Analyzing Bank Negara Malaysia’s Behaviour in Formulating Monetary Policy: An Empirical Approach

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Declaration

Unless otherwise indicated this thesis is my own work.

MOHAMAD HASNI SHAARI
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I dedicate this thesis to my parents, Shaari Ahmad and Che Som Othman.
Abstract

In an economic system, the central bank is entrusted with the responsibility of formulating monetary policy. Despite its important role and significant contribution in influencing the well being of other economic agents in the economy, in general, little is known about a central bank’s underlying behaviour in executing this task. Among the key questions that the non-policymakers raise on this area are: How do central bankers actually formulate monetary policy? Do they behave systematically and follow any form of rule? What are the objectives that they want to pursue? How do they prioritize these different objectives? How does their policy behaviour evolve over time? What happens if they act differently?

Existing studies which analyze a central banks’ behaviour in formulating monetary policy, are mostly concentrated on the experience of developed economies. However, developing economies face a different institutional structure, as well as a different set of constraints and shocks, hence, it would be interesting to analyze how a central bank under this different economic environment performs its monetary policy mandate. This thesis looks at the behaviour of Bank Negara Malaysia (The Central Bank of Malaysia) in formulating monetary policy in Malaysia during the period 1975-2005.

There are four major aspects of Bank Negara Malaysia’s (BNM) policy behaviour that are examined in this thesis. Firstly, with regard to its policy reaction function - does BNM set interest rates according to some form of policy rule or purely on a discretionary manner? After identifying the systematic component of its policy action, we try to establish BNM’s policy objectives and preferences. This will help in understanding the rationale behind its policy action. The third aspect is whether BNM’s policy behaviour changes over time. Lastly, with the use of an estimated Dynamic Stochastic General Equilibrium (DSGE) model, we conduct some policy experiments to observe the possible impact on the Malaysia’s economic outcomes were BNM to behave differently to what we envisaged its policy behaviour has been.
## Contents

1 Introduction

1.1 What do we want to know about a Central Bank’s Behaviour in Formulating Monetary Policy? ................................................................. 3

1.2 Formulation of Monetary Policy in Malaysia in Three Decades: 1975-2005 .............................................................................. 7

1.3 Outline of the Thesis ..................................................................... 15

2 Theoretical and Empirical Framework to Analyze a Central Bank’s Behaviour in Formulating Monetary Policy ................................................. 19

2.1 Monetary Policy Rules .................................................................. 20

2.2 Modelling a Central Bank’s Problems ........................................ 26

2.3 Empirical Methods to Analyze a Central Bank’s Behaviour .......... 32

2.4 Conclusion .................................................................................. 35

3 Estimating Bank Negara Malaysia’s Reaction Function with a Simple Interest Rate Rule ............................................................... 37

3.1 Specification of Simple Interest Rate Rule ................................. 39

3.2 Specification of BNM’s Reaction Function ................................. 41
6 An Estimated DSGE Model of the Malaysian Economy: Sub-sample Periods and Possible Identification Problems 165

6.1 Estimation Results for Sub-sample Period ................................. 166

6.2 Possible Identification Problems ............................................. 174

6.3 Conclusion ............................................................................. 186

7 Simulating Bank Negara Malaysia’s Behaviour in Formulating Monetary Policy: Policy Experiment using a DSGE Model 189

7.1 Assumptions ........................................................................ 191

7.2 Simulation Results ................................................................. 194

7.3 Conclusion .......................................................................... 208

7.4 Appendix .............................................................................. 210

8 Conclusion ............................................................................. 213

8.1 What Have We Learned? ......................................................... 214

8.2 Limitations and Area for Further Research ............................. 219

Bibliography ............................................................................. 223

Definition and Source of Data .................................................... 241
List of Tables

1.1 Malaysia’s Key Macroeconomic Indicators ......................... 8

3.1 BNM’s Estimated Reaction Function with Different Specifications: 1975Q1-2005Q2 ................................. 46

3.2 BNM’s Estimated Reaction Function: Sub-sample Periods ........ 51

3.3 Results of Chow Test for Structural Break ....................... 62

3.4 Results of Unit Root Test .................................. 62

3.5 Correlation Between Dependent Variables and Instruments in IV Estimation .................................. 63

4.1 Estimation Results of SOEM: 1975Q1 to 2005Q2 .................. 82

4.2 Diagnostics for Residuals of Estimated SOEM Equations Across Different Sample Periods ............................. 83

4.3 Comparison of Statistical Moments Across Different Sample Periods ........................................ 84

4.4 Estimation Results of SOEM: Sub-sample Periods ................. 85

4.5 Estimation Results of SOEM: Sub-sample Periods (continue) .... 86

4.6 Estimated Parameters of BNM’s Loss Function ................... 88

5.1 Summary of Log-linearized System of Equations .................. 132
List of Figures

1.1 Malaysia’s Economic Development 1975-2005 .................. 9

3.1 Malaysia’s GDP Growth 1975Q1-2005Q2 .................. 55

3.2 Malaysia’s Inflation Rate 1975Q1-2005Q2 .................. 56

4.1 Residuals of Interest Rates Equation: 1975Q1-2005Q2 ............. 89

4.2 Residuals of Estimated SOEM Equations Across Different Period ...... 102

5.1 Prior and Posterior Distributions: FA Model 1975Q1-2005Q2 ............. 144

5.2 Prior and Posterior Distributions: NFA Model 1975Q1-2005Q2 ............. 145

5.3 FA vs. NFA Specification: Comparison of IRF 1975Q1-2005Q2 ............. 154

5.4 FA vs. NFA Specification: Comparison of IRF 1975Q1-2005Q2 (continue) 162

5.5 FA vs. NFA Specification: Comparison of IRF 1975Q1-2005Q2 (continue) 163

5.6 FA vs. NFA Specification: Comparison of IRF 1975Q1-2005Q2 (continue) 164

6.1 Prior and Posterior Distributions: Sub-Sample Period ............. 169

6.2 Prior and Posterior Distributions: Sub-Sample Period (continue) ....... 170

6.3 Prior and Posterior Distributions: 1975Q1-2005Q2 Period ............. 177
Chapter 1

Introduction

In the economic system, a central bank is the economic agent entrusted with the important responsibility of formulating and executing monetary policy. Acknowledging that a central bank’s actions can greatly influence the behaviour of economic agents and to a large extent overall economic outcomes, the announcement of policy decisions by a central bank generally attracts much attention and is closely scrutinized by a large number of interested parties and observers. These announced policy decisions reveal a central bank’s assessment of the economy and more importantly, its current and future monetary policy stance. Interested parties use this information in various ways to organize and execute their affairs. Despite being one of the most influential and important participants in an overall economic system, central bank behaviour in arriving at monetary policy decisions is not yet fully understood by non-policymakers. Hence, analysis of a central bank’s behaviour in formulating monetary policy is of considerable interest to both academic researchers and financial market participants. To gain further understanding on this issue, the key questions non-policymakers raise regarding a central bank’s behaviour are: How do central bankers actually formulate monetary policy? Do they follow any form of policy rule? What are the objectives they want to pursue? How do central bankers prioritize these different objectives? How does this behaviour evolve over time? What happens to the economic outcomes if they behave differently?

This interest has generated a large literature that attempts to describe, analyze and evaluate a central bank’s behaviour in formulating monetary policy over a specific period of time. However, existing studies in this area are mostly concentrated on
the experience of developed economies and not much information is known about the outcome of the same exercise in the case of developing countries. Given the different institutional structure, as well as the different nature of constraints and shocks faced by central banks in developing economies, it would be an interesting exercise to conduct the same studies on these countries. This thesis chooses Bank Negara Malaysia (The Central Bank of Malaysia) as the case study for three reasons. Firstly, Malaysia is categorized as a small open economy with a history of a low and stable inflation rate. To a large extent, this achievement is a result of the sound conduct of monetary policy formulated by Bank Negara Malaysia (BNM). Secondly, among the developing countries, Malaysia underwent and completed the deregulation process of its financial system relatively early. Deregulation of the banking system began in the early 1970’s and banking institutions’ interest rate was deregulated in 1978. Due to these factors, from 1980 onwards, BNM conducted monetary policy in a more stable financial environment which is one of the important determinants for effective transmission of monetary policy. Lastly, Malaysia has relatively good and long sets of time series data for the empirical exercise.

There are four main objectives of this research. The first objective is to identify and analyze the systematic component of interest rate movement in Malaysia. We do so by estimating BNM’s reaction function using a simple interest rate rule. Second, is to establish what are BNM’s policy objectives and relative preferences in conducting monetary policy. We model BNM’s policy behaviour as the solution to the optimal control problem and estimate the parameters of its loss function. The third objective is to investigate explicitly the possible evolution in BNM’s behaviour in executing its policy mandate. For this, besides using the full sample covering 1975Q1-2005Q2, the estimation exercises in this thesis are also conducted with three sub-sample periods - 1975Q1-1986Q4, 1987Q1-1998Q2 and 1998Q3-2005Q2. Lastly, with the use of an estimated Dynamic Stochastic General Equilibrium (DSGE) model for the Malaysian economy, we conduct a few policy experiments in relation to BNM’s policy behaviour. We analyze the possible impact to the economic outcomes if BNM was to behave differently from the way we have understood them.

This introduction chapter is divided into three sections. Section 1.1 outlines the main areas regarding a central bank’s behaviour in formulating monetary policy that the non-policymakers do not fully understand. Questions that we list in this section are also applicable to the case of BNM. Thus, they serve as the main motivation of this
thesis. Section 1.2 provides background information about the Malaysian economy. It also provides a brief overview about BNM’s roles and functions in the Malaysian financial system. Section 1.3 lays out the structure of this thesis.

1.1 What do we want to know about a Central Bank’s Behaviour in Formulating Monetary Policy?

In general, central banks’ underlying behaviour in arriving at monetary policy decisions is not fully understood by those who are outside the policy-making circle. On this regard, Clarida, Gali, and Gertler (1999) outline two main factors that have led to increased interest among economists in understanding how central banks conduct monetary policy. Firstly, the effect of monetary policy is shown in various empirical studies to be significant and important in influencing the aggregate activity in an economy. Leeper, Sims, and Zha (1996), Christiano, Eichenbaum, and Evans (1996) and King and Watson (1996), among others, have found empirical evidence of the significant effect of monetary policy shocks to the economy in the short-run. Due to its importance in influencing economic outcomes, it is natural for economists to scrutinize policymakers’ behaviour in formulating policy decisions. Secondly, there has been considerable improvement in recent years, in the underlying theoretical framework used for policy analysis. The use of dynamic general equilibrium theory in models’ construction provides better theoretical underpinnings to the analysis of monetary policy. This approach address the Lucas critique - the flaw of the policy evaluation exercise that is undertaken using the traditional macroeconometric structural models which treats parameters to be time invariant to the policy action (Lucas (1976)). As such, working with theoretically consistent models provides a better framework for policy evaluation exercises to be undertaken. It also establishes a better foundation for researchers to extend their analysis on monetary policy from descriptive to normative perspectives. Following these two premises, in the pursuit of gaining a better understanding of central banks’ behaviour in formulating monetary policy, the empirical literature has focused on the following key questions:
Q1. How is monetary policy formulated? Does a central bank’s action follow any form of systematic pattern or rules?

Acknowledging the fact that formulation of monetary policy is a complex procedure, this question tries to determine a suitable framework that outside parties (i.e. those not involved in the policy-making) can use to model a central bank’s decision making process. In effect, the answer to this question is important as the starting point towards understanding a central bank’s behaviour in formulating monetary policy. The analysis of a central bank’s behaviour can be undertaken in an objective and logical manner if the observed central bank’s action could be modelled using a certain form of systematic pattern or principles.

In this regard, a central bank’s behaviour is generally modelled with a certain form of monetary rule. It is either assumed the central bank sets the interest rate according to some simple rule, along the lines of the simple interest rate rule suggested by Henderson and McKibbin (1993) and Taylor (1993) (HMT); or the central bank is assumed to base decisions on an optimal/complex rule derived from an explicit objective function along the line used in Rudebusch and Svensson (1999), Svensson (1999) and Woodford (2003). More detailed discussion on this issue is given in Chapter 2.

Q2. What are the objectives of monetary policy?

Although the answer to this question seems quite obvious for a central bank that officially adopts the inflation-targeting framework, it is not clearly spelled out in most countries that do not officially operate under this framework. Hence, it is informative to uncover this explicit objective. In addition, it is possible a central bank has more than one policy objective. Knowing exactly what these objectives are will form a basis to better understand the possible “balancing act” policymakers face in executing their mandate.

Q3. What are a central bank’s relative preferences between different objective variables?

While the variables that are policy objectives (inflation, output, the exchange rate) could be known, precisely how these stabilization objectives are traded-off is not well known. Thus, in deciding the interest rate level, how much weight does a central bank place in its loss function on each of these objectives? Information on the relative weights
a central bank put on its objective variables can be used to classify the central bank regime. On this point, Svensson (1999) categorized central banks into two types. A central bank with the sole objective of achieving price stability will attach zero weight to other variables in its loss function. Svensson termed this type of central bank as the “strict” inflation targeters. In contrast, a central bank with multiple objectives that allocates non-zero weight to variables other than inflation is known as a “flexible” inflation targeter.

The weights a central bank puts on the different objective variables will also determine the form of its reaction function, as well as the performance and evolution of economic outcomes. For instance, Rudebusch and Svensson (1999) show that in the context of the inflation forecast targeting framework, the higher the weight a central bank puts on output stabilization, the slower the adjustment of the inflation forecast towards the long-run inflation target. Hence, knowing what regime the central bank is operating and the size of the weights it attaches to different objectives will help in better understanding its overall behaviour in making policy decisions. In addition, these policy preferences play a central role in determining the dynamic response of the economy following a particular shock. For example, how the economy responds to an oil price shock will depend on the policy action taken by the policymakers. This policy response is largely guided by the policymakers’ underlying preferences on different objective variables.

Q4. Evolution of central bank behaviour over time

There are three likely reasons for possible changes in a central bank’s preferences over time. Firstly, change could be attributed to changes in a central bank’s top management, who may attach different weighting to different objective variables. This issue is particularly important for an independent central bank which is able to determine its own policy objectives and preferences. Secondly, differences in the preferences between different objectives could be attributed to the evolution of the macroeconomic structure itself. For example, central bankers’ ability to assess the true state of the economy can be jeopardized by the difficulty of estimating the true potential output. With increasing uncertainty on the actual state of the economy, policymakers’ preference to stabilize output around its natural level could be lower, in order to minimize the possibility of compounding errors in policy action. Alternatively, due to an increase in uncertainty, a central bank may increase its policy inertia by demonstrating higher preferences for interest rate smoothing. This risk aversion action is consistent
with the famous recommendation put forward by Brainard (1967). Thirdly, change in policymakers’ policy preferences could happen due to special economic circumstances that requires a different policy response from the central bank. The simplest example for this is the way the ASEAN countries’ central banks (including BNM) responded to the 1997 Asia Financial Crisis. At that time, speculative attack on the regional currency prompted most of the central banks in the region to raise interest rates with the temporary objective of curbing short-term capital outflow. Perhaps, in the recent (2008) Global Financial turmoil, we see the repeat of such behaviour from the central banks around the world. Concern about the stability of the financial system prompted central banks to cut interest rates aggressively.

Q5. Policy Evaluation and Simulation

This analysis acts as a “report card” on the performance of a central bank in formulating monetary policy. For example, to achieve price stability, Taylor (1993) argues central banks must set interest rates by reacting to inflation more than on one-to-one basis. As such, a central bank must set its instrument rule such that the coefficient on inflation is greater than unity – known in the literature as Taylor’s Principle. In the case of the US, several studies like Judd and Rudebusch (1998), Clarida, Gali, and Gertler (1998, 2000), Taylor (1999a) and suggest the high inflation experienced during the 1970’s can be explained by the fact that the Fed’s reaction function did not fulfill Taylor’s principle. More importantly, these studies try to evaluate a central bank’s policy “success” and “mistakes” and relate them to the past performance of the economy. The outcome of this evaluation allows learning from past experience.

In Chapter 2, we will discuss the strategy to answer these key questions. It begins by outlining an analytical framework that can be used to describe a central bank’s behaviour in formulating monetary policy. The empirical approaches employed in the literature to answer the above questions, are then reviewed and discussed.
1.2 Formulation of Monetary Policy in Malaysia in Three Decades: 1975-2005

This section provides a short overview of the economic structure and the conduct of monetary policy in Malaysia. It will be useful to give a general idea about the economic environment in which BNM operates. Since the literature adequately covers the historical development of the Malaysian economy, we do not provide a detailed analysis of this topic here. Interested readers are invited to refer to Salleh and Meyanathan (1993), Athukorala (2001), Navaratnam (2003), Mahadevan (2007) and Ang (2008) who provide detailed analysis of the historical economic development and transformation of the Malaysian economy over the past 50 years. In addition, Gomez and Sundram (1997) and Ritchie (2005) provide an analytical review about Malaysia’s economic development from the perspective of a political economy.

Similarly, areas related to the historical account about the conduct of monetary policy in Malaysia, are reported in great detail in various BNM’s official publications. In particular, two books published by BNM, “Money and Banking in Malaysia” (Bank Negara Malaysia (1994b)) and “The Central Bank and Financial System in Malaysia: A Decade of Change 1989-1999” (Bank Negara Malaysia (1999)) provide detailed analysis about BNM’s role and function in shaping Malaysia’s economic development between 1959-1999.

1.2.1 Snapshot of Malaysia’s Economic Development

Malaysia is a developing economy. The economy is small and open with a total population of around 27 million. Malaysia’s economic system is essentially driven by the private sector, with the Government playing an active role in development planning to promote balanced economic growth and social progress. The utilization and development of the nation’s natural, mineral and human resources, aided by political stability it enjoys, has made Malaysia one of the relatively more progressive, prosperous and among the fastest growing economies in Asia. Together, these factors have contributed to the continuous improvement in the quality and standard of living among the Malaysian population. The Malaysian economic development experience has also been unique in many respects - the economy has managed to achieved consistently high rates of economic growth with relative price stability. It also has a high level of national
Table 1.1: Malaysia’s Key Macroeconomic Indicators

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<tbody>
<tr>
<td>Real GDP (% change)</td>
<td>5.0</td>
<td>7.4</td>
<td>9.0</td>
<td>8.9</td>
<td>5.3</td>
</tr>
<tr>
<td>Inflation (%)</td>
<td>1.9</td>
<td>6.7</td>
<td>3.1</td>
<td>1.6</td>
<td>3.0</td>
</tr>
<tr>
<td>Population (million persons)</td>
<td>10.4</td>
<td>13.7</td>
<td>17.8</td>
<td>23.5</td>
<td>26.7</td>
</tr>
<tr>
<td>Labour force (million persons)</td>
<td>n.a.</td>
<td>n.a.</td>
<td>7.0</td>
<td>9.6</td>
<td>11.3</td>
</tr>
<tr>
<td>Unemployment rate (% of labour force)</td>
<td>7.7</td>
<td>5.6</td>
<td>5.1</td>
<td>3.1</td>
<td>3.5</td>
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<tr>
<td>Composition of GDP (% share)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Agriculture</td>
<td>32.1</td>
<td>22.9</td>
<td>16.3</td>
<td>8.9</td>
<td>8.2</td>
</tr>
<tr>
<td>Mining</td>
<td>6.6</td>
<td>10.1</td>
<td>9.4</td>
<td>7.3</td>
<td>6.7</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>14.0</td>
<td>19.6</td>
<td>24.6</td>
<td>31.9</td>
<td>31.4</td>
</tr>
<tr>
<td>Construction</td>
<td>4.0</td>
<td>4.6</td>
<td>3.5</td>
<td>3.3</td>
<td>2.7</td>
</tr>
<tr>
<td>Services</td>
<td>43.3</td>
<td>42.8</td>
<td>46.2</td>
<td>48.6</td>
<td>58.1</td>
</tr>
<tr>
<td>GNP Per Capita (RM)</td>
<td>1,071</td>
<td>3,734</td>
<td>6,206</td>
<td>13,333</td>
<td>17,715</td>
</tr>
<tr>
<td>Gross National Saving (% of GNP)</td>
<td>18.0</td>
<td>30.4</td>
<td>31.6</td>
<td>40.1</td>
<td>37.1</td>
</tr>
<tr>
<td>Gross Domestic Investment (% of GNP)</td>
<td>17.8</td>
<td>31.6</td>
<td>33.8</td>
<td>29.8</td>
<td>20.7</td>
</tr>
<tr>
<td>Trade balance (RM billion)</td>
<td>0.9</td>
<td>4.7</td>
<td>0.5</td>
<td>61.8</td>
<td>99.8</td>
</tr>
<tr>
<td>Total trade (% GNP)</td>
<td>81.2</td>
<td>100.5</td>
<td>139.5</td>
<td>217.9</td>
<td>200.2</td>
</tr>
<tr>
<td>Current account balance (% GNP)</td>
<td>0.2</td>
<td>-1.2</td>
<td>-2.2</td>
<td>10.3</td>
<td>16.4</td>
</tr>
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<td>Total External debt (% GNP)</td>
<td>n.a.</td>
<td>n.a.</td>
<td>40.3</td>
<td>51.2</td>
<td>41.4</td>
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<td>Federal Government overall balance (% of GNP)</td>
<td>-4.1</td>
<td>-7.2</td>
<td>-3.0</td>
<td>-6.3</td>
<td>-4.1</td>
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<tr>
<td>BNM’s net international reserves (as months of retained imports)</td>
<td>6.3</td>
<td>5.4</td>
<td>4.1</td>
<td>4.5</td>
<td>7.8</td>
</tr>
<tr>
<td>Exchange Rate (end period)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US$/RM</td>
<td>3.077</td>
<td>2.217</td>
<td>2.698</td>
<td>3.800*</td>
<td>3.7780*</td>
</tr>
</tbody>
</table>

* Ringgit Malaysia (RM) was pegged to USD1=RM3.80 between 2 September 1998 to 21 July 2005

Source: BNM’s publication and author’s calculation
Figure 1.1: Malaysia’s Economic Development 1975-2005

savings and investments together with sound fiscal management. This is complemented with prudent monetary management by BNM. Statistics reported in Table 1.1 provide a general overview of Malaysia’s economic development over the last four decades. Movement of inflation, GDP growth, interest rates and exchange rates over the 1975-2005 period is shown in Figure 1.1.

