. *Journal of International Money and Finance 32*, 1008-1031.

Gerlach, S. and Smets, F. (1999). Output gaps and monetary policy in the EMU area. *European Economic Review 43(4)*, 801-812.

Hutchison, M. M., Sengupta, R. and Singh, N. (2013). Dove or hawk? Characterizing monetary policy regime switches in India. *Emerging Markets Review 16*, 183-202.

Judd, J. P. and Rudebusch, G. D. (1998). Taylor's rule and the Fed: 1970–1997. *Economic Review-Federal Reserve Bank of San Francisco*, 3-16.

Kazanas, T., Philippopoulos, A. and Tzavalis, E. (2011). Monetary policy rules and business cycle conditions. *The Manchester School 79(2)*, 73-97.

Khan, F. J. (2011, January 1). *A nonparametric estimation of the Bank of Canada's reaction function*. Retrieved from DigitalResearch@Fordham: http://fordham.bepress.com/dissertations/AAI3466709

Leitemo, K. and Soderstrom, U. (2005). Simple monetary policy rules and exchange rate uncertainty. *Journal of International Money and Finance 24*, 481-507.

Lubik,T. A. and Schorfheide, F. (2007). Do central banks respond to exchange rate movements? A structural investigation. *Journal of Monetary Economics 54*, 1069-1087.

Martins, F., Machado, J. A. and Esteves, P. S. (2004). Modelling Taylor rule uncertainty: An application to the euro area. *Economic Modelling 21(3)*, 561-572.

Mehra, Y. P. and Minton, B. D. (2007). A Taylor rule and the Greenspan Era. *Economic Quarterly 93(3)*, 229-250.

Michaelides, P. and Milios, J. (2009). TFP change, output gap and inflation in the Russian Federation (1994–2006). *Journal of Economics and Business 61*, 339-352.

Moons, C. and Van Poeck, A. (2008). Does one size fit all? A Taylor-rule based analysis of monetary policy for current and future EMU members. *Applied Economics 40*, 193-199.

Mohamad Hasni Shaari. (2008, December). *Analyzing Bank Negara Malaysia's behaviour in formulating monetary policy: An empirical approach.* Retrieved from Autralian National University: https://digitalcollections.anu.edu.au/bitstream/1885/49317/2/02whole.pdf

Moura, M. L. and Carvalho, A. (2010). What can Taylor rules say about monetary policy in Latin America? *Journal of Macroeconomics 32*, 392-404.

Newey, W. K. and West, K. D. (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica 55(3)*, 703-708.

Osterholm, P. (2005). The Taylor rule and real-time data – a critical appraisal. *Applied Economics Letters 12*, 679-685.

Qin, T. and Enders, W. (2008). In-sample and out-of-sample properties of linear and nonlinear Taylor rules. *Journal of Macroeconomics 30*, 428-443.

Ramayandi, A. (2008, May). *Simple model for a small open economy: An application to the ASEAN-5 countries.* Retrieved July 11, 2013, from Department of Economics, Padjadjaran University: http://lp3e.fe.unpad.ac.id/wopeds/200801.pdf

Ramayandi, A. (2009, March). *Assessing Monetary Policy Efficiency in the ASEAN-5 Countries.* Retrieved July 11, 2013, from Department of Economics, Padjadjaran University: http://lp3e.fe.unpad.ac.id/wopeds/200902.pdf

Rudebusch, G. D. and Svensson, L. E. (1999). *Policy rules for inflation targeting.* (J. B. Taylor, Ed.) Chicago, United States of America: University of Chicago Press. Retrieved May 21, 2013, from http://www.nber.org/chapters/c7417

Seyfried, W. L. and Bremmer, D. S. (2001). Analyzing Fed behavior using a dynamic Taylor-rule type. *Journal of Economics and Finance 25(1)*, 23-32.

Smets, F. (2002). Output gap uncertainty: Does it matter for the Taylor rule? *Empirical Economics 27(1)*, 113-129.

Sulaiman D Muhammad, Adnan Hussain, Muhammad Ahsanuddn, Shazia Kazmi and Irlan Lal. (2012). Monetary policy reaction function in open economy version: Empirical evidence in case of Pakistan. *Asian Social Science 8(8)*, 1911-2017.

Surico, P. (2007). The Fed's monetary policy rule and US inflation: The case of asymmetric preferences. *Journal of Economic Dynamics and Control 31(1)*, 305-324.

Taylor, J. B. (1993). Discretion versus policy rules in practice. *Public Policy 39*, 195-214.

Taylor, J. B. (1999). A historical analysis of monetary policy rules. *Monetary Policy Rules*, 319 - 348.

Umezaki, S. (2007). Monetary policy in a small open economy: The case of Malaysia. *The Developing Economies XLV-4*, 437-64.

Williams, J. C. (2003). Simple Rules for Monetary Policy. *Economic Review-Federal Reserve Bank of San Francisco*, 1-12. Retrieved June 24, 2013, from http://www.frbsf.org/economic-research/econrev/2000/article1.pdf

Yau, R. (2010). Estimating forward-looking Taylor rule by GMM with factor instruments. *International Conference On Applied Economics*, 837-843.