Malaysia is essentially a trade-oriented economy. In 1970, its value of trade (both exports and imports) amounted to 80% of GNP and this has increased tremendously over the years. By 2005, the value of Malaysia’s trade was about 200% of its GNP. The exports sector plays a dominant role in the Malaysian economy and is traditionally the most important determinant of the state of economic activity in the country over the short and medium term.

The Malaysian economy has undergone profound structural changes over the last 50 years. Since Independence in 1957, the economy has diversified away from the heavy reliance on the agricultural sector into a more broad-based and resilient economy with a well diversified production structure. In the early 1960s, agriculture accounted about 40% of GDP and over 60% of total employment and export earnings. However, following the implementation of several policy measures in the 1960s and 1970s aimed at export diversification, the economy has become more broad-based. By the mid-1980s, the manufacturing sector played a more dominant role in leading the growth process.
By 1995, the manufacturing sector accounted for nearly 35% of total GDP, compared with only 20% in 1980 and a mere 14% in 1970. In contrast, contributions of the agriculture sector declined steadily over the period. Starting from more than 30% in 1970, agriculture contributed less than 9% of the overall domestic output and 13% of total employment in 2005.

The expansion in the manufacturing sector came predominantly from production for exports purposes. The ratio of exports to total production (gross output) in manufacturing increased from around 10% in the early 1970s to over 65% by mid-1990s (Athukorala and Menon (1999)). Rapid export orientation of domestic manufacturing brought about a dramatic transformation in Malaysia’s export structure, which historically had been dominated by a limited range of primary commodities. In the early 1970s, the share of manufactures in Malaysia’s total exports was only 10% and by the mid-1990s, the share increases to about 78%. Foreign direct investment (FDI) played a pivotal role in the expansion of the manufacturing sector and in particular manufacturing exports. Foreign firms accounted for over 45% of total manufacturing value added and they accounted for over three-quarters of total manufactured exports by the mid-1990s (Athukorala (1998)).

As mentioned before, Malaysia had consistently enjoyed a high rate of economic growth. Overall real GDP grew by about 6.5% between 1975-2005. During 1988-1996, Malaysia experienced a long period of economic boom where GDP grew at an average rate of 9.5%. There were two brief periods of economic recession. The first, happened in 1985 following the collapse of commodity prices in the world market. The second recession was more severe. In 1998, in the aftermath of the 1997 Asian Financial Crisis, Malaysia’s GDP contracted by almost 7.5%. The economy bounced back in 1999 and from there on, enjoyed a more modest economic expansion.

1.2.2 BNM’s Role and Stipulated Policy Objectives

BNM, like other central banks, has many roles and responsibilities in the financial system and in the economy at large. Besides being responsible for formulating and conducting monetary policy, BNM is also the sole authority regulating and supervising the banking and insurance industry in Malaysia.
The principal objective of BNM is to promote monetary stability and a sound financial system. This objective is clearly defined as item (iii) in the Central Bank of Malaysia Act 1958 (Revised 1994):¹

"i. To issue currency and keep the reserves safeguarding the value of the currency;

ii. To act as a banker and adviser to the Government;

iii. To promote monetary stability and a sound financial structure; and

iv. To influence the credit situation to the advantage of Malaysia."

From a legislation point of view, besides its role to formulate and to conduct monetary policy, BNM views the multiple objectives of its formation as inter-related and complementary (page 84, Chapter 4: The Central Bank: Objectives, Functions and Organization Bank Negara Malaysia (1994b)).² BNM, because of its ability to issue currency, has the primary responsibility to ensure that domestic prices remain stable. Monetary stability, in turn, is dependent on the existence of a sound and stable financial system for the effective conduct of monetary policy. In contrast to matured industrial economies that have developed sophisticated financial systems, BNM has a wider role in developing the financial infrastructure. Of importance is also the need to promote the soundness of the financial system to allow the smooth functioning of the intermediation process.

While BNM recognizes that the role of monetary policy is crucial in attaining price stability, it also recognizes that price stability is not an end in itself. It is essential that there is coordination and an optimum mix of monetary and fiscal policies, in order to achieve growth with price stability. Hence, BNM works closely with other key agencies within the Government, particularly the Ministry of Finance, to achieve this objective.

¹Revision of the Act in 1994 does not involve any change in the way BNM conducts monetary policy. The revision was conducted in conjunction to the introduction of the Banking and Financial Institution Act (BAFIA) in 1994. BAFIA was introduced to enhance BNM's role as a financial regulator to banks and financial institutions in Malaysia. See Chapter 4 of Bank Negara Malaysia (1994b) for details.

²While BNM's objectives (i), (ii) and (iii) of the Act are self-explanatory, item (iv) warrants further explanation. BNM's stipulated objective "To influence the credit situation to the advantage of Malaysia" is related to BNM's mandate to mobilize financial resources (in particular domestic savings) for a productive use. This large scope involves BNM's role to develop the domestic financial system, i.e. banking system and capital market. See Chapter 4 of Bank Negara Malaysia (1994b) for details.
Consequently, in performing its role, BNM regards itself to be independent within the Government, but not of the Government (page 109, Chapter 3: Bank Negara Malaysia: Objectives, Functions and Organization Bank Negara Malaysia (1999)). This means that BNM has independence to make and execute policy actions that it sees fit in order to fulfill the objectives set by the Government.

1.2.3 Key Challenges in Formulating Monetary Policy

In general, the stance of monetary policy at any point of time reflects BNM’s reaction to the prevailing economic condition. We divide the description of key policy challenges that BNM face in conducting monetary policy in Malaysia in the last 30 years into three periods - 1975-1986, 1987-1996 and 1997-2005.

1.2.3.1 1975-1986: Managing High Inflation and Economic Recession

The unsettling and destabilizing international monetary conditions in the late 1970s meant that monetary policy during the 1975-84 period was directed primarily at maintaining price stability and ensuring a stable currency. In 1977-78, the international environment was subjected to strains arising from high inflation and growing imbalances in external payments among the major industrial countries. This led to turmoil in international currency markets centering on the marked weakening of the US dollar. Then, the international economic and financial environment in the 1980s posed a new dimension of challenges for the operation of monetary policy in Malaysia. The world economy in the early 1980s was characterized by the global recession, high energy prices in the wake of the “second oil-price shock” of 1979-1980, high global inflation stemming from price pressures emanating from the oil price increases and loose global monetary policy. Due to these factors, Malaysia’s inflation during this period started to gain momentum and reach its historical high of almost 9% in 1981 (see Figure 1.1).

By the mid-1980s, another challenge confronted Malaysia’s policymakers. With inflation no longer a threat, the sharp decline in commodity prices in the world market had a significant adverse impact on the Malaysian economy. By 1985, the Malaysian economy was in recession. Under these circumstances, monetary policy during 1984-86
was eased in stages. In addition, to complement the monetary easing, the ringgit was allowed to depreciate in small steps. Compared to the level in 1980 (US$1=RM2.17) the value of ringgit against the US dollar in 1986 had depreciated by almost 20% (US$1=RM2.62). Undoubtedly, weakening of the domestic currency provided impetus to the export market.

1.2.3.2 1987-1996: Managing Economic Success

Monetary management during the 1987-1996 period was confronted with challenges posed by prolonged and rapid domestic economic growth. Rapid expansion of the domestic economy over the nine years (averaging 9.3% per year) exerted substantial pressures on the existing resources. The economy was operating at full employment. This led to a steady increase in domestic inflation from around 0.3% in 1987 to reach its peak of 5% in 1992. To contain inflationary pressures, BNM adopted a tight monetary policy stance.

The task to manage inflationary pressures was made more difficult with the general decline in global interest rates. In the face of rising domestic interest rates, it caused interest rate differentials favouring Malaysia. This attracted substantial inflow of short-term foreign funds into the country. During the 1993-94 period, this large capital inflow led to a bull-run in the local stock market. It also caused excess liquidity in the banking system. Thus, monetary policy had to strike a delicate balance in terms of managing excess liquidity and reducing inflationary pressure, while at the same time avoiding undesirable speculative short-term capital inflows from destabilizing the economy.

Beside the interest differential favouring Malaysia, another factor that encouraged the inflow of short-term capital into the country was the general perception among the market players during that period that the Malaysian currency was undervalued. Given the booming export sector and the capacity constraint faced by the economy at that time, most market players expected BNM would allow the ringgit to appreciate to complement the tight monetary policy stance that it had adopted. However, this turned out not to be the case. Except for a small appreciation in 1992 (from around US$1=RM2.70 in 1991 to US$1=RM2.50 in 1992), between 1992-1996 BNM kept the exchange rate relatively stable (see Figure 1.1). Perhaps, BNM was reluctant to allow the ringgit to appreciate as such action would have hurt the export sector. To smooth
the upward pressure on the domestic currency, like other central banks, BNM conducted sterilized intervention operations.\textsuperscript{3} With the benefit of hindsight, BNM's strategy was not successful fending off the inflow of short-term capital. Given the severity of the problem, BNM opted to introduce several exchange control measures in January and February 1994 to deal with the highly destabilizing capital movement and to reassert control over monetary policy (page 289, Chapter 8: The Money and Foreign Exchange Markets, Bank Negara Malaysia (1999)). The controls were specific and intended to be short-term in nature to contain the speculative inflows. By August 1994, all these measures were lifted.

1.2.3.3 1997-2005: Managing Financial and Economic Crisis

The most challenging period for monetary policy came towards the end of the decade, following the outbreak of the regional financial crisis in mid-1997. The period saw extreme volatility in the financial markets. The crisis had severe and wide-ranging effects on financial and economic activities. Although the banking system was in a strong position at the beginning of the crisis, structural weaknesses in the system emerged as the crisis worsened. As such, BNM was faced with a difficult balancing act in fulfilling the objectives of its various roles. Besides the need to address the sharp contraction in GDP and rising inflation, BNM also needed to ensure the Malaysian banking system and financial markets remained intact and continued to operate effectively to weather this unprecedented financial crisis.

Following the speculative attacks and large capital outflow, the ringgit depreciated by 40\% against the US dollar in the period July 1997 - August 1998. The market perception of emerging risks in the Malaysian financial system and economic outlook resulted in the contagion effects on Malaysia being more severe, leading to a large liquidation of portfolio investment by the foreign investors. This led to significant downward pressure on the ringgit. The ringgit breached a historical low of US$1=RM4.88 on 7 January 1998. In addition to the continued uncertainty in the region, new risks emerged following the build-up of ringgit balances in the regional offshore centres. This can fuel further speculative activities and exert further downward pressure on the

\textsuperscript{3}In Chapter 4, we will discuss in more detail the mechanics of sterilized intervention in the foreign exchange market. In there, we will also discuss the role of exchange rate smoothing in BNM's policy framework.
ringgit. These developments led BNM to impose capital control on 1 September 1998 and the fixing of the ringgit at US$1=RM3.80 on 2 September 1998.

The full effect of the regional financial crisis was felt in 1998. By end-August 1998, the index for the Kuala Lumpur Stock Exchange fell by almost 80% from the level at end-March 1997. GDP contracted by 7.5%. Large depreciation in domestic currency caused upward pressure on imported goods. As a result, inflation rose and reached a peak of 6.2% in June 1998. Following this, the Government put together a series of policy actions to bring the economy back into recovery.

The sharp easing of monetary policy following the introduction of the exchange control measures provided an environment of low interest rates to support the economic recovery. Together with other macroeconomic measures, the nation has been able to weather the crisis. By end-1999, most key economic indicators were showing significant improvements. Inflation had been reduced to 2.1% and GDP grew by almost 6%. Apart from a brief slowdown in GDP growth experienced during the end-2001 and early-2002 following the September 11, 2001 events, the Malaysian economy recorded a commendable expansion during the 2003-2005 period.

1.3 Outline of the Thesis

This thesis is divided into eight chapters.

Chapter 2 reviews the analytical framework that will be used to model BNM’s behaviour in formulating monetary policy. It begins by reviewing the role of policy rules in a central bank’s decision-making process, with particular attention to the importance of the interest rate rule. The chapter then presents the formal specification of the central bank’s policy problem as a solution to an optimal control problem.

Chapter 3 presents empirical results of BNM’s reaction function. Results of this exercise form a foundation to investigate in detail, BNM’s behaviour in formulating monetary policy in Malaysia. The subsequent analysis of BNM’s behaviour in formulating monetary policy depends crucially on the premise that BNM’s reaction function could be reasonably established and estimated. Based on this reaction function, the systematic component of BNM’s policy making could then be identified and analyzed.
Thus, in this chapter, we explore the usefulness of the Henderson and McKibbin (1993) and Taylor (1993) (HMT) interest rate rule as a benchmark for analyzing monetary policy in Malaysia. We estimate the HMT rule as a single equation.

While estimated reaction functions are useful for describing how the target interest rate changes in relation to macroeconomic factors, it must be acknowledged that this policy rule is formulated on an ad-hoc basis and is estimated, analyzed and interpreted in the absence of a fully specified economic model. As a result, important insights into monetary policy formulation cannot be inferred from the estimated decision rule. To gain further understanding and evaluate central bank behaviour in conducting monetary policy, information on the policy objectives and policymakers' relative preferences between these different objectives, is essential to be known. Thus, in Chapter 4, we try to unveil these aspects of BNM's policy behaviour. We model BNM's formulating monetary policy as a solution to the optimal control problem. We represent the Malaysian economy using a simple small open economy model. Then, by assuming BNM's set interest rates according to the optimal interest rate rule, we identify BNM's policy objectives and estimate its relative preferences. We also discuss what is the role of the exchange rate in the overall conduct of monetary policy in Malaysia.

After gaining a general understanding about the way BNM behaves in formulating monetary policy in Malaysia, we use this knowledge to ask another important question regarding BNM's policy behaviour. What would happen to the outcomes of the Malaysian economy if BNM was to behave differently than what we have understood so far? To answer this, we conduct counter-factual policy simulations. To do so, a good representation of the Malaysian economy is firstly needed. For this purpose, we use dynamic stochastic general equilibrium (DSGE) models. The main attractiveness of DSGE models is that they are derived from first principles and they provide structural equations that form the structural features of the economy. The "deep" parameters of these structural equations are assumed to be invariant to policy actions - an important feature for the policy simulations exercise that we want to conduct in order to analyze the impact to the Malaysia's economic outcomes if BNM was to change its policy behaviour.

Based on this premise, Chapter 5 and 6 discuss the derivation and estimation of the DSGE model for Malaysia. The key structural parameters of the Malaysian economy are estimated using the Bayesian methodology. In this DSGE model, we use the same HMT
interest rate rule specifications as in Chapter 3 to represent BNM’s reaction function. However, in this two chapters, the same interest rate rule is estimated under a different estimation approach. As part of the equations in the DSGE model, parameters of HMT interest rate rule in Chapter 5 and 6 are estimated simultaneously with other parameters of the DSGE model in the system of equations. Then, we compare these estimated parameters to the results generated by the single equation estimation in Chapter 3. Importantly, we find the use of a different estimation approach produces a different estimation result for BNM’s reaction function.

After establishing the general understanding about BNM’s policy behaviour over the period, Chapter 7 presents simulation results about the possible impact to the Malaysia’s economic outcomes during the 1975-2005 period if BNM behaves differently to what we have understood. For this purpose, we use the estimated DSGE model presented in Chapter 5, as the workhorse. There are two aspects of BNM’s policy behaviour that we look at in this simulation exercise. One, is about BNM’s policy action. We investigate the difference to the economic outcomes when BNM’s reaction function is based on the estimated (historical) specification and if BNM was to set interest rates according to the optimized HMT-rule. Two, we look at the impact when BNM has different policy preferences regarding its multiple objectives for monetary policy. All in all, these simulation results have given us a good understanding about the possible impact to the Malaysia’s economic outcomes if BNM was to change its behaviour in formulating monetary policy in Malaysia during the 1975-2005 period.

Lastly, Chapter 8 provides conclusion of this thesis and our few suggestions for further research.
Chapter 2

Theoretical and Empirical Framework to Analyze a Central Bank’s Behaviour in Formulating Monetary Policy

Similar to the analysis of consumer behaviour, which begins with outlining consumers’ problems and assumptions, this chapter discusses the framework commonly used in the literature to examine a central bank’s behaviour in formulating monetary policy. This framework will put in perspective, the rationale and theoretical reasoning behind the observed policy action taken by a central bank. Based on this framework, the empirical exercise to analyze Bank Negara Malaysia’s (BNM) behaviour in formulating and conducting monetary policy in Malaysia will be implemented in the subsequent chapters.

This chapter is divided into three sections. First, there is a brief discussion on the role of monetary policy rule as a tool to represent a central bank’s behaviour in setting monetary policy. Using this approach, it is assumed policymakers use the monetary policy rule as a “rule of thumb” to guide them in making policy decisions. Obviously, if this type of rule has guided a central bank’s action, it should be possible to track the systematic pattern of such action from the empirical exercise. This will provide some insights in describing policymakers’ behaviour in coming out with interest rate decisions. The second section discusses the approach to modelling a central bank’s optimization problem explicitly. It assumes a central bank treats the process of
formulating monetary policy as a solution to the optimal control problem. It involves specifying the objective function and setting the policy constraint. Also, from specifying a central bank’s optimization problem explicitly, the central bank is assumed to execute its policy action according to an optimal rule. The last section provides the empirical methods that have been used in the literature to bring this theoretical framework to data.

2.1 Monetary Policy Rules

In the theoretical and empirical work, a central bank’s behaviour in formulating monetary policy is represented by some type of monetary policy rule, which summarizes the complex decision process of how a central bank adjusts its policy instruments in response to changes in the macroeconomic environment. There are different kinds of monetary policy rules that have been developed. Among others are the Friedman (1969) money rule, the McCallum and Nelson (1999) nominal income rule, the Svensson (1999) inflation targeting rule and the Henderson and McKibbin (1993)/Taylor (1993) (HMT) interest rate rule.

What is the attraction of rule based policy formulation? Economists have debated this issue for a few decades and important results from Kydland and Prescott (1977) and Barro and Gordon (1983) have contributed to the general consensus among economists on the advantages of commitment to the policy rule. Discretionary policy-making leads to the famous result of “inflation bias” as economic agents revise their inflation expectation upwards following concern that policymakers will renege from their earlier policy announcement. This finding highlights the importance of a course of action that is time-consistent. In addition, studies among others by Ehrmann and Smets (2003), Dennis and Soderstrom (2006) and Lees (2007) quantify the benefits from optimal policy under discretion to optimal policy with pre-commitment. They show that welfare gain to the society from pre-commitment policy is quite large.

While there is general agreement that there is a distinct advantage to rule based vis-à-vis pure discretion, there is no clear evidence that central bankers have actually practiced it. Up to now, no central bank in the world has officially committed to basing their policy decisions on any specific monetary rule. On this point, William Poole, the President of the Federal Reserve Bank of St. Louis, states:
“We apply our best judgment to the task and do not rely on a formal rule, because we do not have a formal rule we trust.” (page 8, Poole (1999)).

Poole’s comment may represent a general skepticism among central bankers around the world on the limitation of applying the monetary policy rule to their actual decision making process. The major reasons cited by central bankers in avoiding commitment to a particular policy rule are that the policy rule is too mechanical and inflexible, and so cannot fully accommodate all possible shocks and unanticipated events. On this point, McCallum (2003) argues that when central bankers object to the use of a policy rule, the conception that they have in mind is it must be applied rigidly and mechanically - a regime which policymakers do not put any form of judgment on the policy making process. They interpret the term “rule” as representing a constant, non-responsive instrument setting, or what is also known as the “non-activist” rule. This interpretation stems from Milton Friedman’s famous money rule (Friedman (1969)), which promoted a constant growth rate for some specified monetary aggregate. In contrast, McCallum advocated the “activist” type of a rule - like the HMT interest rate rule - which represents a contingency plan that guides central banks’ policy action. The activist rule provides a general, but systematic guideline to the policymakers on how to set interest rates in response to their assessment of the current and future economic conditions.

Thus, while Poole’s comment about the inflexibility of rule based could be a valid concern, it does not mean the general framework behind the use of the policy rule is totally impractical. Instead, central bankers can capitalize on certain principles of rule-based decision-making and should put them into practice (McCallum (2000)). On this point, Woodford (2003) stresses the importance of a central bank committing to a framework of decision-making. While policymakers are not expected to follow a specific policy rule mechanically, it is important that they should adopt a consistent state-contingent plan in formulating monetary policy. In doing so, Woodford argues policymakers should follow a time-invariant policy framework, that is “optimal from a timeless perspective”. Rule-based policy-making in this sense avoids the sort of rigidity often associated with a commitment to mechanically follow a policy rule.

Besides reducing inflation bias, Woodford (2003) also outlines two further advantages as to why a central bank should commit to a systematic or “rule based” approach to policy
making. Firstly, commitment to a systematic approach of policy-making enhances the effectiveness of monetary policy through anchoring economic agents’ expectations. He argues that the ability to successfully steer private-sector expectations is favoured by a decision procedure based on a rule, since in this case the systematic character of the central bank’s action can be most easily made apparent to the public. Hence, the “rule-based” approach of policy-making facilitates better public understanding of the policy action that consequently contributes to better expectation formation among economic agents. Secondly, Woodford highlighted that discretionary optimization (or in other words changing the decision framework from time to time) will generally result in a central bank choosing a suboptimal response to shocks. Under purely discretionary policy formulation, the setting of policy instruments is determined period-by-period, with no attempt to follow a well-defined contingency plan for the future. Following the shock, policy action based on discretionary optimization will only focus on “one-off” action aimed at neutralizing such a shock. The failure of discretionary policy action to take into account the dynamic behaviour of economic agents in responding to the initial shocks, cause the chosen policy responses to be sub-optimal. Rather, Woodford shows policy must be made “history dependent”, that is, dependent upon past conditions even when they are no longer relevant to the determination of the current policy decisions.

Bernanke and Mishkin (1997) and Bernanke (2003) support Woodford’s view by highlighting the advantage of policy decision making based on “constrained discretion”. The constrained discretion approach is the middle ground between the inflexibility of the strict policy rules and the instability of purely discretion decision making. While it does not completely eliminate the time inconsistency problems, the constrained discretion approach will be able to mitigate them to some extent, by recommending policymakers voluntarily commit their decision making process based on a particular framework.

Under constrained discretion, a central bank is free to do its best to stabilize output and employment in the face of short-run disturbances. However, this is done with the appropriate caution of the fact that policymakers have imperfect knowledge of the economy. Due to this factor, in conducting the stabilization policy, a central bank must also maintain a strong commitment to keep inflation firmly under control. In other words, a constrained discretion approach acknowledges that policymakers need to be given some latitude. Due to information imperfection and uncertainty in assessing the true state of the economy, policymakers are allowed to use their judgment in deciding the best course of action to minimize cyclical swings in the economy. However, such latitude
must be used within the boundary that policymakers will not sacrifice its commitment to achieve price stability. Hence, for a constrained discretion approach to work, the policymakers’ commitment to achieve price stability is crucial to ensuring the public’s inflation expectations are kept under control. If this commitment is compromised, the disadvantage of a purely discretion approach in the form of an inflation bias problem suggested by Kydland-Prescott and Barro-Gordon will come into full effect and lead to a suboptimal economic outcome.

Svensson (1999) argues that the inflation-targeting framework is the example of how the principle of “constrained discretion” decision-making is formally put into practice. On the same point, Bernanke (2003) claims that to some extent, the principle of constrained discretion has been practiced by many central banks around the world. This is evident from the stronger commitment among central bankers towards price stability, as evident from the lower inflation rate in many countries from the 1980’s onwards. This was achieved without central banks mechanically following any pre-announced policy rule.

2.1.1 Ad-hoc Interest Rate Rule

Out of many monetary policy rules proposed by economists, the interest rate rule is the most widely used in recent theoretical and empirical literature to represent central bank behaviour in formulating monetary policy. The outcome of influential studies by Henderson and McKibbin (1993) and Taylor (1993), which suggest the past behaviour of the US Federal Reserve in setting interest rates can be summarized with a simple interest rate rule, have become a standard starting point in modelling central bank reaction functions in various theoretical and empirical studies. The Henderson-McKibbin-Taylor (HMT) type interest rate ‘rules’ have a strong intuitive appeal to researchers in this area, since they provide a simple organizing principle for assessing monetary policy and avoid outsiders “second-guessing” how central banks set their instruments. Besides its simplicity, HMT type interest rate rule is generally found to describe central bank’s policy action fairly well. The same rule is also regarded

There are three grounds for the preference of modelling the central bank reaction function by the interest rate type rule – practical, empirical and theoretical.
On “practical” grounds, modelling central bank behaviour using the interest rate rule is the “closest to reality” for the actual execution and formulation of monetary policy by a central bank. Goodfriend (1991) and Goodhart (1989, 1995) argue that regardless of what monetary regime a central bank claims it follows, the implementation of monetary policy was actually executed by a central bank setting the short-term interest rate (price) rather than by controlling base money (quantity). The main factor supporting this argument is that in its actual money market operation, a central bank has limited ability to accurately forecast the exact quantity of base money it requires to supply to the money market. For example, the effect of financial deregulation and product innovation cause the demand for base money to be more unstable and unpredictable (Laidler (1993)). The problem of controlling base money with a high degree of precision is compounded with the fact that demand for base money on a daily basis is inelastic (Borio (1997)). Borio shows that demand for base money is inelastic due to market participants’ obligation to settle all their trading commitments at the end of each business day. The combination of these two factors mean the use of base money as a policy instrument could in practice lead to large fluctuations in short-term interest rates. For example, any errors on the side of a central bank in determining the correct quantity required by market participants leaves the price (i.e. short-term interest rates) to adjust freely in order to ensure market clearing. As in other markets, large price fluctuations increase market uncertainties and deter smooth trading from taking place. Similarly, large fluctuations in short-term interest rates make controlling base money as a monetary instrument less practical, thereby making interest rates more popular instruments among central banks. The empirical studies by Bernanke and Blinder (1992) and Bernanke and Mihov (1998) support these arguments and show that movement of the Fed Fund rate is the best indicator to measure the US Federal Reserve’s monetary policy stance.

Following the above arguments, on the empirical ground, the estimated reaction function modelled by the interest rate rule is found to track real data well. Among others, studies by Judd and Rudebusch (1998), Taylor (1999a), Kozicki (1999) and Clarida, Gali, and Gertler (2000) in the case of the US Federal Reserve; Nelson (2000) for the UK; Clarida, Gali, and Gertler (1998) for country comparison of G8 economies; Taylor (1999b), Gerlach and Schnabel (2000) for the European Union; de Brouwer and Gilbert (2005) for Australia; Umezaki (2007) for Malaysia and Ramayandi (2008) for the ASEAN countries have all found that the simple interest rate rule they estimated
as a single equation, provided a reasonably good descriptions of the way major central banks around the world behaved over a specified period of time.

On theoretical grounds, the interest rate rule also emerges as a valid principle that is effective in achieving price stability. Woodford (2003) analyzes the idea put forward by Knut Wicksell about the relationship between price stability and the interest rates level set by the central bank. In Wicksell’s view, price stability can be achieved when a central bank sets its nominal interest rate to be in line with the natural rate of interest. The logic behind Wicksell’s view is simple. As the natural rate of interest is determined by real factors which are not affected by monetary policy actions (such as the marginal product of capital), deviation of the interest rate set by the central bank from the natural rate of interest will cause disequilibrium in the goods market. Hence, prices need to adjust to bring the goods market to its new equilibrium level. In subsequent chapters of his book, Woodford formalizes Wicksell’s idea into what he terms “Neo-Wicksellian Monetary Theory” and argues that the HMT interest rate rules are in spirit, consistent with Wicksell’s idea. Woodford further proves that when the “Taylor Principle” is fulfilled (i.e. when the feedback coefficient on inflation in the interest rate rule is greater than 1), such an interest rate rule is consistent with the optimal equilibrium and ensures price determinacy and stability in the model.

Taylor (1999a) and Orphanides (2003) examine the usefulness of the HMT interest rate rule framework as an organizing device for describing the evolution of monetary policy in the United States. In their respective studies, Taylor and Orphanides examine the consistency of the US Federal Reserve’s historical interest rate movement with the interest rate level suggested by the HMT-rule framework. They then compare them with the narrative descriptions of events and information available to policy practitioners when policy was made. The theme emerging from Taylor’s and Orphanides’ examination is that Federal Reserve policies over many periods can be broadly interpreted in terms of the HMT-rule framework with surprising consistency. This historical analysis suggests the HMT-rule appears to serve as a useful organizing device for interpreting past policy decisions and mistakes.

In conclusion, while central banks do not mechanically follow the monetary policy rule, the advantages of formulating monetary policy in a systematic manner is acknowledged and perhaps has been practiced by many central bankers. The use of the “rule-based” or systematic approach in the actual formulation of monetary policy is also consistent with
the evidence observed in the empirical exercises. As mentioned earlier, empirical studies in estimating a central banks’ reaction function modelled by simple HMT type interest rate rules are found to track well the actual movement of policy rates in many countries. As no central bank in the world has ever announced that it officially follows any type of interest rate rule, these empirical results suggest central banks actually formulate monetary policy by adhering to the “rule-based” approach – i.e. they set interest rates by responding to certain variables like inflation and output gap in a systematic manner.

2.2 Modelling a Central Bank’s Problems

The HMT interest rate rule suggests the Fed’s behaviour in formulating monetary policy can be represented by a systematic pattern of reacting to inflation and the output gap. But, what exactly is the objective the Fed wants to achieve? Does the Fed have a dual objective of stabilizing prices and output? Or does it have a single objective of maintaining price stability, and only treats the output gap as a leading indicator? (i.e. reacting systematically to output gap as high output gap will lead to high inflation). In order to overcome this ambiguity, another approach to understanding central bank behaviour is to formally model a central bank’s problem. This approach starts with explicitly specifying the policymakers’ loss function and deriving the optimal policy rule that should be followed in order to minimize the specified loss function.

The central banks behaviour in formulating monetary policy is commonly modelled as the solution to the optimal control problem. In their famous paper, which outlines and summarizes recent research in monetary policy, Clarida, Gali, and Gertler (1999) indicate that modelling a central bank’s problem in this way has become a standard approach for the literature in this area. This approach is favoured due to its simple, but realistic representation of the real world problems facing policymakers. More importantly, it treats a central bank like any other agent in the economy, which intends to maximize some objective function subject to certain constraints. Similar to the analysis of consumer behaviour, which assumes the observed action is the outcome of the constrained optimization problem of trying to maximize utility subject to a budget constraint, a central bank’s problem in conducting monetary policy can also be put in the same perspective. The policymaker’s problem can be characterized as using an instrument such as the interest rate, together with knowledge of the evolution of the
economy and the transmission mechanism process, seeking to minimize its loss function by stabilizing the objective variables (such as inflation and output).

In this regard, Cecchetti (2000) characterizes a central banks’ problem as the solution to a complex control problem similar in structure to the one faced by an aircraft pilot. Given knowledge of the weather and wind, a pilot’s objective is to use the aircraft’s controls, to fly from one place and land safely at the destination point. Similarly, a central bank’s objective is to move interest rates, given its knowledge on how the economy evolves, to achieve certain objectives like maintaining steady income growth and stable prices. Hence, the optimal control problem facing central bankers involves minimizing a loss function (consisting of weighted sum of price variability, output variability, financial variability, etc), subject to the evolution of the state variables (the economic structure describing the paths of output and inflation) which act as a policy constraint, using a control rule (the optimal policy rule describing the optimal reaction of a central bank in solving the problem).

In order to understand the framework of a central bank’s problem, the rest of this section reviews the general set-up about the application of optimal control problem as a tool to formulate monetary policy. It covers a short description about specification of the loss function, state variables and how to model their movement and the use of optimal rule. However, to minimize repetition, we will not provide in this section any illustration about the mechanics and workings of the optimal control theory framework in modelling a central bank’s policy behaviour. We leave that to Chapter 4, where we will illustrate how the optimal control theory is used to represent BNM’s policy behaviour.

2.2.1 Specification of a Central Bank’s Loss Function

To determine a central bank’s policy choice, specification of its preferences is needed. The specified objective function becomes the “point of reference” for policymakers to evaluate and discriminate all possible policy options at their disposal. As each policy option will generate a different policy outcome, the objective function is used as a tool to summarize how consistent each policy outcome is with the policymakers’ ultimate aim. This is done by comparing the quantitative result of the objective function for each policy option.
In general, a central bank’s objective function can be written in different forms, depending on its underlying policy objectives and preferences. Cukierman (1992) provides a detailed discussion of several motivations behind different central bank’s preferences and objectives. Besides the common objective for monetary policy of achieving price and output stability, Cukierman, argues a central bank’s objective in formulating monetary policy could also be motivated by political pressure to ensure a government being re-elected. A central bank may also have a balance-of-payment motive, an objective to maximize seignorage revenue, or the objective of stabilizing the financial system. Hence, different objectives pursued by central banks will influence the way the loss function is formulated in the theoretical model.

Walsh (2003) claims it is standard practice in the literature to assume a central bank’s preference is represented by an objective function that consists of target variables like inflation, output and stabilizing (smoothing) interest rates. The benefit of low and stable inflation to an economy is well known and documented. Among others, the cost of inflation to an economy is high and entails significant social losses. Hence, the primary objective of the monetary policy adopted by many central banks around the world is to stabilize inflation at a level low enough that it becomes irrelevant to household and firm decision-making.

The role of output stabilization in the loss function is to ensure the economy always operates at or near its full potential. The benefit of an economy operating at its full potential is straightforward. For example, operating below potential means resources are redundant. Social welfare, as a whole, can be improved by utilizing these idle resources. Similarly, the notion that inflation is created by excess demand (demand pull inflation) is related to the fact that an economy is operating beyond its potential level. The capacity constraint to produce this additional demand will be translated into upward price pressure. In addition, a central bank also wants to minimize output volatility in order to promote further economic growth. Ramey and Ramey (1995) present evidence that in a broad group of 95 countries, there is a strong negative correlation between output volatility and growth.

Many empirical studies have shown that the interest rate movement is highly correlated with its past value. This observation has caused many to include interest rate smoothing in a central bank’s loss function. While the reason for including price and output stability is intuitive, the rationale for including an interest rate smoothing objective
in a central bank’s loss function is more controversial and has been discussed in many papers. See among others Lowe and Ellis (1997) and Sack and Wieland (2000) for detailed discussion and a literature review on this area. For example, central banks smooth interest rates to maintain financial stability (Cukierman (1992)), to enhance credibility by minimizing policy reversal (Goodhart (1999)) or just a reflection of a central bank’s cautious attitude to information and model uncertainty (Clarida, Gali, and Gertler (1999)).

The loss function central banks try to minimize is commonly written in a quadratic form. There are three main reasons for this. The first is to incorporate a central bank’s preference to stabilize its objective variable around a certain target. For example, Walsh (2003) argues that most central banks have a desire to minimize output and inflation fluctuations. In conducting monetary policy, central banks always prefer output to be near its natural level. This will ensure an economy operates at near full employment, as operating below full capacity is inefficient, while operating above capacity puts upward pressure on price levels. Likewise, central banks always try to keep inflation close to its target level. Hence, specifying the loss function in a quadratic form will generate a role for a stabilization policy that is absent when the loss function is specified in a quasi-linear form. The second reason for the popular use of a quadratic loss function is theoretical. Woodford (2003) (Chapter 6) shows that, under certain conditions, the quadratic central bank’s loss function can be shown to originate from the second order approximation to the expected utility of the economy’s representative household. Hence, it can be argued that a central bank’s objective function in formulating monetary policy is not done on an ad-hoc basis, but is instead chosen based on a public welfare consideration. The last reason for the preference of using quadratic form is its mathematical convenience. A quadratic loss function, together with a linear specification for the economic structure, results in an optimal decision rule that is also linear. This simplifies the computation and estimation burden of the theoretical and empirical exercise.

2.2.2 State Variables and Modelling of the Economy

As the name suggests, state variables describe the state or existing condition of the system. In the context of monetary policy formulation, they are macroeconomic
variables that provide information on the condition of the economic system at a point in time. The three most common state variables central banks monitor very closely are inflation, output and the level of interest rates. These variables are closely monitored not only for their importance for central banks’ policy objectives, but also due to their information content in summarizing the overall condition of an economic system. For example, an economic system that produces a large output gap or has an inflation rate above its targeted level, give signals that it is currently “overheating” or operating beyond its optimal level. Similarly, interest rates that are persistently high indicate a tight money market condition; or that agents’ inflation expectations are on the upward trend. After doing an assessment on the overall state of the system, policymakers will consider the appropriate policy action to refine the current condition of the economic system. In the example given here, the central bank’s reaction would be to raise its policy instrument (short-term interest rate) to slow down aggregate demand with the objective of steering the system towards its optimal path.

The dynamics of the state variables are assumed to follow a certain form of structure, which essentially describes the mechanical operation of the economic system. This will form the constraint to the central bank’s optimization problem. There are two general approaches to construct these constraints. The first approach constructs the simple structural equations like the IS and Phillips Curve functions on an ad-hoc basis to fit the data. This method was popularized by Rudebusch and Svensson (1999) and was used in other subsequent work, among others by Favero and Rovelli (2003), Ozlale (2003), Soderstrom, Soderlind, and Vredin (2005) and Dennis (2004, 2006). Another approach to represent the operation of the economy is to develop a dynamic stochastic general equilibrium (DSGE) model. The main attractiveness of DSGE models is that they are derived from first principles. This approach overcomes the limitation of structural modelling in treating parameters to be time invariant, or as popularly known in the literature as the Lucas critique (Lucas (1976)). Obviously, for this reason, DSGE models are seen as powerful tools that provide a coherent framework for policy discussion and analysis. Among examples of work that apply this approach and use it to analyze central banks’ policy behaviour are Devereux, Lane, and Xu (2006), Justiniano and Preston (2006) and Kam, Lees, and Liu (Forthcoming). In this thesis, we adopt both approaches to model the Malaysian economy and later use them to analyze BNM’s policy behaviour.
The control variable in this optimal control problem is the instrument a central bank uses to execute its monetary policy. It operates to steer the economic system by affecting the movement of the state variables (output and inflation). After knowing the overall set-up and operation of the system, how should a central bank use its control instrument to steer the economic system towards achieving its specified objectives? The solution to a central bank’s optimal control problem is to set its control variable according to the optimal rule. It is mathematically derived to minimize the specified loss function, given the knowledge of the economic structure. The optimal rule serves as the ‘decision rule’ or ‘optimal reaction function’ to policymakers in determining the correct value of “fine-tuning” the economic system needs in order to ensure the objective variables are moving on the desired path.

In this regard, most of the recent literature derives the optimal decision rule for the control variable in the form of an interest rate rule. Depending on the way the optimal control problem is constructed, the corresponding optimal interest rate rule derived from this optimization problem may have a different form than the HMT interest rate rule. To differentiate between these two classes of interest rate rule, the HMT-type interest rate rule is sometimes known as the ‘simple interest rate rule’ while the optimal interest rate rule is known as the ‘complex interest rate rule’.

This distinction leads to another strand of research in the literature – which class of interest rate rules perform better and hence should be favoured by central bankers? This strand of research compares the performance of the optimal interest rate rule vis-à-vis the simple HMT-type interest rate rule across different economic models. See among others Taylor (1999b), Levin, Wieland, and Williams (1999, 2003), Batini, Harrison, and Millard (2001) and Orphanides and Williams (2007) for examples and results of these comparisons. The general conclusion of the research in comparing the performance of simple and complex rules is that the simple interest rate rule performs better on average than the complex rule when each of them is used across different economic models. This result is not surprising. As mentioned earlier, the optimal interest rate rule is mathematically derived from a specific model that forms a central bank’s optimization problem, hence making it “model-specific”. The optimal interest rate rule only works best in a model where it is originally assumed.
In contrast, the simple HMT-type interest rate rule is more robust to model misspecification. Since the HMT interest rate rule is not derived from any economic model, but instead originates from the attempt to describe the systematic behaviour of central bankers in formulating monetary policy, the HMT rule has implicitly incorporated the “best practice” principle that central bankers around the world should follow in setting policy instruments. Perhaps, besides its simplicity, the robustness of the HMT rule is the main property that has contributed to its popularity. Even though it is not explicitly derived to solve the optimization problem by formally considering the economic structure and a central bank’s loss function, the notion of setting interest rates by reacting systematically to inflation and output gap; and adhering to Taylor’s Principle, are the general code-of-conduct that lead to a favourable economic outcome.

2.3 Empirical Methods to Analyze a Central Bank’s Behaviour

There are two general approaches to analyzing central bank behaviour in formulating monetary policy. One is to carefully examine the central bank’s legislative act and public statements such as reports, publications, policy statements, public speeches and interviews to analyze what central bankers say they are trying to accomplish. Known as ‘narrative measures of monetary policy’, examples of this approach include the classic analysis by Friedman and Schwartz (1963) and the work by Romer and Romer (1989), Boschen and Mills (1991) and Judd and Rudebusch (1999). While this approach can uncover some useful information regarding central bank’s behaviour, it falls short of formally modelling the policy formulation process. See Leeper (1993) for a critical review of this approach. In addition, Walsh (2003) states that the narrative approach captures both exogenous shifts in policy and the endogenous response of monetary policy to economic development. Hence, analytical study of central bank’s behaviour to isolate these two factors is difficult.

The second approach, and the one that will be used in this thesis, is to apply statistical methods to detect the systematic relationships between the actual movement of the central bank’s instrument and other macroeconomic variables. If policymakers behave purposefully, with well-defined preferences for achieving different goals, it may be possible to uncover these preferences and goals from the empirical response of the interest
rates to other macroeconomic variables. With that, this section outlines two empirical approaches that have been used in the literature to analyze a central bank’s behaviour in formulating monetary policy.

2.3.1 Estimating a Central Bank’s Reaction Function

As we mentioned in Section 2.1, there are a large number of empirical studies which estimate the systematic components of monetary policy using HMT type interest rate rule. In these studies, a central bank’s reaction function is estimated as a single equation. The estimation method used to estimate the reaction function is dependent on the model specification of the interest rate rule. Ordinary least squares (OLS) is applied for the case when the HMT interest rate rule uses contemporaneous and backward looking set-up, while the Instrumental Variables (IV) and the Generalized Method of Moments (GMM) is favoured when the HMT rule uses the forward looking specification.

Dennis (2004) states that one of the reasons why using estimated interest rate rules to describe monetary policy behaviour is attractive and widely used in the literature is that they are able to capture the systematic relationship between interest rates and macroeconomic variables. He argues that the estimated rules from this exercise can be viewed as approximations to the decision rules used by the central banks. These estimates are then commonly used in the literature to analyze and evaluate central bank behaviour in setting monetary policy. The outcome of this approach provides a few important contributions to understanding central bank behaviour in formulating monetary policy. It indicates the suitability of modelling the central bank reaction function by the HMT type interest rate rule. The ability of the interest rate rule to track the historical movement of central bank instruments provides information on its systematic behaviour in making monetary policy decisions. In addition, the result of this approach is also used to provide the answer to the question regarding policy evaluation. Analysis on the policy evaluation is done by looking at whether a central bank’s past behaviour in setting the interest rate fulfills the Taylor’s principle.

The main feature of this approach is that the policy reaction function is estimated as a single equation. The reaction function is constructed on an ad hoc basis, without a need to specify or estimate the underlying central bank loss function or the structure of the economy. The essential point is that estimated policy rules are reduced-form equations,
which are uninformative of policy issues that involve structural parameters or that require a structural interpretation because they are formulated, estimated, analyzed, and interpreted in the absence of a fully specified economic model (Lucas (1976)). While it is relatively simple, the main limitation of this approach is that it is only able to provide a descriptive analysis of a central bank’s systematic behaviour in setting past interest rates. To reveal what central banks aim to achieve through their policy actions, it is necessary to recognize central banks behave purposefully when setting policy to achieve a specific goal. Due to this fact, important information regarding central banks’ behaviour in formulating monetary policy cannot be obtained from the reduced form approach. Hence, this approach could not provide answers to the questions related to what are the policy objectives that a central bank wants to pursue and its relative preferences between these policy objectives. Lastly, since the estimated policy rules are reduced-form equations, analysis on the possible evolution of policymakers’ behaviour cannot be conducted.

2.3.2 Estimating Central Bank’s Policy Preference

To address the limitations of the narrative approach, the empirical approach goes one step further. It looks at the central bank’s optimal control problem as a whole and tries to estimate simultaneously parameters for the central bank’s loss function, reaction function and model equations representing the economy. Identifying and estimating parameters of the model equations representing the economy is much more straightforward and has been widely done in the empirical literature involving the New Keynesian model. In contrast, estimating parameters in a central bank’s loss function from the real data is far more complicated, mainly because a central bank’s loss function itself is not observable. What is observed from the central bank’s action over time is the actual movement of its monetary instrument (interest rates) and the evolution of the state variables. In this regard, the estimation exercise needs to infer the parameters in the loss function by extracting the information from the observed policy action taken by the central bank as well as the evolution of economic variables over time. As such, this approach involves an estimation procedure that searches over the parameters of the model representing the economic structure, for values that reconcile a policy rule that fits the data and compares it with one that minimizes the expected loss function.

There are several examples in the literature that apply this approach to the case of
central banks in developed economies. Using the closed economy set-up, Salemi (1995), Favero and Rovelli (2003), Ozlale (2003), and Dennis (2004, 2006), investigated the case of the US Federal Reserve, while Assenmacher-Wesche (2006) did a country comparison involving the US, Germany and Japan. Kam, Lees, and Liu (Forthcoming) took the approach one step further and used the open economy model to estimate the central banks’ preferences in several developed, inflation targeting countries.

There are three estimation methods that have been used to estimate the system of simultaneous equations for this approach. The first two are the maximum likelihood method as used in Ozlale (2003) and Dennis (2004, 2006) and the GMM method as applied in Favero and Rovelli (2003). Lastly, Kam, Lees, and Liu (Forthcoming) employ the Bayesian method.

2.4 Conclusion

This chapter reviews the analytical framework and empirical approaches to analyze a central bank’s systematic behaviour in formulating monetary policy. Based on the framework and empirical approaches that we outline in this chapter, empirical exercises to analyze BNM’s behaviour in formulating and conducting monetary policy in Malaysia will be implemented. This will be presented and discussed in the next five chapters.
Chapter 3

Estimating Bank Negara Malaysia’s Reaction Function with a Simple Interest Rate Rule

The main aim of this chapter is to explore the validity of modelling Bank Negara Malaysia’s (BNM) reaction function by a simple interest rate rule. The results of the empirical exercise in this chapter will form a foundation to investigate in detail, BNM’s behaviour in formulating monetary policy in Malaysia. The subsequent analysis of BNM’s behaviour in formulating monetary policy depends crucially on the premise that BNM’s reaction function could be reasonably established and estimated. Based on this reaction function, the systematic component of BNM’s policy making could then be identified and analyzed.

The empirical exercise in this chapter aims to fulfill four main objectives. The first, is to examine the ability of a simple, Henderson-McKibbin-Taylor (HMT) type interest rate rule, to model the reaction function of BNM. The second, is to investigate the role of exchange rates in influencing BNM’s decision rule. Acknowledging the fact that Malaysia is a small, open economy, the exchange rate could play an important role in the overall monetary transmission mechanism. Hence, this exercise will compare the outcome of the closed-economy interest rate rule, with an open-economy interest rate rule in tracking interest rate determination in Malaysia. The third objective is to analyze BNM’s overall behaviour in setting interest rates. In particular, the empirical results will indicate whether BNM’s behaviour is consistent with Taylor’s principle and whether BNM practices interest rate smoothing. It will also provide the implicit
estimates of the inflation target that BNM tries to achieve in conducting monetary policy. The final objective is to assess whether BNM’s reaction function has been consistent over time. In doing so, three sub-periods are considered. These include the period prior to and during the capital controls and fixed exchange rate regime was in place.

To our knowledge, there are only two published empirical studies that have attempted to estimate BNM’s reaction function. First, is by Umezaki (2007). Similar to the methodological approach we use in this chapter, Umezaki estimates BNM’s reaction function using monthly data, covering the period of January 1988 to August 1998. He investigates how BNM’s behaviour is affected by external factors, like the change in the exchange rate regime (float and managed float) and by the degree and size of capital mobility. Likewise, Ramayandi (2008) applies the same approach and uses the estimated reaction function based on the HMT interest rate rule to compare the formulation of monetary policy in 5 ASEAN countries - Malaysia, Indonesia, Singapore, Thailand and The Philippines. Like the one we used in this chapter, Ramayandi also uses quarterly data in his empirical exercise but he covers a shorter sample period of 1989Q1 to 2004Q4. While to some extent, the estimation of BNM’s reaction function that we do in this chapter is largely similar to those reported in Umezaki (2007) and Ramayandi (2008), there are also new areas about BNM’s policy behaviour that this chapter will explore and that have not been previously covered. For example, in our estimation exercise, we will cover a longer sample period, 1975Q1 to 2005Q2. This longer period covers different phases and stages of economic development experienced by the Malaysian economy, thus it provides a good avenue to analyze how BNM may behave under different economic circumstances. In addition, with the use of estimation results for the sub-sample periods, we will also investigate the possible evolution of BNM’s reaction function over time.

This chapter is organized as follows. Section 3.1 discusses different specifications of the simple interest rate rule that has been used in the literature to represent a central bank’s reaction function. Based on this discussion, Section 3.2 presents the specifications of the simple interest rate rule that is used to represent BNM’s reaction function. Section 3.3 presents the estimation results. The last section concludes.
3.1 Specification of Simple Interest Rate Rule

The original form of the simple interest rate rule suggested by the seminal contribution by Henderson and McKibbin (1993) and Taylor (1993), is as follows:

\[ r_t = \alpha + \beta_{\pi} \pi_t + \Theta_y y_t \]

where \( r_t \) is the central bank’s policy rate, \( \pi_t \) the inflation rate, \( y_t \) the output gap (defined as deviation of current GDP from its full potential level). \( \beta_{\pi} \) and \( \Theta_y \) are the feedback parameters for inflation and the output gap respectively. The intercept parameter, \( \alpha \), is defined as

\[ \alpha = r^* + (1 - \beta_{\pi}) \pi^* \]

where \( \pi^* \) is the central bank’s implicit inflation target and \( r^* \) is the real interest rate in the steady state.

The HMT rule given above represents the standard starting point for the family of simple interest rate rules that has been used in the theoretical and empirical literature. One common extension to this set-up is to introduce the desire of the central banks to smooth interest rate changes. This is done by including a lagged interest rate term to the reaction function, as shown below:

\[ r_t = (1 - \rho) [\alpha + \beta_{\pi} \pi_t + \Theta_y y_t] + \rho r_{t-1} \]

(3.1)

where coefficient \( \rho \) measures the degree of the smoothing behaviour. The economic rationale behind such smoothing behaviour has been well documented in the literature. Among others, central banks smooth interest rates to maintain financial stability (Cukierman (1992)), to enhance credibility by minimizing policy reversal (Goodhart (1999)) or just a reflection of a central bank’s cautious attitude to information and model uncertainty (Clarida, Gali, and Gertler (1999)).

\[ \text{1See Lowe and Ellis (1997) and Sack and Wieland (2000) for the literature review on this area.} \]
Another extension is to introduce variables other than inflation and the output gap into the reaction function. For example, Ball (1999) proposes the inclusion of an exchange rate target in the simple interest rate rule in the analysis of the open economy. The main justification for the inclusion of an exchange rate is to acknowledge the importance of the exchange rate as one of the monetary transmission channels. Svensson (2000) outlines three mechanisms on how exchange rates act as an additional channel of the monetary transmission mechanism. Firstly, the real exchange rate affects the relative price between domestic and foreign goods, and thus contributes to the aggregate demand channel through expenditure switching. Secondly, the exchange rate affects consumer prices directly via the domestic currency price of imported final goods. Finally, Svensson argues that the exchange rate will affect inflation indirectly through imported intermediate goods, which will eventually affect the cost of domestically produced goods.

The open-economy interest rate rule suggested by Ball (1999) is:

\[
    r_t = (1 - \rho) [\alpha + \beta_t \pi_t + \Theta_y y_t + \Omega_1 rer_t + \Omega_2 rer_{t-1}] + \rho r_{t-1}
\]

with \(rer\) representing the real exchange rate. In the above model, the appreciation of the exchange rate (\(\downarrow rer\)) has a contractionary impact on aggregate demand. Appreciation makes imported goods cheaper and domestic goods more expensive, hence reducing net exports. The same effect will also reduce domestic inflation. Thus, the appreciating exchange rate puts downward pressure on the inflation rate and output gap, which could induce the central bank to reduce interest rates (Obstfeld and Rogoff (1995)). Following this, parameter \(\Omega\) in the interest rate rule is expected to be positive. Nevertheless, in reality, measuring the equilibrium level of the real exchange rate on a real time basis is not an easy task for policymakers. This implies that the interest rate rule that reacts to the level of the real exchange rate as suggested by Ball may not be very useful in practice. Following this, Batini, Harrison, and Millard (2001) and Leitemo and Soderstrom (2005) modify Ball’s original model by suggesting that the interest rate rule should react to the change in and not to the level of the exchange rate. Their suggestion imposes the restriction that \(\Omega_2 = -\Omega_1\) in equation 3.2, suggesting that the central bank should react to the “speed” of depreciation/appreciation of the exchange rate rather than to the fluctuations in its exact level. Imposing this restriction reduces the open-economy interest rate rule suggested by Ball to:
The estimation of the interest rate rule also differs on the specification about the time dimension used for the explanatory variables. The original HMT-rule uses a contemporaneous set-up, with current inflation and the output gap included in the simple interest rate rule. However, McCallum (1993) argues that this set-up is not realistic in the real world, as data on current inflation and output gap is not available at the time the interest rate decision is made. Hence, McCallum suggests inclusion of lags of inflation and the output gap in the simple interest rate rule. With this set-up, the central bank is assumed to adopt backward-looking behaviour in setting monetary policy. Given the fact that monetary policy works with lags, the assumption of policymakers to be backward looking may not be sensible in the real world. Hence, Clarida, Gali, and Gertler (1998) propose the use of a forward looking interest rate rule, which is a function of the central bank’s expectations of inflation and the output gap.

3.2 Specification of BNM’s Reaction Function

To explore the correct specification of BNM’s reaction function, this estimation exercise considers separately the closed economy and open economy versions of the simple interest rate rule. In addition, three specifications about the time dimension used for the explanatory variables - inflation, output gap and exchange rates - are explored. Different time specifications used for BNM’s reaction function are the backward-looking, contemporaneous and forward-looking set-up.

From equation 3.1, the closed economy version of the simple interest rate rule to represent BNM’s reaction function is,

$$r_t = (1 - \rho) [\alpha + \beta \pi_t + \Theta_y y_t + \Omega \Delta r_{t+1}] + \rho r_{t-1} + \varepsilon_t$$

(3.4)
while the open-economy version of the simple interest rate rule is taken from equation 3.3,

\[
    r_t = (1 - \rho) \left[ \alpha + \beta_\pi \pi_{t+n} + \Theta_y y_{t+n} + \Omega \Delta rer_{t+n} \right] + \rho r_{t-1} + \varepsilon_t
\]

with \( \alpha = \overline{\pi} + (1 - \beta_\pi) \pi \).

For the purpose of estimation, the definitions of variables are as follows:

- \( r_t \) is the average 3-month interbank rate for the quarter, the operational target of BNM;
- \( \pi_t \) is the annual inflation rate for the quarter;
- \( y_t \) is the output gap for the quarter, defined as \( y_t = GDP_t - GDP_t^* \), where \( GDP_t \) is the real GDP for the quarter and \( GDP_t^* \) is the potential output, estimated by Hodrick-Prescott filter;
- \( \Delta rer_t \) is the changes in Real Exchange Rate (↑ \( \Delta rer_t \) denotes depreciation), defined as \( \Delta rer_t = rer_t - rer_{t-1} \);
- \( r_{t-1} \) is the lag interest rate to capture BNM's smoothing behaviour;
- \( \varepsilon_t \) is the the error term;
- \( \overline{\pi} \) is the long run equilibrium (neutral) interest rate;\(^2\)
- \( \pi \) is BNM's inflation target, derived by using the estimated value for \( \alpha \) and the proxy value of \( \overline{\pi} \).

Definitions and source of data is given at the end of this thesis. Variables \( r_t \), \( \pi_t \), \( y_t \) and \( \Delta rer_t \) are all found to be stationary. See Table 3.4 (placed in the Appendix) for the result of unit root test.

To explore the most appropriate time specifications for BNM's reaction function, different values for \( n \) are used in the above model of the simple interest rate rule:

\(^2\)This is not estimated by the model. Following the suggestion of Clarida, Gali, and Gertler (1998), the average real interest rate from 1973 to 1998 is used as the proxy for \( \overline{\pi} \).
\begin{itemize}
\item\( n = -1 \) for a backward-looking set-up, as suggested by McCallum (1993, 1999);
\item\( n = 0 \) for a contemporaneous set-up, in accordance to the original specification suggested by Henderson and McKibbin (1993) and Taylor (1993); and
\item\( n = 1 \) for a forward-looking set-up, in line with the specification suggested by Clarida, Gali, and Gertler (1998).
\end{itemize}

On the estimation procedure, the simple interest rate rule with the contemporaneous and the backward-looking specifications employ the Ordinary Least Squares (OLS) method. Due to the possible existence of correlation between the explanatory variables and the disturbance term in the forward-looking interest rate rules, the Instrumental Variables (IV) estimation method is chosen to estimate the forward-looking reaction function. For this purpose, the instruments used for the IV estimation are four lags of 3-month interbank rate \( (r_t) \), inflation \( (\pi_t) \), output gap \( (y_t) \), log M3, and \( \Delta RER_t \).\(^3\)

For both estimation methods, the Newey-West heteroscedasticity and serial correlation consistent standard error is used.

**Estimation Period**

The estimation of BNM’s reaction function covers the period of 1975Q1 to 2005Q2. To investigate the consistency of BNM’s behaviour during this 30 years period, three different sub-periods are considered. Two sub-periods prior to capital control and the fixed exchange rate regime are 1975Q1 to 1986Q4 and 1987Q1 to 1998Q2. The third sub-period is 1998Q3 to 2005Q2, during which capital controls and the fixed exchange rate regime, were in place.

There are several reasons for choosing 1987Q1 and 1998Q3 as the breaking point to the estimation period. First, is to take into account the changes in Malaysia’s economic development. After recovering from a severe recession in 1984-1985, the Malaysian economy went through several structural changes and grew significantly from 1987.

\(^3\)One of the criticisms of the IV estimation technique is the use of “weak” instruments, i.e. the instruments used are poor predictors of the variable being instrumented for. However, this is not the case for the set of instruments that we used in this exercise. Correlations between the instruments used and the variables being instrumented for are quite high. See summary of correlation coefficients of variables in Table 3.5, placed in Appendix.
onwards. This sudden change in the economic structure could have induced different policy responses from BNM in formulating its monetary policy. Second, is the structural break in the monetary policy framework adopted by BNM. During the 1970’s and a large part of the 1980’s, BNM adopted a monetary targeting framework. During this period, M1 and later, M3, was used as the nominal anchor to BNM’s policy (Bank Negara Malaysia (1999)). Also, as a result of financial and payment system innovations – such as the introduction of Automated Teller Machine (ATM) facilities in mid-1980’s – demand for money in Malaysia was unstable. The unstable money demand function makes the operation of monetary targeting framework less viable. Following this, from 1987 onwards, BNM gradually reduced its policy emphasis on targeting particular monetary aggregates before officially adopting the interest rate targeting framework in 1994. Hence, the change in the BNM’s monetary framework could affect the stability of the estimated reaction function. Finally, results of the Chow-test on the estimated reaction function for 1975Q1 to 2005Q2 period reconfirm 1987Q1 and 1998Q3 as a valid breaking point.

During the period of September 1998 to July 2005, BNM adopted the capital controls and fixed exchange rate regime. The adoption of this controversial policy in the aftermath of the Asian Financial Crisis may have resulted in significant changes in the behaviour of the policymakers. For example, the introduction of this regime provided BNM with monetary independence (Bank Negara Malaysia (1999)) and the breathing-space needed to adopt pro-growth policies to reflate the Malaysian economy (Athukorala (2001)).

The best approach to investigate the possible changes in the BNM’s behaviour during the imposition of this regime is to estimate the model separately. This way, the estimated reaction function will exclusively represent policymakers’ underlying objectives and allow consideration for the possible change in the decision making process during the period. Nevertheless, with the short data point which covers the period of this regime - 26 quarterly data points – the use of separate regression does not produce a good fit. To overcome this problem, dummy variable $F_t$ is introduced to equation 3.4 and equation 3.5. Dummy variable $F_t$ takes a value of 1 for period 1998Q3 to 2005Q2 and zero otherwise. The amended model for the estimation period 1987Q1 to 2005Q2 is as follows:

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5See results in Table 3.3, placed in Appendix
Closed economy version:

\[ r_t = (1 - \rho) \left[ \alpha + \beta_\pi \pi_{t+n} + \Theta_y y_{t+n} \right] + \rho r_{t-1} \]
\[ + (1 - d\rho) [\partial \alpha F_t + \partial \beta_\pi F_t \pi_{t+n} + \partial \Theta_y F_t y_{t+n}] + \partial \rho F_t r_{t-1} + \varepsilon_t \]

Open economy version:

\[ r_t = (1 - \rho) \left[ \alpha + \beta_\pi \pi_{t+n} + \Theta_y y_{t+n} + \Omega \Delta r e r_{t+n} \right] + \rho r_{t-1} \]
\[ + (1 - d\rho) [\partial \alpha F_t + \partial \beta_\pi F_t \pi_{t+n} + \partial \Theta_y F_t y_{t+n} + \partial \Omega F_t \Delta r e r_{t+n}] + \partial \rho F_t r_{t-1} + \varepsilon_t \]

with \( \partial \rho, \partial \alpha, \partial \beta_\pi, \partial \Theta_y, \partial \Omega \) representing changes in estimated parameters when the capital controls and fixed exchange rate regime was in operation.

### 3.3 Estimation Results

To answer the question whether the interest rule specified in equation 3.4 and 3.5 is a good representation of BNM’s behaviour, it must be tested against the data. The outcome from this exercise highlights several main features about BNM’s behaviour in formulating monetary policy. Each of these features is discussed below.

**Establishing BNM’s Reaction Function**

From the result in Table 3.1, it is found that the simple HMT-type interest rate rule that has been widely used in the analysis of monetary policy in various developed and developing economies, is also equally applicable in summarizing the historical behaviour of the policymakers in Malaysia. This is shown from the very high adjusted \( R^2 \) for each of the estimated equations.\(^6\) Moreover, in all of the estimated equations involving the closed economy version, the estimated coefficients are correctly signed with a plausible

\(^6\)In almost all cases, the estimated equations pass the standard diagnostic test for autocorrelation and ARCH. In the case where the existence of heteroscedasticity cannot be rejected, the Newey-West consistent standard error is used.
Table 3.1: BNM’s Estimated Reaction Function with Different Specifications: 1975Q1-2005Q2

<table>
<thead>
<tr>
<th>Backward-Looking Specification</th>
<th>Closed Economy Version</th>
<th>Open Economy Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_\pi$ $\Theta_y$ $\rho$ $\alpha$ $\pi^*$ Adj. R$^2$ SEE</td>
<td>0.683 0.864 0.857 3.777 2.451 0.874 0.890</td>
<td>0.822 0.789 0.840 3.089 -0.352 0.501 0.874 0.890</td>
</tr>
<tr>
<td>std. err.</td>
<td>(0.243) (0.199) (0.049) (0.956)</td>
<td>std. err.</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.006) (0.000) (0.000)</td>
<td>p-value</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contemporaneous Specification</th>
<th>Closed Economy Version</th>
<th>Open Economy Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_\pi$ $\Theta_y$ $\rho$ $\alpha$ $\pi^*$ Adj. R$^2$ SEE</td>
<td>0.937 1.101 0.871 3.080 1.254 0.886 0.847</td>
<td>1.053 1.032 0.863 2.434 -0.274 10.727 0.889 0.836</td>
</tr>
<tr>
<td>std. err.</td>
<td>(0.256) (0.255) (0.044) (1.082)</td>
<td>std. err.</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.000) (0.000) (0.000)</td>
<td>p-value</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Forward-Looking Specification</th>
<th>Closed Economy Version</th>
<th>Open Economy Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_\pi$ $\Theta_y$ $\rho$ $\alpha$ $\pi^*$ Adj. R$^2$ SEE</td>
<td>1.089 1.196 0.879 2.546 5.095 0.886 0.847</td>
<td>1.444 0.918 0.870 1.234 -0.143 3.981 0.885 0.851</td>
</tr>
<tr>
<td>std. err.</td>
<td>(0.318) (0.356) (0.038) (1.184)</td>
<td>std. err.</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.001) (0.001) (0.000)</td>
<td>p-value</td>
</tr>
</tbody>
</table>
size. Estimated coefficients for the model are also statistically significant. Hence, the results indicate the existence of a systematic relationship between the movement of BNM’s operational target with inflation and output gap, as well as the tendency of BNM to smooth interest rates. Most importantly, the results suggest that the simple interest rate rule tracks BNM’s reaction function reasonably well. This result will be an important platform to analyze BNM’s behaviour in formulating monetary policy in Malaysia.

In general, our estimation results are largely consistent with the results reported in two other empirical studies that look at the conduct of monetary policy in Malaysia. Studies by Umezaki (2007) and Ramayandi (2008) model BNM’s reaction function using a forward looking HMT rule and they find that it tracks the historical interest rate movement fairly well. The same outcomes are also found here.

BNM’s Smoothing Behaviour

The results also indicate the tendency of BNM to smooth the interest rate movement over the period. Using different specification, the estimated smoothing coefficient of its reaction function is within the range of 0.8. The size of the estimated smoothing parameter for BNM is comparable to the estimates found in similar studies involving central banks in the developed countries. See among others the study by Judd and Rudebusch (1998), Clarida, Gali, and Gertler (1998) and Nelson (2003). This suggests that in setting its policy rate, BNM’s smoothing behaviour is not very different from its fellow counterparts in developed economies.

Choice of Time Dimension for the Reaction Function – Backward, Contemporaneous and Forward Looking Specifications

From Table 3.1, results using the backward looking specification in both versions of the HMT rule raised some questionable doubts about BNM’s actual behaviour in managing its interest rate policy. Even though the backward looking specification is able to track the data well, the estimates on the feedback coefficient on inflation \( (\beta_\pi) \) are found to be well below one. This result suggests that BNM’s general behaviour in setting interest rates during the estimation period, was not consistent with the Taylor’s principle. If
Taylor’s principle is violated over an extended period, it will lead to a self-fulfilling inflation spiral (Woodford (2001)). Given that the history of inflation in Malaysia was fairly low and stable during the estimation period, the finding that the estimated coefficient for $\beta_\pi$ to be well below 1 for the backward looking specification is not really consistent with the actual economic development experience in Malaysia.\(^7\) For this reason, modeling BNM’s reaction function using the backward-looking specification may not represent the actual behaviour of BNM in setting its policy rate during the estimation period.

In contrast, specifications using the contemporaneous and forward-looking set-up, produce more sensible results in tracking the formulation of monetary policy in Malaysia. The size of the estimated coefficient on $\beta_\pi$ is more reasonable and consistent with Taylor’s principle. In addition, results of both specifications also produce a better overall fit, with higher adjusted-$R^2$ and lower standard error than the backward looking model. Hence, the results suggest that BNM has not adopted a backward-looking behaviour in setting its interest rate policy. Instead, the policymakers are more likely to give large consideration to current (contemporaneous) or future (forward-looking) information in arriving at their policy decision. This result is not surprising. In several of its past reports and publications, BNM always provided its view and evaluation about the current and future economic outlook – suggesting their importance to BNM’s monetary policy formulation. The results of this exercise further supports this proposition. Hence, a simple HMT rule with the contemporaneous or forward-looking specification seems to better represent BNM’s reaction function than the backward-looking specification.

Having said that, the estimation results using the contemporaneous and the forward looking specifications are found to be very similar to each other. The strong similarities between the two estimation results, give no clear cut indication to single out which specification is the best choice to represent BNM’s actual reaction function. Due to this reason, both, the contemporaneous and the forward-looking specifications will be considered interchangeably in the subsequent analysis about the formulation of monetary policy in Malaysia.

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\(^7\)The average inflation during the estimation period is 3.51%, which is very low for a developing economy like Malaysia. See Figure 3.2 below to see the overall trend.
Closed vs. Open Economy Version of the Simple Interest Rate Rule

Contrary to Ball’s suggestion on the importance of the exchange rate to the interest rate rule, the estimated result of the closed and open economy versions of the interest rate rule for Malaysia is almost identical to each other (see results in Table 3.1). More notably, the estimated results suggest that the exchange rate variable is not really important in influencing BNM’s interest rate decision. In all cases, the estimated coefficient for the change in exchange rate is wrongly signed and is not statistically significant.\(^8\) Similar outcomes were also reported in Umezaki (2007) and Ramayandi (2008).

The insignificance of the exchange rate in influencing the determination of the interest rate in Malaysia is not really surprising, given the fact that Malaysia adopted a managed float exchange rate regime during most of the estimation period. Like other central banks in developing countries with a similar exchange rate regime, BNM smoothed the fluctuation of the ringgit by intervening directly in the exchange rate market (Page 15, Bank Negara Malaysia (1994b) and page 270, Bank Negara Malaysia (1999)). As the objective to smooth exchange rate fluctuations is conducted separately using the direct intervention method, it is very likely that BNM’s decision to set interest rates purposely exclude this factor.\(^9\) This could be the main explanation to the findings that the exchange rate parameters in the estimated BNM’s reaction function are insignificant.

Similar results on the unimportance of exchange rate movement to the interest rate determination are also found in the empirical studies for developed economies. For example, Clarida, Gali, and Gertler (1998) concluded that the quantitative impact of exchange rate movements to the estimated interest rate rule for the industrialized countries is very small. Similarly, Lubik and Schorfheide (2007) find little evidence of exchange rate effects on the interest rate movement in Australia, New Zealand and UK. On this point, Taylor (2001) argues that even though the closed economy version of a simple interest rate rule does not include the exchange rate variable directly, the impact of exchange rate movement is already reflected on the outcome of inflation and output

---

\(^8\)Estimation results using backward looking specification indicate weak evidence on the significance of the exchange rate movement in BNM’s reaction function. However, the estimate is still wrongly signed. As stated earlier, backward looking specification may not truly represent BNM’s actual behaviour in formulating monetary policy. Thus, we still view exchange rate movement is not an important component in BNM’s decision rule.

\(^9\)We will discuss this issue in more detail in Chapter 4.
gap that is considered in making interest rate decisions. Hence, adding the exchange rate as an additional variable to the interest rate rule only gives marginal improvement to the closed economy version of the interest rate rule. Results of studies by Batini, Harrison, and Millard (2001) and Leitemo and Soderstrom (2005) supported Taylor's argument. In their respective studies they find that including exchange rates directly into the interest rate rule does not yield much improvement in the performance of the optimal interest rate rule of their model. Clarida, Gali, and Gertler (2001) take Taylor’s point even further. Using a dynamic stochastic general equilibrium (DSGE) model as a workhorse, they show how the monetary policy problem in an open economy set-up of their model, is isomorphic to its closed economy counterpart. They conclude that central banks’ policy objectives of smoothing output and inflation variations remain the same in the case of an open economy; what changes, however, is the structure of the reduced form of the optimal interest rate rule. Hence, following this argument and the fact that estimated parameters for the real exchange rates are found to be statistically insignificant in the estimated model for Malaysia, the estimation result of the closed economy version of the simple interest rate rule will be used in the subsequent analysis of this chapter.

3.4 Evolution of BNM’s Reaction Function

BNM’s estimated reaction function is found to be considerably different for the three sub-periods that are considered. The results are presented in Table 3.2 below.

3.4.1 Pre-capital controls and fixed exchange rate regime
period: 1975Q1 to 1986Q4 and 1987Q1 to 1998Q2

There are significant differences in the size of the estimated coefficients for $\beta_\pi$, $\Theta_y$ and $\rho$ during the two sub-periods. It is found that the feedback coefficient for the interest rate smoothing ($\rho$) and the feedback coefficient on the output gap ($\Theta_y$) for the 1987-1998 period decrease notably compared with the estimates for the 1975-1986 period. In contrast, the feedback coefficient for inflation ($\beta_\pi$) increases considerably during the later period, suggesting the increase in importance of inflation outlook in influencing
Table 3.2: BNM’s Estimated Reaction Function: Sub-sample Periods

Closed Economy Version of HMT Rule

### Contemporaneous Specification

#### 1975Q1-1986Q4

<table>
<thead>
<tr>
<th>$\beta_\pi$</th>
<th>$\Theta_y$</th>
<th>$\rho$</th>
<th>$\alpha$</th>
<th>$\pi^*$</th>
<th>Adj. $R^2$</th>
<th>SEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.470</td>
<td>0.845</td>
<td>0.858</td>
<td>5.549</td>
<td>4.805</td>
<td>0.824</td>
<td>1.050</td>
</tr>
<tr>
<td>(0.405)</td>
<td>(0.252)</td>
<td>(0.062)</td>
<td>(2.352)</td>
<td>std. err.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.253)</td>
<td>(0.002)</td>
<td>(0.000)</td>
<td>(0.023)</td>
<td>p-value</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 1987Q1-1998Q2

<table>
<thead>
<tr>
<th>$\beta_\pi$</th>
<th>$\Theta_y$</th>
<th>$\rho$</th>
<th>$\alpha$</th>
<th>$\pi^*$</th>
<th>Adj. $R^2$</th>
<th>SEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.491</td>
<td>0.656</td>
<td>0.740</td>
<td>1.692</td>
<td>2.667</td>
<td>0.896</td>
<td>0.635</td>
</tr>
<tr>
<td>(0.304)</td>
<td>(0.339)</td>
<td>(0.109)</td>
<td>(0.983)</td>
<td>std. err.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.000)</td>
<td>(0.057)</td>
<td>(0.000)</td>
<td>(0.089)</td>
<td>p-value</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 1987Q1-2005Q2

<table>
<thead>
<tr>
<th>$\beta_\pi$</th>
<th>$\Theta_y$</th>
<th>$\rho$</th>
<th>$\alpha$</th>
<th>$\partial\beta_\pi$</th>
<th>$\partial\Theta_y$</th>
<th>$\partial\rho$</th>
<th>$\partial\alpha$</th>
<th>$\pi^*$</th>
<th>Adj. $R^2$</th>
<th>SEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.491</td>
<td>0.656</td>
<td>0.740</td>
<td>1.692</td>
<td>-0.005</td>
<td>-0.149</td>
<td>-0.445</td>
<td>0.721</td>
<td>1.211</td>
<td>0.936</td>
<td>0.569</td>
</tr>
<tr>
<td>(0.304)</td>
<td>(0.339)</td>
<td>(0.109)</td>
<td>(0.983)</td>
<td>(0.203)</td>
<td>(0.042)</td>
<td>(0.214)</td>
<td>(0.217)</td>
<td>std. err.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.000)</td>
<td>(0.057)</td>
<td>(0.000)</td>
<td>(0.089)</td>
<td>(0.980)</td>
<td>(0.001)</td>
<td>(0.041)</td>
<td>(0.002)</td>
<td>p-value</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Forward-Looking Specification

#### 1975Q1-1986Q4

<table>
<thead>
<tr>
<th>$\beta_\pi$</th>
<th>$\Theta_y$</th>
<th>$\rho$</th>
<th>$\alpha$</th>
<th>$\pi^*$</th>
<th>Adj. $R^2$</th>
<th>SEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.351</td>
<td>1.125</td>
<td>0.852</td>
<td>6.171</td>
<td>4.883</td>
<td>0.819</td>
<td>1.063</td>
</tr>
<tr>
<td>(0.380)</td>
<td>(0.463)</td>
<td>(0.062)</td>
<td>(2.044)</td>
<td>std. err.</td>
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<td></td>
</tr>
<tr>
<td>(0.361)</td>
<td>(0.019)</td>
<td>(0.000)</td>
<td>(0.004)</td>
<td>p-value</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 1987Q1-1998Q2

<table>
<thead>
<tr>
<th>$\beta_\pi$</th>
<th>$\Theta_y$</th>
<th>$\rho$</th>
<th>$\alpha$</th>
<th>$\pi^*$</th>
<th>Adj. $R^2$</th>
<th>SEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.880</td>
<td>0.568</td>
<td>0.674</td>
<td>1.028</td>
<td>3.440</td>
<td>0.913</td>
<td>0.583</td>
</tr>
<tr>
<td>(0.201)</td>
<td>(0.160)</td>
<td>(0.067)</td>
<td>(1.411)</td>
<td>std. err.</td>
<td></td>
<td></td>
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<tr>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.984)</td>
<td>p-value</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 1987Q1-2005Q2

<table>
<thead>
<tr>
<th>$\beta_\pi$</th>
<th>$\Theta_y$</th>
<th>$\rho$</th>
<th>$\alpha$</th>
<th>$\partial\beta_\pi$</th>
<th>$\partial\Theta_y$</th>
<th>$\partial\rho$</th>
<th>$\partial\alpha$</th>
<th>$\pi^*$</th>
<th>Adj. $R^2$</th>
<th>SEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.888</td>
<td>0.546</td>
<td>0.679</td>
<td>1.070</td>
<td>-0.057</td>
<td>-0.279</td>
<td>-0.210</td>
<td>1.084</td>
<td>1.732</td>
<td>0.941</td>
<td>0.547</td>
</tr>
<tr>
<td>(0.380)</td>
<td>(0.177)</td>
<td>(0.075)</td>
<td>(1.432)</td>
<td>(0.210)</td>
<td>(0.075)</td>
<td>(0.064)</td>
<td>(0.481)</td>
<td>std. err.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.978)</td>
<td>(0.203)</td>
<td>(0.000)</td>
<td>(0.015)</td>
<td>(0.040)</td>
<td>p-value</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
the movement of interest rates during the 1987-1998 period. The difference is also seen on the policymakers’ implicit inflation target. During the later period, monetary policy aimed to achieve a lower inflation target.

Lower interest rate smoothing behaviour

The lower estimate for the smoothing coefficient (\( \rho \)) for the 1987-1998 period suggests that monetary policy had been used more aggressively as the demand management tool during this period. The main reason to explain this outcome is the improvement in the domestic financial landscape and infrastructure. This condition provided BNM with greater flexibility to maneuver monetary policy, with less concern about the negative impact of such action on the overall stability of the financial system. For example, the successful deregulation of the interest rate regime for the banking institutions in the late 1970s, provided the Malaysian banking system with greater flexibility and resilience. Together with the progression and advancement of the Malaysian financial system that permits a more efficient working of the money and capital markets to allocate financial resources, the importance of monetary policy has also become more important and dominant over time. This translated into a lower interest rate smoothing behaviour.

Lower feedback coefficient on the output gap

While there is evidence of more aggressive use of monetary policy during the later period, the estimated reaction function also indicates that BNM was less responsive to the development in the output gap (\( \Theta_y \)). This indicates that, as Malaysia’s economy became more developed, BNM was more cautious in its action responding to the output gap.

BNM’s cautious behaviour could be attributed to the increasing difficulty for the policymaker to assess the true state of the Malaysian economy. With the rapid and sustained expansion of GDP experienced during the post-1987 period, together with the continuing evolution in the economic and financial condition of the Malaysian economy, the policymakers’ task to get the clear picture on the economic conditions becomes more challenging. To give a snapshot on the dynamic changes of the Malaysian economy, Malaysia experienced a large increase in foreign direct investment (FDI).
The total amount of FDI inflow during the 1975-1986 period was USD9.048 billion and in 1987-1998, this amount increased significantly to USD47.072 billion. The large inflow of FDI during this short period of time contributed to the rapid expansion of the Malaysian economy. During this period, Malaysian GDP grew at the average rate of 9% annually. Hence, the dynamic economic progress during this short span of time gave the central bank a great challenge to evaluate the true state of the economy before making monetary policy decisions.

The result of the estimated reaction function suggests that BNM has reacted to this increasing uncertainty by putting smaller weight on the output gap. Given that the structure of the Malaysian economy changed considerably and experienced rapid growth during this period, BNM’s cautious behaviour as inferred from this result is sensible and consistent with the famous proposition made by Brainard (1967). Faced with multiplicative uncertainty, in deciding policy actions, the central bank should be on the cautious side. As Alan Blinder, former member of Federal Reserve Board, put it on this issue:

“...estimate how much you need to tighten or loosen monetary policy to ‘get it right’. Then do less.” Blinder (1998)

The results of the estimated reaction function suggests BNM did just that from 1987 onwards.

The observation that in the face of increasing difficulty to assess the true economic condition, BNM reacted less forcefully to the output gap (\( \downarrow \theta_y \)) but showed less tendency to smooth interest rates (\( \downarrow \rho \)), is quite interesting. Normally, we would expect, faced with increase policy uncertainty, BNM to become more cautious in its overall policy action and this would translate into a higher interest rate smoothing. This turns out not to be the case. During the 1987-1998 period, BNM demonstrates its precautionary policy stance by responding less to the output gap but not to the willingness to change interest rate. There could be two reasons for this policy behaviour. One, as we mentioned before, from 1987 onwards BNM operated in a more resilient banking system that allows it to use monetary policy more effectively as one of the tools in the macroeconomic demand management. Second, this could reflect the

\[10\] Source: UNCTAD FDI database (http://stats.unctad.org/FDI/TableViewer/tableView.aspx)
outcome from policymakers’ strategy at that time to address the inflationary pressure in Malaysia. During that period, inflationary pressure was dominantly emanated from the supply constraint to keep up with the increase demand. The continuous expansion of the economy from 1987 onwards resulted the Malaysian economy to operate at the full employment level by 1992 (Bank Negara Malaysia (1994b)). Instead of focusing its policy action to slowdown the demand side, Malaysia’s policymakers (BNM and other Government agencies like the Treasury and the Economic Planning Unit) took a different approach to tackle this issue. They tried to address the supply constraint by encouraging more capacity building. Thus, to encourage investment, particularly from the private sector, monetary policy (and interest rate) was made more “accommodative” when responding to the development in the output gap. As we will see in Chapter 4, this policy action is consistent with BNM’s policy preferences. Compared to the 1975-1986 period, BNM increases its policy preference to stabilize the output gap during the later period.

Higher feedback coefficient on the inflation outlook

The estimation results reveal that the coefficient for $\beta_\pi$, (the feedback coefficient for inflation) during the period of 1975-1986 is small and is not statistically significant. Interestingly, BNM’s estimated reaction function for this period was not really consistent with the behaviour predicted by the HMT-type interest rate rule in the way the central bank articulates its interest rate decision. Even though the simple HMT rule fits the data fairly well (with the adjusted $R^2$ for 1975-1986 period is around 0.8), the estimation results indicate that the inflation factor was not statistically significant in influencing the movement of interest rates during this period. Stabilizing the output gap was the dominant factor that contributed to BNM’s action to change the interest rate.

Does this result imply that the simple HMT-rule fails to represent BNM’s reaction function for this period? While this is one of the possibilities, the fact that the simple HMT rule is able to track the actual data well suggests the high possibility for this rule to be a valid representation of BNM’s reaction functions for the 1975-1986 period. Hence, the result could indicate possible inconsistencies on the part of BNM’s behaviour at that time, in particular its failure in setting the interest rates to be in line with the Taylor’s principle (i.e. to set $\beta_\pi > 1$ ). On this note, the simple HMT-rule fits the data
Figure 3.1: Malaysia’s GDP Growth 1975Q1-2005Q2  
(quarterly, seasonally adjusted, %)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>5.91</td>
<td>9.09</td>
<td>4.77</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>4.49</td>
<td>2.43</td>
<td>5.42</td>
</tr>
</tbody>
</table>

This result highlights two important observations on BNM’s behaviour in formulating monetary policy in Malaysia. Firstly, it indicates that the formulation of monetary policy during the 1975-1986 period was geared towards achieving output stability, with little consideration to the inflation outlook. During this period, the growth of Malaysia’s GDP was more volatile (see Figure 3.1 for details). GDP growth was badly affected by the oil price shocks (early and end-1970’s) and the collapse of commodity prices in the international market (mid-1980s). Perhaps, these factors prompted BNM to temporarily sacrifice its price stability objective and focus more towards stabilizing the output fluctuations. Secondly, BNM’s failure to comply with the Taylor’s principle during this period caused a temporary increase in the level and volatility of the inflation rate in Malaysia. During 1975-1986, it is found that the inflation rate was much higher and volatile than what was experienced during the later period. While higher domestic inflation during the period could be attributed to the effects of “supply shock” experienced by the Malaysian economy following the first (1973) and the second (1979) oil price

55
shocks, failure of BNM to set interest rates by responding to the inflation outlook could be the amplifying factor contributing to this high inflation experience. In particular, BNM’s failure to set interest rates by reacting more than one-to-one to inflation could have exacerbated the impact of the oil price shocks on the domestic price. See table and graph in Figure 3.2 for details. This outcome is in-line with the theoretical findings advocated by Taylor (1999b) and Woodford (2001) about the importance of an interest rate rule to fulfill Taylor’s principle in order to ensure price stability. Failure to do so, leads to the self-fulfilling inflationary process to take effect. In the Malaysian case during this episode, the supply shocks from the higher oil price triggered the upward adjustment on the price of general goods, as well as the inflationary expectation among economic agents. These factors contributed to the higher domestic inflation. When nominal interest rates failed to adjust more than one-to-one to changes in the inflation rate, the reduction in the real interest rates pushed up the aggregate demand through the interest rate channel. The higher aggregate demand put further upward pressure on the general price level. Hence, the price level continued to be adjusted upwards.
As a result, inflation during 1975-1986 remained high for an extended period and peaked at 10.5% in Q2 1984.

In contrast, inflation rate during the 1987-1998 period was much lower and relatively stable. During the estimation period, the estimated coefficient for $\beta_\pi$ of BNM’s reaction function is well above 1 and is statistically significant. Despite the Malaysian economy growing at a rapid rate during this period – with GDP expanding at an average annual rate of 9% - the inflation rate remained low and stable. Again, the stable inflation outcome during this period was attributed to BNM’s sound conduct of monetary policy by setting interest rates according to Taylor’s principle.

The benefit of this sound policy to Malaysia’s economy was considerable. Inflation during the later period was much lower and more stable. The volatility of the inflation rate declined substantially, with its standard deviation reduced to just 1.232 (2.624 for 1975-1986). In addition, the benefit from stable inflation is prosperous economic growth. During the period, Malaysia experienced the longest economic boom in its history. GDP grew at an average rate of 9% with a much lower volatility. This outcome is consistent with the argument put forward by Clarida, Gali, and Gertler (2000) - aggressive monetary policy to fight inflation works to reduce aggregate output volatility by eliminating “sunspot” equilibria.

### Lower inflation target

The estimated reaction function across the two time periods also reveals that there is a significant decline in the BNM’s implicit inflation target, $\pi$. Using the respective estimates for $\Theta_y$ and $\beta_\pi$ of the two sub-samples, the inflation target during the later period is derived to be between 2.7-3.4% (about 4.8% for the 1975-1986 period). This decline may indicate the change in BNM’s policy objective. In-line with the overall improvement in Malaysia’s real-sector economy during the 1987-1998 period, monetary policy was indeed implemented to achieve a lower inflation target.
3.4.2 Post-capital controls and fixed exchange rate regime period: 1998Q3 to 2005Q2

From the results in Table 3.2, there is strong evidence to suggest that BNM’s reaction function changes considerably during the engagement of this regime. The estimated coefficient on the interactive dummy for output gap \( \partial \Theta_y \) and interest rate smoothing \( \partial \rho \) are found to be statistically significant, indicating changes in BNM’s responses to stabilize output and the tendency to change its policy stance. The estimated coefficient on the interactive dummy for inflation \( \partial \beta \pi \) is not significant; suggesting that the policymakers’ concern on the inflation outlook in formulating monetary policy remained unchanged when the regime was in place. Nevertheless, there is evidence that BNM reduced its inflation target to around 1.2-1.7% (from around 2.7-3.4% previously).

The estimated coefficient for \( \partial \Theta_y \) is negative, suggesting that BNM’s feedback reaction to stabilize the output gap decreases during the period. At first glance, this result may seem to be counter-intuitive, given the fact that the main aim of the introduction of this regime was to revive the Malaysian economy. With the Malaysian economy at that time operating well below its potential level, it is expected that BNM’s concern to stabilize output would have increased. Nevertheless, this result is indeed consistent with the downward trend observed earlier regarding BNM’s feedback coefficient on output. As found earlier, the estimated coefficient for \( \Theta_y \) declines in the 1987-1998 period and this trend continues when the capital control and fixed exchange rate regime was introduced. Again, a possible reason to explain the decline in BNM’s feedback coefficient to stabilize output is the increasing uncertainty on the Malaysian economic structure following the 1997 Asian Financial Crisis and the subsequent introduction of capital controls and fixed exchange rate regime. The impact of these unprecedented and short-lived events to the Malaysian economy must have been considerable and perhaps unknown to BNM at that point of time. With the increased uncertainty of the impact of such events to the real sector, the result suggests that BNM acted cautiously by reacting less forcefully to the output gap.

In contrast, the estimated coefficient for \( \partial \rho \) is also negative, suggesting BNM’s reduced tendency to smooth the interest rates. The lower interest rate smoothing coefficient on its estimated reaction function indicated the changing behaviour of BNM’s during the period to change its policy rate more forcefully than the manner showed before
the regime was introduced. This also suggests that monetary policy was used more aggressively during the period as part of the key strategies to revive the Malaysian economy on the aftermath of the Asian Financial Crisis. This result is not surprising, given the fact that one of the main objectives of capital control that was introduced at this time was to provide BNM with autonomy to conduct independent monetary policy. Despite imposing a fixed exchange rate regime by pegging the ringgit to the US dollar, the imposition of capital control allowed BNM to pursue an independent monetary policy without being dictated by the US’s monetary policy. The result of BNM’s reaction function for this period indicated that BNM took full advantage of the ‘window opportunity’ provided by the capital control, by actually changing its policy rate more aggressively. From 1998Q3 onwards, BNM drastically loosened its monetary stance. Between 1998Q3 to 1999Q4, BNM reduced its policy rate 7 times. Within that 13-months period, interest rates declined from 11% in June 1998 to 5% at end-1999.

3.5 Conclusion

This chapter established a few important features about the way Bank Negara Malaysia (BNM) formulates monetary policy in Malaysia.

First, modeling BNM’s reaction function by using a simple HMT-type interest rate rule is able to track the interest rate movement generally well. As it is being commonly used to model the reaction function of central banks in various developed and developing countries, this exercise indicates that a similar approach also works equally well in summarizing the central bank’s behaviour in Malaysia.

Second, the estimated reaction function with the backward looking specification performs poorly in tracking BNM’s past behaviour. This provides empirical evidence that interest rate movements in Malaysia have been largely influenced by current and future economic development. Hence, it is very likely that BNM has always adopted a “forward-looking” approach in its policy making.

Third, the exchange rate factor is not statistically significant in explaining the movement of BNM’s reaction function. Despite the fact that BNM does smooth exchange rate movement, this exercise failed to capture any empirical evidence to establish a relationship between BNM’s interest rate policy and the movement of exchange
rates. This indicates BNM does not directly use its interest rate policy to stabilize exchange rates. Instead, this outcome is achieved mainly through BNM influencing the movement of the nominal exchange rate by adopting a managed float exchange rate regime. In doing so, BNM intervenes directly in the foreign exchange market and does not directly use interest rates as the instrument.

Fourth, BNM’s behaviour in setting interest rates changed considerably over time. The change in behaviour was triggered by the continuous development and progression of the Malaysian economy, as well as the change in the policy landscape following the introduction of the capital control and fixed exchange rate regime in September 1998. Fifth, like other central banks in the developed countries, the results indicate that BNM also smoothed interest rates. Interestingly, this smoothing behaviour tends to decline over time. It suggests that monetary policy in the later period has been used more aggressively and forcefully. Even though the other results suggest that BNM did react more cautiously when responding to the development in the output gap during the later period - possibly due to the increasing difficulty to gauge the true state of the economy – but this does not make BNM more risk averse in taking policy action. When it comes to combating inflation, interest rates have been used forcefully. Hence, it is most likely that the lower smoothing coefficient as found in this exercise reflects the outcome from the increased importance of monetary policy as part of the demand management tool to achieve price stability in the later period. This can be seen from the bigger estimated coefficient for $\beta_\pi$, with its magnitude surpassing the value of $\Theta_y$ after the 1987 period.

Lastly, the results also reconfirm the importance of interest rate setting to fulfill Taylor’s principle in order to achieve price stability. Similar to the result by Clarida, Gali, and Gertler (2000) from analyzing the US Federal Reserve’s interest rate setting behaviour before and during the Volker-Greeenspan period (that found the administration before the Volker-Greeenspan era failed to comply with Taylor’s principle), the same conclusion also holds in the case of developing countries like Malaysia. Hence, in general, the sound conduct of monetary policy requires that central banks always be aggressive in fighting inflation. Not only will such action put inflation at bay, but also it benefits the aggregate stability of the economy in the form of lower output variability.

Even though the estimation of BNM’s reaction function as a single equation as conducted in this chapter is able to shed a few important insights about the systematic components of BNM’s policy-making, it must be acknowledged that this approach also
has its own limitations. As is generally known from the econometrics field, the simplicity of a single equation estimation as used in this chapter, requires a strict assumption that the explanatory variables in the HMT interest rate rule are exogenous. If this assumption is invalid, estimated parameters from the single equation estimation could be biased. Obviously, this would affect the representation of the estimated BNM’s decision rule. We will look at this possibility in Chapter 5 and 6. As part of the equations in the DSGE model, parameters of HMT interest rate rule in these two chapters are estimated simultaneously with other parameters of the DSGE model in the system of equations. We then compare the estimation results of BNM’s reaction function from this alternative estimation approach, to what is reported in this chapter. Interestingly, we find the use of a different estimation approach produces a different estimation result for BNM’s reaction function.

Apart from the estimation issues, Dennis (2002) argues that while estimated policy rules can usefully summarize past movement of interest rates, their main drawback is that they are unable to address questions about the actual policy formulation process. This drawback is evident in the fact that the feedback coefficients of the reaction function is constructed on an ad-hoc basis, without specifying the loss function and structure of the economy. Indeed, as Svensson (1997a) shows, given an appropriate form of the objective function, the HMT-type reaction function is the solution to a central bank’s inter-temporal optimization problem. In this framework, the coefficients of the policy rule will not only depend on parameters defining the preferences of the policymaker but also on those describing the structure of the economy. As will be seen in Chapter 4, this relationship is complicated and identification of the policy parameters might be non-trivial since changes in the estimated parameters of the policy rules could be induced not only by a shift in the central bank’s preferences but also by variations in the structure of the economy. Hence, the next chapter will try to address this issue by estimating simultaneously BNM’s reaction function and equations representing Malaysia’s economic structure as a whole system.
### 3.6 Appendix

Table 3.3: Results of Chow Test for Structural Break (based on estimation results for full sample period 1975Q1 to 2005Q2)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Closed Economy Version</td>
<td>Open Economy Version</td>
<td>Closed Economy Version</td>
</tr>
<tr>
<td>1986Q4</td>
<td>F-statistic p-value</td>
<td>F-statistic p-value</td>
<td>F-statistic p-value</td>
</tr>
<tr>
<td></td>
<td>2.778 0.030</td>
<td>1.966 0.089</td>
<td>2.823 0.028</td>
</tr>
<tr>
<td>1998Q2</td>
<td>2.852 0.028</td>
<td>2.134 0.066</td>
<td>2.209 0.072</td>
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</tbody>
</table>

Table 3.4: Results of Unit Root Test

<table>
<thead>
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<th>Test Stats</th>
<th>Bandwidth</th>
<th>Test Stats</th>
<th>Bandwidth</th>
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<tbody>
<tr>
<td>$r_t$</td>
<td>0.292</td>
<td>-2.252</td>
<td>3</td>
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<tr>
<td>$\pi_t$</td>
<td>0.396</td>
<td>-4.761</td>
<td>4</td>
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<tr>
<td>$y_t$</td>
<td>0.054</td>
<td>-4.696</td>
<td>7</td>
</tr>
<tr>
<td>$\Delta r e_t$</td>
<td>0.057</td>
<td>-7.489</td>
<td>1</td>
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</table>

KPSS - Kwiatkowski, Phillips, Schmidt and Shin Method.
Table 3.5: Correlation Between Dependent Variables and Instruments in IV Estimation

<table>
<thead>
<tr>
<th>Variables</th>
<th>( \pi_t )</th>
<th>( \pi_{t+1} )</th>
<th>( y_t )</th>
<th>( y_{t+1} )</th>
<th>( \Delta rer_t )</th>
<th>( \Delta rer_{t+1} )</th>
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</thead>
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<tr>
<td>( \pi_t )</td>
<td>1.000</td>
<td>0.756</td>
<td>1.000</td>
<td>0.690</td>
<td>1.000</td>
<td>0.377</td>
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<tr>
<td>( \pi_{t-1} )</td>
<td>0.920</td>
<td>0.756</td>
<td>0.661</td>
<td>0.352</td>
<td>0.376</td>
<td>-0.015</td>
</tr>
<tr>
<td>Instruments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \pi_{t-2} )</td>
<td>0.797</td>
<td>0.593</td>
<td>0.328</td>
<td>0.223</td>
<td>-0.018</td>
<td>0.006</td>
</tr>
<tr>
<td>( \pi_{t-3} )</td>
<td>0.665</td>
<td>0.447</td>
<td>0.189</td>
<td>0.152</td>
<td>0.003</td>
<td>0.017</td>
</tr>
<tr>
<td>( \pi_{t-4} )</td>
<td>0.520</td>
<td>0.337</td>
<td>0.152</td>
<td>-0.097</td>
<td>0.015</td>
<td>-0.042</td>
</tr>
<tr>
<td>\log M3_{t-1}</td>
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<td>-0.385</td>
<td>0.113</td>
<td>0.088</td>
<td>-0.010</td>
<td>-0.007</td>
</tr>
<tr>
<td>Instruments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\log M3_{t-2}</td>
<td>-0.422</td>
<td>-0.388</td>
<td>0.109</td>
<td>0.083</td>
<td>-0.013</td>
<td>-0.009</td>
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<tr>
<td>\log M3_{t-3}</td>
<td>-0.424</td>
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<td>0.105</td>
<td>0.079</td>
<td>-0.015</td>
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<tr>
<td>\log M3_{t-4}</td>
<td>-0.428</td>
<td>-0.398</td>
<td>0.101</td>
<td>0.075</td>
<td>-0.013</td>
<td>-0.006</td>
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Chapter 4

Identifying Bank Negara Malaysia’s Policy Preferences: Estimating Parameters of its Loss Function

As seen in Chapter 3, the Henderson-McKibbin-Taylor (HMT) type interest rate rule is able to represent Bank Negara Malaysia’s (BNM) reaction function fairly well. While the estimation of its reaction function sheds some light on the way BNM conducts monetary policy in Malaysia, several key questions regarding its policy actions remain unanswered. What really were the factors that led to the evolution of BNM’s reaction function over time? Does it mean BNM changed its policy objectives and preferences over the period? Or was the change in its reaction function the outcome of the changing structure of the Malaysian economy?

While estimated reaction functions are useful for describing how the target interest rate changes in relation to macroeconomic factors, it must be acknowledged that the policy rule itself is a reduced form equation. Due to this factor, important insights to monetary policy formulation cannot be inferred from the estimated decision rule. To gain further understanding and to evaluate the central bank’s behaviour in conducting monetary policy, information on the policymakers’ policy objectives and relative preferences between different objectives, is essential. There are several benefits that can be gained from inferring policymakers’ policy objectives and preferences. By analyzing central bank behaviour at the level of policy objectives, rather than at the level of reaction function coefficients, allows for direct estimation of policymakers’ implicit policy targets and preferences. Therefore, this approach is more appropriate when
an investigation of policy evolution over time is a researcher’s primary objective. For a central bank, like BNM, that does not officially adopt the inflation-targeting framework, the estimated policy objectives would provide valuable information about the implicit policy goals that it wants to achieve. Hence, this chapter will try to address this issue by estimating simultaneously BNM’s reaction function and Malaysia’s economic structure as a system.

This chapter aims to fulfill two main objectives. First, it attempts to reveal the underlying objectives and preferences of the policymakers in formulating monetary policy in Malaysia. While the previous chapter highlighted the possible economic variables that BNM responded to in setting interest rates, the approach used in this chapter goes one step further by trying to infer the actual objective variables that influence the policy making. To do so, it models BNM’s policy behaviour as the solution to the optimal control problem. For this purpose, four objective variables will be considered - inflation, output, exchange rates and smoothing interest rates. Based on this consideration, the second objective of this chapter is to estimate the relative importance of these different objective variables to the policymakers. It will also investigate how BNM’s relative preferences evolve over time.

This chapter is divided as follows. Section 4.1 lays out the specification of BNM’s loss function and the economic model that will be used in this exercise. Section 4.2 explains the mechanics of the estimation procedure. It will also discuss the choice of estimation period and give a description of the data used for this empirical exercise. Section 4.3 presents the estimation results. Section 4.4 discusses the main outcome of this exercise and highlights the key points towards understanding BNM’s policy behaviour. Conclusion follows.

4.1 Model Set-up

One of the main objectives of this chapter is to estimate the parameters of BNM’s loss function. To do so, it assumes BNM’s policy behaviour can be represented by an optimal control problem. A similar approach has been used in the literature to investigate the behaviour of central banks in developed economies. Using the closed economy set-up, Favero and Rovelli (2003), Ozlale (2003), and Dennis (2004, 2006), investigated the case of the US Federal Reserve, while Assenmacher-Wesche (2006)
did a country comparison involving the US, Germany and Japan. Collins and Siklos (2004) and Kam, Lees, and Liu (Forthcoming) took the approach one step further and used the open economy model to estimate the central banks’ preferences in several developed, inflation targeting countries. This chapter broadens the research in this area by extending the same approach to the case of a developing country like Malaysia. Below is the outline of the model used to analyze BNM’s policy behaviour.

4.1.1 Specification of BNM’s loss function

As stated in Chapter 1, BNM’s policy objectives are defined in the Central Bank of Malaysia Act 1958 (Revised 1994), as:

"i. To issue currency and keep the reserves safeguarding the value of the currency;

ii. To act as a banker and adviser to the Government;

iii. To promote monetary stability and a sound financial structure; and

iv. To influence the credit situation to the advantage of Malaysia."

Clearly from the above, the Act is silent on the explicit objective of the monetary policy that needs to be pursued by BNM. On this regard, Tang (2006) states that BNM’s monetary policy objective has often been interpreted to mean the attainment of sustainable economic growth with price stability. In doing so, BNM’s policy action always weighs more heavily on the side of output growth than price stability (page 43, Tang (2006)). As BNM’s monetary policy objective is unclear to the non-policymakers, one of the main motivations of this empirical exercise is to explicitly identify the objective(s) of monetary policy in Malaysia. In doing so, it will also authenticate Tang’s propositions that BNM’s policy preferences is biased towards output growth rather than to stabilizing inflation.

By taking into account the above considerations, BNM’s policy objective function is represented by the quadratic loss function;
\[ \text{Loss} = E_t \sum_{j=0}^{\infty} \beta^j \left[ (\pi_{t+j}^a - \bar{\pi})^2 + \lambda_1 (y_{t+j})^2 + \lambda_2 (rer_{t+j})^2 + \lambda_3 (r_{t+j} - r_{t+j-1})^2 \right] \ \ (4.1) \]

where \( E_t \) denotes expectation conditional on information available at time \( t \); \( 0 < \beta < 1 \) is the discount factor; \( y_t \) is the output gap; \( \pi_t^a \) is the average inflation (defined as \( \pi_t^a = \frac{1}{4} \sum_{j=0}^{3} \pi_{t-j} \), with \( \pi_t \) is the annual inflation for the quarter); \( r_t \) is the short-term interest rate and \( rer_t \) is the real exchange rate. \( \pi \) is the inflation target, and parameter \( \lambda_1, \lambda_2, \lambda_3 > 0 \), is the relative weights (relative to the inflation stabilization objective, whose weight is set to 1) given to the policy objective for the output gap, exchange rate stabilization and interest rate smoothing respectively. While the inclusion of inflation, output stabilization and interest rate smoothing in the loss function is a standard practice in expressing a central bank’s loss function, the model set-up for this chapter explores the suitability of including real exchange rate stabilization as an additional policy objective of BNM. The main motivation of this exploration is to find the exact role of the exchange rate stabilization in the overall conduct of monetary policy in Malaysia.

There are two reasons to believe that exchange rate stabilization is an important element in influencing BNM’s policy behaviour. First, is from BNM’s own admission on the importance of exchange rate stability to the Malaysian economy. As a small open economy that relies heavily on international trade, constant fluctuation in the exchange rate will affect the Malaysian economy negatively. On this account, there is a need for BNM to smooth excessive fluctuation of the ringgit in the foreign exchange market (page 114, Bank Negara Malaysia (1999)). Second, is the general observation that such objective is common among central banks in the developing countries (Moreno (2004)). For example, a survey conducted by Fry, Goodhart, and Almeida (1996) on the objectives and activities of central banks in developing countries, finds that there is a general tendency among central banks in this group to smooth the exchange rate movement.\(^1\) To achieve this, the common practice among the central banks is to intervene directly in the foreign exchange market (Jurgensen (1983)).\(^2\) Due to these two

\[^1\] Chapter 4, Fry, Goodhart, and Almeida (1996). BNM is one of the respondents to this survey.

\[^2\] This topic on central banks direct intervention in the foreign exchange market is well documented and widely researched in the literature. See among others, Taylor (1982), Macfarlane (1993), Lewis (1995); Baillie and Osterberg (1997); Sarno and Taylor (2001) and Kim and Sheen (2002) for
reasons, this chapter will explore how the exchange rate stability factor was translated into BNM's actual policy action. Most importantly, the approach used in this chapter will indicate whether empirical exercise can capture this proposition.

Note that the inclusion of the exchange rate smoothing objective in BNM’s loss function involves the use of real rather than nominal exchange rates. In practice, as the real exchange rate cannot be influenced directly by the policymakers, central bank’s foreign exchange intervention is conducted in the nominal exchange rate market. This raises the question that the use of the nominal rather than the real exchange rate could be more appropriate to be included in BNM’s loss function. To address this question, note that BNM’s action to intervene in the (nominal) exchange rate market cannot be viewed as its final policy objective. Unlike the central bank that adopts the currency board or the fixed exchange rate regime - that demands the central bank to intervene in the foreign exchange market to maintain the stipulated exchange rate peg - nothing in BNM’s Legal Act obligates it to maintain the stability of the ringgit against any particular currency. Instead, BNM’s action to intervene in the foreign exchange market is conducted on a “voluntary” basis, most likely to complement interest rates as its policy instrument. On this account, it is more sensible to include the real exchange rate smoothing as a possible policy objective and take its intervention operation in the nominal exchange rate market as a means towards achieving other objectives.

4.1.2 Modelling the Malaysian Economy

The structure of Malaysia’s economy is represented by a simple small open economy model (SOEM). The main characteristic of this model is similar to the one used in Ball (1999); Lees (2007); Svensson (2000) and Collins and Siklos (2004). The open economy version of the IS and Phillips curve see the introduction of the exchange rate
as the additional variable. This is to capture the exchange rate channel as one of the important conduits to the monetary transmission mechanism. In addition, other variables like foreign output and commodity prices are also included in the model. For a small open economy like Malaysia, these foreign influences will affect the movement of domestic inflation and output. The set-up of the model is as follows:

Open economy Aggregate Demand (IS equation):

\[ y_t = \gamma_0 + \gamma_1 y_{t-1} + \gamma_2 y_{t-2} + \gamma_3 \left[ r^a_{t-1} - \pi^a_{t-1} \right] + \gamma_4 rer^a_{t-1} + \gamma_5 y^*_t + \epsilon_{yt} \] (4.2)

Open economy Aggregate Supply (Phillips Curve)

\[ \pi_t = \kappa_0 + \kappa_1 \pi_{t-1} + \kappa_2 \pi_{t-2} + \kappa_3 \pi_{t-3} + \kappa_4 \pi_{t-4} + \kappa_5 y_{t-1} + \kappa_6 rer^a_{t-1} + \kappa_7 com_{t-1} + \epsilon_{\pi t} \] (4.3)

where, \( y_t \) is the output gap; \( \pi_t \) is quarterly inflation; \( r^a_t \) is the average short-term interest rates; \( rer^a_t \) is the average real exchange rate (\( rer \uparrow \) denotes depreciation); \( y^*_t \) is the output gap of the foreign country; \( com_t \) is the oil price index.

The movement of the real exchange rate, \( rer_t \), is governed by the real uncovered interest parity (UIP) condition:

\[ rer_t = rer_{t-1} - \varphi \left[ (r_{t-1} - \pi_{t-1}) - (r^*_t - \pi^*_t) \right] + \epsilon_{qt} \] (4.4)

where \( r^*_t \) and \( \pi^*_t \) is foreign interest rates and inflation rate respectively. With the way \( rer_t \) is defined here (\( rer \uparrow \) denotes depreciation), parameter \( \varphi \) is expected to be negative.

Variables \( \epsilon_{yt} \), \( \epsilon_{\pi t} \) and \( \epsilon_{qt} \) are the random shocks that affect aggregate demand, Phillips curve and real UIP condition respectively.

Movement of aggregate demand is influenced by its own lags, real interest rates, real exchange rate and foreign output. The difference between average short-term interest rate \( r^a_t = \frac{1}{4} \sum_{j=0}^{3} r_{t-j} \) and \( \pi^a_t = \frac{1}{4} \sum_{j=0}^{3} \pi_{t-j} \) average inflation, is the real interest rate
that affects the IS curve in equation 4.2. As an increase in the real interest rate affects spending negatively, parameter $\gamma_3$ is expected to be less than zero. In addition, domestic output is also affected by the performance of the export sector. An average of the real exchange rate, $rer_t^a = \frac{1}{4} \sum_{j=0}^{3} rer_{t-j}$ and the lag of foreign output would capture this effect. The real exchange rate determines the country's export competitiveness in the world market, hence a depreciation is expected to increase demand for Malaysia’s export ($\gamma_4 > 0$). Similarly, higher foreign output is expected to increase Malaysia’s export demand and contribute positively to aggregate output ($\gamma_5 > 0$).

For the Phillips curve, inflation is determined by its own lags, lag of output gap, average real exchange rate and lag of oil price. Increase in the output gap leads to “demand-pull” inflation ($\kappa_5 > 0$). Exchange rate depreciation makes imported goods more expensive for the domestic residents. The substitution effect among consumers favouring domestic goods, contributes to higher inflation ($\kappa_6 > 0$). Lastly, the Phillips curve equation also takes into account the possible “cost-push” inflation factor. This is done by including the movement of the oil price index into the inflation equation ($\kappa_7 > 0$).

Variables for the rest of the world are taken as exogenous and are represented by a stationary, univariate AR(1) process. This specification is chosen for its simplicity. As the main focus of this exercise is to estimate the parameters of the Malaysian economy, the model simplification for the exogenous variables is instrumental for the statistical flexibility and the parsimony of the model parametrization (Kam, Lees, and Liu (Forthcoming)). Nevertheless, despite its simplicity, the use of AR(1) process in our model specification does not lead to a loss of information from the perspective of inferring the influence of the foreign variables on the Malaysian economy. Perhaps, due to this reason, the same approach is also used in Ball (1999); Svensson (2000); Collins and Siklos (2004); Lees (2007) and Kam, Lees, and Liu (Forthcoming) in representing the external sector in their respective model’s specifications. The model for the exogenous variables is;

$$y_t^* = \mu_1 y_{t-1}^* + \epsilon_{y^*,t} \quad (4.5)$$

$$r_t^* = \mu_2 r_{t-1}^* + \epsilon_{r^*,t} \quad (4.6)$$
\[ \pi^*_t = \mu_3 \pi^*_{t-1} + \epsilon_{\pi,t} \tag{4.7} \]

\[ com_t = \mu_4 com_{t-1} + \epsilon_{c,t} \tag{4.8} \]

where the coefficients \( \mu_1 \) to \( \mu_4 \) are non negative and less than unity.\(^5\)

From the above, the small open economy model that will be used to fit Malaysia’s data is clearly backward looking in nature. There are two main reasons why the backward looking model is chosen for this exercise. Firstly, the performance of the forward-looking model in tracking the actual data is not very good. From the results using data of the developed economies, forward looking models tend not to fit the data as well as the Rudebusch-Svensson model (Estrella and Fuhrer (2002)). However, similar comparison cannot be made on the performance of these models to fit the Malaysian data due to lack of known studies. Hence, to start, a backward looking model will be used to represent the Malaysian economy. Secondly, the use of a backward-looking model precludes the issue of time consistency in BNM’s policy decisions. The estimation problem becomes significantly more complicated when time-inconsistency issues are taken into account. With a backward looking model, there is no need to take into account possible differences in the law of motion of the state variables when central bank action is taken either with commitment or discretion. Admittedly, these two areas are among the limitations of this exercise. Perhaps, these limitations would be a suitable extension for future research involving data of the Malaysian economy.

\(^5\)Note that in this chapter, parameters for the exogenous variables \( \mu_1 \) to \( \mu_4 \) are estimated separately. They are not estimated jointly with the other parameters of interest of equation 4.5 to 4.8, in order to reduce the computation burden of the FIML procedure. This is not expected to affect the overall results. As a small economy, it is unlikely that the movement of the Malaysian economy will directly affect the performance for the rest of the world.
4.2 Estimation Set-up

4.2.1 Deriving the Optimal Interest Rate Rule

It is assumed that BNM’s objective is to minimize its inter-temporal loss function (equation 4.1), by choosing its policy instrument $r_t$, subject to the economic structure given as equations 4.2 to 4.8. Equations 4.2 to 4.8 are written in the state-space form;

$$z_{t+1} = C + Az_t + Bx_t + u_{t+1}$$  \hspace{1cm} (4.9)

where $x_t = [r_t]$ is the policy instrument or control variable, $z_t$ is the state vector, $u_{t+1}$ is the shock vector, with variance-covariance matrix $\Sigma$. $A$, $B$, $C$ are matrices of coefficients that describe the economic structure.

$$A = \begin{bmatrix}
\kappa_1 & \kappa_2 & \kappa_3 & \kappa_4 & \kappa_5 & 0 & \frac{\kappa_6}{4} & \frac{\kappa_6}{4} & \frac{\kappa_6}{4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \kappa_7 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\gamma_3 & -\gamma_3 & -\gamma_3 & \gamma_1 & \gamma_2 & \frac{\gamma_4}{4} & \frac{\gamma_4}{4} & \frac{\gamma_4}{4} & \frac{\gamma_4}{4} & \frac{\gamma_4}{4} & \frac{\gamma_4}{4} & \frac{\gamma_4}{4} & \frac{\gamma_4}{4} & \frac{\gamma_4}{4} & \gamma_5 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\varphi & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\mu_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\mu_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\mu_3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\mu_4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 
\end{bmatrix}$
\[
\begin{bmatrix}
\pi_t \\
\pi_{t-1} \\
\pi_{t-2} \\
\pi_{t-3} \\
y_t \\
y_{t-1} \\
r_{t-1} \\
r_{t-2} \\
r_{t-3} \\
y^{*}_{t-1} \\
r^{*}_t \\
\pi^{*}_t \\
com_{t-1}
\end{bmatrix}
= \begin{bmatrix}
\varepsilon_{\pi,t+1} \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}
\begin{bmatrix}
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}
+ \begin{bmatrix}
\kappa_0 
\end{bmatrix}
\]

\[
\begin{bmatrix}
\varepsilon_{\pi,t+1} \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}
\begin{bmatrix}
\kappa_0 
\end{bmatrix}
\]

\[
\begin{bmatrix}
\varepsilon_{\pi,t+1} \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}
\begin{bmatrix}
\kappa_0 
\end{bmatrix}
\]

\[
\begin{bmatrix}
\varepsilon_{\pi,t+1} \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}
\begin{bmatrix}
\kappa_0 
\end{bmatrix}
\]

\[
\begin{bmatrix}
\varepsilon_{\pi,t+1} \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}
\begin{bmatrix}
\kappa_0 
\end{bmatrix}
\]

\[
\begin{bmatrix}
\varepsilon_{\pi,t+1} \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}
\begin{bmatrix}
\kappa_0 
\end{bmatrix}
\]

Now, writing the loss function in the state and control vectors

\[
Loss = E_t \sum_{j=0}^{\infty} \beta^j [(z_{t+j} - \bar{z})^\prime W (z_{t+j} - \bar{z}) + (x_{t+j} - \bar{x})^\prime Q (x_{t+j} - \bar{x}) + 2(z_{t+j} - \bar{z})^\prime H (x_{t+j} - \bar{x}) + 2(x_{t+j} - \bar{x})^\prime G (z_{t+j} - \bar{z})] \quad (4.10)
\]

Where \( W, Q, H, G \) are matrices containing policy preference parameters (or weights), defined as;

\[
Q = [\lambda_3]
\]

\[
H' = G = \begin{bmatrix}
0_{1x16} & -\frac{\lambda_3}{2} & 0_{1x10}
\end{bmatrix}
\]

\[
W = P' RP \quad \text{with}
\]

74
\[
P = \begin{bmatrix}
\frac{1}{4} & \frac{1}{4} & \frac{1}{4} & \frac{1}{4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
\]

\[
R = \begin{bmatrix}
1 & 0 & 0 & 0 \\
0 & \lambda_1 & 0 & 0 \\
0 & 0 & \lambda_2 & 0 \\
0 & 0 & 0 & \lambda_3
\end{bmatrix}
\]

\(\beta\) is the vector of the subjective discount factor, which is fixed as 0.985.\(^6\)

The target vectors for \(z_t\) and \(x_t\) are denoted \(z_t\) and \(x_t\) respectively. Particular interest is on the estimate of \(\pi_t\), which is BNM’s target inflation rate.

The estimation exercise seeks to identify and subsequently estimate the parameters in the structural model, \(A\), \(B\) and \(C\) jointly with the policy regime parameters \(W\), \(Q\), \(H\) and \(G\). As suggested by Dennis (2004), the strategy to achieve this is to extract information from actual economic outcomes. In doing so, it is assumed that the central bank has set the interest rate optimally and the observed economic outcome has evolved according to a known law of motion. Hence, following Ljungqvist and Sargent (2000), the solution to the stochastic linear optimal regulator problem, is given by the optimal policy rule;

\[
x_t = f + Fz_t
\]

where,

\[
f = \bar{x} + F\beta
\]

\[
F = -\left[Q + \beta B'MB\right]^{-1}\left[H' + G + \beta B'MA\right]
\]

\[
M = W + F'QF + 2HF + 2F'G + \beta(A + BF)'M(A + BF)
\]

Equations 4.9 and 4.10 can be solved by first substituting equation 4.13 into equation 4.14. Then iterating over the resulting matrix Riccati equation until convergence,

\(^6\)Which is a common approach used in the literature. Ireland (1997) states that parameter \(\beta\) is invariably imposed ex ante in the literature involving business cycle models and the New Keynesian model because it is difficult to be estimated precisely.
thereby obtaining a solution for $M$. Once a solution for $M$ has been found, $F$ can be determined recursively.

When subject to control, the state variables evolve according to a certain law of motion. This is done by substituting equation 4.11 into equation 4.9, resulting in:

$$z_{t+1} = C + Bf + (A + BF)z_t + u_{t+1} \quad (4.15)$$

This system of dynamic equations will be stable provided all eigenvalues of $(A + BF)$ are less than unity; otherwise the system will be explosive. This stability condition depends on parameters $A$, $B$, and $F$, and is independent of parameter $f$. Following this, estimated values of $z$ and $x$ will not influence the stability properties (Dennis (2006)). Hence, the restriction that has been imposed by equation 4.12, will not affect the overall results.

### 4.2.2 Transforming Model into Estimable Format

After setting up the model in this way, the next step is to conduct the estimation exercise. To do this, equations 4.9 and 4.11 are estimated simultaneously. To avoid a stochastic singularity problem, a new disturbance term is introduced. This disturbance term represents possible measurement errors that exist when policymakers assess the true state of the economy. Hansen and Sargent (1980) argue that in model estimation, econometricians have less information than policymakers do when actually formulating monetary policy. Hence, adding a vector of disturbance term $\varepsilon_{it}$ to equation 4.11, results in:

$$x_t = f + Fz_t + \varepsilon_{it} \quad (4.16)$$

To transform the model into an estimable format, first rewrite equations 4.9 and 4.16 in the structural form as follows:
\[ y_t = \gamma_0 + \gamma_1 y_{t-1} + \gamma_2 y_{t-2} + \gamma_3 \left[ r_{t-1}^a - \pi_{t-1}^a \right] + \gamma_4 \text{rer}_{t-1} + \gamma_5 y_{t-1}^* + \epsilon_{yt} \]

\[ \pi_t = \kappa_0 + \kappa_1 \pi_{t-1} + \kappa_2 \pi_{t-2} + \kappa_3 \pi_{t-3} + \kappa_4 \pi_{t-4} + \kappa_5 y_{t-1} + \kappa_6 \text{rer}_{t-1} + \kappa_7 \text{com}_{t-1} + \epsilon_{\pi t} \]

\[ \text{rer}_t = \text{rer}_{t-1} - \varphi \left[ (r_{t-1} - \pi_{t-1}) - (r_{t-1}^* - \pi_{t-1}^*) \right] + \epsilon_{\text{rer} t} \]

\[ r_t = f + F_1 \pi_t + F_2 \pi_{t-1} + F_3 \pi_{t-2} + F_4 \pi_{t-3} + F_5 y_t + F_6 y_{t-1} + F_7 \text{rer}_t + F_8 \text{rer}_{t-1} + F_9 \text{rer}_{t-2} + F_{10} \text{rer}_{t-3} + F_{11} r_{t-1} + F_{12} r_{t-2} + F_{13} r_{t-3} + F_{14} y_{t-1} + F_{15} r_{t-1}^* + F_{16} \pi_{t-1}^* + F_{17} \text{com}_{t-1} + \epsilon_{r t} \]

Now defining \( J_t = \begin{bmatrix} \pi_t & y_t & \text{rer}_t & r_t \end{bmatrix} \) as a vector of endogenous variables,

\[ E_t = \begin{bmatrix} y_{t-1}^* & r_{t-1}^* & \pi_{t-1}^* & \text{com}_{t-1} \end{bmatrix} \]

as a vector of exogenous variables, and

\[ \xi_t = \begin{bmatrix} \epsilon_{\pi t} & \epsilon_{yt} & \epsilon_{q t} & \epsilon_{r_t} \end{bmatrix} \]

as a vector of disturbance terms,

the above structural form model can be written in the VAR(4) system as;

\[ A_0 J_t = A_1 J_{t-1} + A_2 J_{t-2} + A_3 J_{t-3} + A_4 J_{t-4} + A_5 E_t + A_6 + \xi_t \quad (4.17) \]

With matrices \( A_0 \) to \( A_6 \) defined as;

\[
A_0 = \begin{bmatrix}
1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 \\
0 & 0 & 0 & 1 \\
-F_1 & -F_5 & -F_7 & 1
\end{bmatrix},
A_1 = \begin{bmatrix}
\kappa_1 & \kappa_1 & \frac{\kappa_6}{4} & 0 \\
-\frac{\gamma_3}{4} & 1 & \frac{\gamma_3}{4} & \frac{\gamma_3}{4} \\
\varphi & 0 & 1 & -\varphi \\
F_2 & F_6 & F_8 & F_{11}
\end{bmatrix},
\]

\[
A_2 = \begin{bmatrix}
\kappa_2 & 0 & \frac{\kappa_6}{4} & 0 \\
-\frac{\gamma_3}{4} & \kappa_2 & \frac{\gamma_3}{4} & \frac{\gamma_3}{4} \\
0 & 0 & 0 & 0 \\
F_3 & F_9 & F_{12}
\end{bmatrix},
A_3 = \begin{bmatrix}
\kappa_3 & 0 & \frac{\kappa_6}{4} & 0 \\
-\frac{\gamma_3}{4} & 0 & \frac{\gamma_3}{4} & \frac{\gamma_3}{4} \\
0 & 0 & 0 & 0 \\
F_4 & F_{10} & F_{11}
\end{bmatrix},
\]

77
\[ A_4 = \begin{bmatrix} \kappa_4 & 0 & \kappa_6 & 0 \\ -\gamma_2 & \gamma_2 & \gamma_4 & \gamma_4 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}, \quad A_5 = \begin{bmatrix} 0 & 0 & 0 & \kappa_7 \\ \gamma_5 & 0 & 0 & 0 \\ 0 & \varphi & -\varphi & 0 \\ F_{14} & F_{15} & F_{16} & F_{17} \end{bmatrix}, \]

\[ A_6 = \begin{bmatrix} \kappa_0 \\ \gamma_0 \\ 0 \\ F \end{bmatrix} \]

### 4.2.3 Estimation Procedure

As the parameters of the central bank’s loss function are not directly observable, they need to be inferred from the observed data. To do so, the estimation method based on the maximum likelihood approach is chosen for this exercise. To estimate the parameters of interest, the Full Information Maximum Likelihood (FIML) method is employed to the above system of equations. The same method is also used in Ozlale (2003), Dennis (2004, 2006) and Assenmacher-Wesc he (2006). The set-up of the FIML estimation procedure is as follows:

Let \( \Psi \) denote the variance-covariance matrix of disturbance vector \( \xi_t \) in equation 4.17 and let \( \theta = \{\gamma, \kappa, \varphi, \lambda_1, \lambda_2, \lambda_3, \pi\} \). Then by construction, \( A_0, A_1, A_2, A_3, A_4, A_5, A_6 \) are each a function of \( \theta \). Hence, the joint probability density function (PDF) for the data is

\[
P\left( \{J_t\}_{t=1}^T : \theta, \Psi \right) = P\left( \{J_t\}_{t=5}^T | \{J_t\}_{t=1}^4 : \theta, \Psi \right) \cdot P\left( \{J_t\}_{t=1}^4 : \theta, \Psi \right)
\]

where \( T \) is the sample size.

Now assume \( \xi_t \mid \{J_s\}_{s=1}^{t-1} \sim N(0, \Psi) \) for all \( t \). Then, the joint PDF for \( \{J_t\}_{t=1}^T \) can be written as

\[
P\left( \{J_t\}_{t=1}^T : \theta, \Psi \right) = \left[ \frac{1}{(2\pi)^{T/2}} |\Phi_0|^{(T-4)} |\Psi^{-1}|^{T/2} \exp \sum_{t=5}^T \left( -\frac{1}{2} \xi_t^\prime \Psi^{-1} \xi_t \right) \right] \cdot P\left( \{J_t\}_{t=1}^4 : \theta, \Psi \right)
\]
where $n$ equals the number of stochastic endogenous variables, i.e. four. It is assumed that the initial conditions $\{J_t\}_1^4$ are fixed and thus $P(\{J_t\}_1^4; \theta, \Psi)$ is proportionally constant. From this joint PDF, the following quasi-likelihood function is derived as

$$ln L(\theta, \Psi; \{J_t\}_1^T) \propto -\frac{n(T-4)}{2} \ln(2\pi) + (T-4) \ln |\Phi_0| - \frac{T-4}{2} \ln |\Psi| - \frac{1}{2} \sum_{t=5}^T \left( \xi_t \Psi^{-1} \xi_t \right)$$

The quasi maximum likelihood estimator (QMLE) of $\Psi$ is

$$\hat{\Psi}(\theta) = \sum_{t=5}^T \frac{\hat{\xi}_t \hat{\xi}_t'}{T-4}$$

which can be used to simplify the quasi-likelihood function above to

$$ln L(\theta; \{J_t\}_1^T) \propto -\frac{n(T-4)}{2} \left(1 + \ln(2\pi)\right) + (T-4) \ln |\Phi_0| - \frac{T-4}{2} \ln |\hat{\Psi}(\theta)| \quad (4.19)$$

The estimation of $\theta$ will be done by maximizing equation 4.19, and then using equation 4.18 to recover the estimate for $\Psi$.

To test the significance of the estimated parameters, the QMLE for the variance-covariance matrix of $\hat{\theta}$ is constructed using the method proposed by White (1982). This robust sandwich estimator allows for the possibility that the errors are not normally distributed.\(^7\) Hence, the variance-covariance matrix is given by

$$Var\left(\hat{\theta}\right) = \left[H(\theta) |_{\hat{\theta}}\right]^{-1} \left[G(\theta) |_{\hat{\theta}}\right] \left[H(\theta) |_{\hat{\theta}}\right]^{-1}$$

where $H(\theta) = -\left[\frac{\partial^2 \ln L_c(\theta; \{J_t\}_1^T)}{\partial \theta \partial \theta'}\right]$ is the inverse of the Fisher-Information matrix; and

$$G(\theta) = \left[\frac{1}{T-4} \sum_{t=5}^T \left( \frac{\partial \ln L_c(\theta; \{J_t\}_1^t)}{\partial \theta} \frac{\partial \ln L_c(\theta; \{J_t\}_1^{t-1})}{\partial \theta'} \right) \right]$$

is the outer-product variance estimator.

\(^7\)See Calzolari and Panattoni (1988) for discussion on the use of different estimators for the variance-covariance matrix in the FIML procedure.
Both $H(\theta)$ and $G(\theta)$ are evaluated at $\hat{\theta}$.

The estimation exercise for this chapter is conducted using the GAUSS program. The FIML procedure is operated by employing the OPTMUM library tools in GAUSS, with the Broyden, Fletcher, Goldfarb and Shanno (BFGS) algorithm is used to run the iteration for maximizing the likelihood function.\footnote{Algorithm developed by Davidson, Fletcher and Powell (DFP) is another common method that can be used for this purpose. These two methods are complementary (Luenberger (1984), page 268). The BFGS method is chosen here due to its faster speed to achieve convergence.}

### 4.2.4 Estimation Period

The estimation exercise covers the period of 1975Q1 to 2005Q2. To investigate the consistency of BNM’s behaviour during this 30 year period, four sub-sample periods are considered. Three sub-sample periods prior to capital control and the fixed exchange rate regime are 1975Q1 to 1998Q2, 1975Q1 to 1986Q4 and 1987Q1 to 1998Q2. The fourth sub-sample period is 1998Q3 to 2005Q2, during which capital control and the fixed exchange rate regime, was in place.

### 4.2.5 Data description

The description of the data used for this estimation exercise is given below.

- $r_t$ is the average 3-month interbank rate for the quarter, the operational target of BNM;
- $\pi_t$ is the annual inflation rate for the quarter;
- $y_t$ is the output gap for the quarter, defined as $y_t = GDP_t - GDP_t^*$, where $GDP_t$ is the real GDP for the quarter and $GDP_t^*$ is the potential output, estimated by Hodrick-Prescott filter;
- $rer_t$ is the real exchange rate for the quarter, expressed as the deviation from its equilibrium level.
$y_t^*$ is the foreign output gap for the quarter, represented by the deviation of the US’s real GDP from the potential output. The US’s potential output is estimated using the Hodrick-Prescott filter;

$\pi_t^*$ is the foreign annual inflation rate for the quarter, calculated using the US’s Consumer Price Index;

$r_t^*$ is the foreign short-term interest rate, represented by the US’s 3-month interbank rate; and

$com_t$ is the commodity price expressed in log, represented by the index of World Oil Price.

All the Malaysian data are sourced from the Monthly Statistical Bulletin, published by Bank Negara Malaysia. Data for real exchange rate and foreign variables are sourced from the International Financial Statistics (IFS).

4.3 Estimation Results

Estimation results for the simple small open economy model (SOEM) of the Malaysian economy are given in Tables 4.1, 4.4 and 4.5. Properties of residuals for the estimated equations (test for normality and autocorrelation) are summarized in Table 4.2. Comparison of the statistical moments (mean, standard deviation and persistence) of the actual data and fitted values are given in Table 4.3. Results of policy preference parameters are presented in Table 4.6.\(^9\) Discussion on the estimation results follows.

4.3.1 Performance of the SOEM in representing the Malaysian Economy

The results indicate that the simple SOEM fits Malaysian data reasonably well. Most of the estimated parameters of the IS and PC equations have a plausible size, correctly

\(^9\)Note: Estimation results for the 1998Q3-2005Q2 cannot be generated. See Sub-section 4.3.2 for the explanation. Hence, no result for this period is reported in the respective tables.
Table 4.1: Estimation Results of SOEM: 1975Q1 to 2005Q2
(standard error and p-value in parenthesis)

<table>
<thead>
<tr>
<th>Phillips Curve</th>
<th>IS Equation</th>
<th>UIP Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \kappa_0 )</td>
<td>0.153</td>
<td>-0.116</td>
</tr>
<tr>
<td>(3.334) (0.156)</td>
<td>(0.213) (0.236)</td>
<td>(0.580) (0.421)</td>
</tr>
<tr>
<td>( \kappa_1 )</td>
<td>0.127</td>
<td>0.750</td>
</tr>
<tr>
<td>(0.088) (0.076)</td>
<td>(0.086) (0.000)</td>
<td></td>
</tr>
<tr>
<td>( \kappa_2 )</td>
<td>0.144</td>
<td>-0.202</td>
</tr>
<tr>
<td>(0.093) (0.062)</td>
<td>(0.055) (0.000)</td>
<td></td>
</tr>
<tr>
<td>( \kappa_3 )</td>
<td>-0.157</td>
<td>-0.099</td>
</tr>
<tr>
<td>(0.089) (0.040)</td>
<td>(0.041) (0.009)</td>
<td></td>
</tr>
<tr>
<td>( \kappa_4 )</td>
<td>-0.348</td>
<td>0.025</td>
</tr>
<tr>
<td>(0.075) (0.000)</td>
<td>(0.013) (0.028)</td>
<td></td>
</tr>
<tr>
<td>( \kappa_5 )</td>
<td>0.214</td>
<td>0.043</td>
</tr>
<tr>
<td>(0.108) (0.025)</td>
<td>(0.044) (0.161)</td>
<td></td>
</tr>
<tr>
<td>( \kappa_6 )</td>
<td>0.214</td>
<td></td>
</tr>
<tr>
<td>(0.098) (0.016)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \kappa_7 )</td>
<td>1.143</td>
<td></td>
</tr>
<tr>
<td>(0.766) (0.069)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.278</td>
<td>0.496</td>
</tr>
</tbody>
</table>

signed and are statistically significant. As indicated in Table 4.2, except for the UIP equation, in most cases residuals of the estimated model pass the standard diagnostic test for normality and autocorrelation.\(^{10}\) The ability of the estimated model in matching the characteristic of the actual data is also fairly good. As shown in Table 4.3, except for the real exchange rate, the mean and persistence of the actual data and the fitted values for each variable are generally very close to each other. However, this simple model fails to track the short-run volatility of the quarterly data very well, which explains a low \( R^2 \) of the estimated model. This limitation also causes the standard deviation of the fitted value to be much lower than those of the actual data (see Table 4.3). Having

---

\(^{10}\)Figure 4.2 (placed in the Appendix) provides the graphical representation of the residuals for the estimated equations across different sample periods. Except for the residuals for the UIP equation, movement of residuals for other equations seems to be random and well behaved. In contrast, residuals for the UIP equation exhibits some stickiness in its movement, which is consistent with the results of the diagnostic test that suggest existence of a serial correlation.
Table 4.2: Diagnostics for Residuals of Estimated SOEM Equations Across Different Sample Periods

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phillips Curve</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normality</td>
<td>Jacque-Berra</td>
<td>7.314</td>
<td>0.202</td>
<td>1.181</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.025)</td>
<td>(0.989)</td>
<td>(0.554)</td>
<td>(0.509)</td>
</tr>
<tr>
<td>Autocorrelation</td>
<td>Q-stats. AR(1)</td>
<td>1.9491</td>
<td>1.745</td>
<td>1.919</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.163)</td>
<td>(0.187)</td>
<td>(0.166)</td>
<td>(0.238)</td>
</tr>
<tr>
<td><strong>IS Equation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normality</td>
<td>Jacque-Berra</td>
<td>0.131</td>
<td>0.567</td>
<td>0.635</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.936)</td>
<td>(0.753)</td>
<td>(0.727)</td>
<td>(0.939)</td>
</tr>
<tr>
<td>Autocorrelation</td>
<td>Q-stats. AR(1)</td>
<td>0.4493</td>
<td>0.191</td>
<td>5.209</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.503)</td>
<td>(0.662)</td>
<td>(0.022)</td>
<td>(0.221)</td>
</tr>
<tr>
<td><strong>UIP Equation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normality</td>
<td>Jacque-Berra</td>
<td>36.537</td>
<td>18.558</td>
<td>49.550</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Autocorrelation</td>
<td>Q-stats. AR(1)</td>
<td>39.750</td>
<td>22.266</td>
<td>13.069</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td><strong>Interest Rates Equation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normality</td>
<td>Jacque-Berra</td>
<td>20.375</td>
<td>14.257</td>
<td>0.005</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.997)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Autocorrelation</td>
<td>Q-stats. AR(1)</td>
<td>0.5275</td>
<td>0.519</td>
<td>0.716</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.468)</td>
<td>(0.471)</td>
<td>(0.397)</td>
<td>(0.083)</td>
</tr>
</tbody>
</table>

said that, given the dynamic of the developing economy like Malaysia, the ability of this simple model to track this overall movement is quite astounding.

Nevertheless, the performance of a simple UIP model in explaining the movement of Malaysian real exchange rates is less encouraging. For each estimation periods, its residuals fail the diagnostic test of normality and serial correlation. In addition, the mean and standard deviation of the fitted value are very different than those of the actual data (see Table 4.3). Even though the estimated coefficient for $\varphi$ is correctly signed, it is not statistically significant. This result suggests that the effect of the
Table 4.3: Comparison of Statistical Moments Across Different Sample Periods
Actual Data vs. Fitted Value

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inflation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (actual)</td>
<td>3.226</td>
<td>3.929</td>
<td>3.369</td>
<td>3.655</td>
</tr>
<tr>
<td>(fitted)</td>
<td>3.281</td>
<td>3.693</td>
<td>3.427</td>
<td>3.544</td>
</tr>
<tr>
<td>Std. Dev. (actual)</td>
<td>3.097</td>
<td>4.036</td>
<td>2.385</td>
<td>3.327</td>
</tr>
<tr>
<td>(fitted)</td>
<td>1.821</td>
<td>3.392</td>
<td>1.419</td>
<td>2.075</td>
</tr>
<tr>
<td>Persistence (actual)</td>
<td>0.838</td>
<td>0.814</td>
<td>0.880</td>
<td>0.818</td>
</tr>
<tr>
<td>(fitted)</td>
<td>0.829</td>
<td>0.754</td>
<td>0.918</td>
<td>0.812</td>
</tr>
<tr>
<td><strong>Output Gap</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (actual)</td>
<td>-0.240</td>
<td>-0.126</td>
<td>0.115</td>
<td>-0.008</td>
</tr>
<tr>
<td>(fitted)</td>
<td>-0.214</td>
<td>-0.147</td>
<td>0.173</td>
<td>-0.104</td>
</tr>
<tr>
<td>Std. Dev. (actual)</td>
<td>2.899</td>
<td>2.851</td>
<td>2.969</td>
<td>2.896</td>
</tr>
<tr>
<td>(fitted)</td>
<td>1.920</td>
<td>1.881</td>
<td>1.348</td>
<td>1.616</td>
</tr>
<tr>
<td>Persistence (actual)</td>
<td>0.686</td>
<td>0.679</td>
<td>0.636</td>
<td>0.656</td>
</tr>
<tr>
<td>(fitted)</td>
<td>0.558</td>
<td>0.524</td>
<td>0.687</td>
<td>0.535</td>
</tr>
<tr>
<td><strong>Real Exchange Rates</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (actual)</td>
<td>-0.427</td>
<td>0.067</td>
<td>-0.407</td>
<td>0.998</td>
</tr>
<tr>
<td>(fitted)</td>
<td>-1.197</td>
<td>1.254</td>
<td>1.169</td>
<td>-0.165</td>
</tr>
<tr>
<td>Std. Dev. (actual)</td>
<td>5.301</td>
<td>5.373</td>
<td>7.336</td>
<td>9.910</td>
</tr>
<tr>
<td>(fitted)</td>
<td>10.081</td>
<td>10.031</td>
<td>9.543</td>
<td>5.483</td>
</tr>
<tr>
<td>Persistence (actual)</td>
<td>0.829</td>
<td>0.827</td>
<td>0.800</td>
<td>0.813</td>
</tr>
<tr>
<td>(fitted)</td>
<td>0.881</td>
<td>0.891</td>
<td>0.845</td>
<td>0.869</td>
</tr>
<tr>
<td><strong>Interest Rates</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (actual)</td>
<td>5.990</td>
<td>7.098</td>
<td>6.432</td>
<td>6.729</td>
</tr>
<tr>
<td>(fitted)</td>
<td>5.987</td>
<td>7.062</td>
<td>6.421</td>
<td>6.772</td>
</tr>
<tr>
<td>Std. Dev. (actual)</td>
<td>2.510</td>
<td>2.502</td>
<td>1.972</td>
<td>2.147</td>
</tr>
<tr>
<td>(fitted)</td>
<td>2.491</td>
<td>2.393</td>
<td>1.899</td>
<td>2.271</td>
</tr>
<tr>
<td>Persistence (actual)</td>
<td>0.987</td>
<td>0.895</td>
<td>0.938</td>
<td>0.912</td>
</tr>
<tr>
<td>(fitted)</td>
<td>0.984</td>
<td>0.920</td>
<td>0.935</td>
<td>0.912</td>
</tr>
</tbody>
</table>

Note: Persistence is the estimated coefficient of the AR(1) regression.
Table 4.4: Estimation Results of SOEM: Sub-sample Periods
(standard error and p-value in parenthesis)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma_0$</td>
<td>-0.139</td>
<td>-0.170</td>
<td>1.214</td>
</tr>
<tr>
<td></td>
<td>(2.546) (0.478)</td>
<td>(0.454) (0.354)</td>
<td>(0.593) (0.021)</td>
</tr>
<tr>
<td>$\gamma_1$</td>
<td>0.629</td>
<td>0.756</td>
<td>0.350</td>
</tr>
<tr>
<td></td>
<td>(0.179) (0.000)</td>
<td>(0.155) (0.000)</td>
<td>(0.153) (0.012)</td>
</tr>
<tr>
<td>$\gamma_2$</td>
<td>-0.100</td>
<td>-0.176</td>
<td>0.059</td>
</tr>
<tr>
<td></td>
<td>(0.135) (0.234)</td>
<td>(0.105) (0.048)</td>
<td>(0.072) (0.208)</td>
</tr>
<tr>
<td>$\gamma_3$</td>
<td>-0.123</td>
<td>0.030</td>
<td>-0.435</td>
</tr>
<tr>
<td></td>
<td>(0.074) (0.050)</td>
<td>(0.124) (0.403)</td>
<td>(0.139) (0.001)</td>
</tr>
<tr>
<td>$\gamma_4$</td>
<td>0.027</td>
<td>0.004</td>
<td>0.061</td>
</tr>
<tr>
<td></td>
<td>(0.015) (0.041)</td>
<td>(0.133) (0.489)</td>
<td>(0.030) (0.023)</td>
</tr>
<tr>
<td>$\gamma_5$</td>
<td>0.953</td>
<td>-0.110</td>
<td>1.224</td>
</tr>
<tr>
<td></td>
<td>(0.130) (0.000)</td>
<td>(0.132) (0.303)</td>
<td>(0.149) (0.000)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.437</td>
<td>0.482</td>
<td>0.734</td>
</tr>
</tbody>
</table>

IS Equation

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varphi$</td>
<td>-0.091</td>
<td>-0.049</td>
<td>-0.252</td>
</tr>
<tr>
<td></td>
<td>(0.105) (0.193)</td>
<td>(0.077) (0.263)</td>
<td>(0.103) (0.008)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.460</td>
<td>0.514</td>
<td>0.541</td>
</tr>
</tbody>
</table>

interest rate differential to the Malaysian real exchange rate is negligible. If the interest rate differential factor is excluded, the results suggest that the random walk model could represent the movement of Malaysian real exchange rates quite closely.

Results using the sub-period sample are broadly consistent with the way the Malaysian economy has evolved over time. Through analyzing the estimated parameters in the IS and PC equations, it is evident that the Malaysian economy in the later period is becoming more mature and responding more forcefully to the movement of interest rates and exchange rates. The estimation results also suggest how inflation dynamics in Malaysia changes after 1986, with price pressures mainly emanating from the robust economic growth experienced during this period.

On the output side, the results of the IS equation suggest that the Malaysian economy during the later period, was more responsive to financial price (interest rate
Table 4.5: Estimation Results of SOEM: Sub-sample Periods (continue) (standard error and p-value in parenthesis)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\kappa_0$</td>
<td>-7.449</td>
<td>-13.465</td>
<td>-9.818</td>
</tr>
<tr>
<td></td>
<td>(4.310) (0.043)</td>
<td>(0.824) (0.000)</td>
<td>(6.516) (0.067)</td>
</tr>
<tr>
<td>$\kappa_1$</td>
<td>0.089</td>
<td>-0.021</td>
<td>0.048</td>
</tr>
<tr>
<td></td>
<td>(0.097) (0.180)</td>
<td>(0.114) (0.428)</td>
<td>(0.118) (0.342)</td>
</tr>
<tr>
<td>$\kappa_2$</td>
<td>0.151</td>
<td>0.154</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td>(0.117) (0.099)</td>
<td>(0.127) (0.113)</td>
<td>(0.112) (0.421)</td>
</tr>
<tr>
<td>$\kappa_3$</td>
<td>-0.233</td>
<td>-0.312</td>
<td>-0.028</td>
</tr>
<tr>
<td></td>
<td>(0.126) (0.034)</td>
<td>(0.106) (0.002)</td>
<td>(0.124) (0.411)</td>
</tr>
<tr>
<td>$\kappa_4$</td>
<td>0.280</td>
<td>0.200</td>
<td>0.302</td>
</tr>
<tr>
<td></td>
<td>(0.079) (0.000)</td>
<td>(0.107) (0.033)</td>
<td>(0.134) (0.013)</td>
</tr>
<tr>
<td>$\kappa_5$</td>
<td>0.246</td>
<td>-0.026</td>
<td>0.361</td>
</tr>
<tr>
<td></td>
<td>(0.141) (0.042)</td>
<td>(0.183) (0.444)</td>
<td>(0.152) (0.009)</td>
</tr>
<tr>
<td>$\kappa_6$</td>
<td>0.335</td>
<td>0.681</td>
<td>0.088</td>
</tr>
<tr>
<td></td>
<td>(0.137) (0.008)</td>
<td>(0.000) (0.000)</td>
<td>(0.018) (0.000)</td>
</tr>
<tr>
<td>$\kappa_7$</td>
<td>2.344</td>
<td>4.020</td>
<td>2.926</td>
</tr>
<tr>
<td></td>
<td>(1.087) (0.017)</td>
<td>(1.738) (0.011)</td>
<td>(1.552) (0.031)</td>
</tr>
<tr>
<td>$R^2$</td>
<td><strong>0.301</strong></td>
<td><strong>0.362</strong></td>
<td><strong>0.453</strong></td>
</tr>
</tbody>
</table>

and exchange rate) factors and to foreign output. For example, for the 1975-1986 period, the estimated parameter for $\gamma_3$ - which measures the responsiveness of output to the interest rate - is initially found to be wrongly signed (positive) and is not statistically significant. This result could reflect the effect of the restrictive interest rate structure for this period. The result however, changes in the later period. The estimated parameter for $\gamma_3$, turns negative and statistically significant for the 1987-1998 period, reflecting the benefit of liberalizing the banking system’s interest rate structure undertaken in late-1978. As expected, the liberalization of the interest rate structure allows a more efficient price determination process through market based mechanisms. In the case of Malaysia, it also improves the overall monetary transmission process. Consequently, output is more responsive to monetary policy action taken by the central bank. Similarly, the impact of the exchange rate and foreign income to output is also much bigger in the later period. In line with the expansion
of the export sector as the main engine of growth, the estimated parameter for $\gamma_4$ and $\gamma_5$ - which measure the responsiveness of output to the exchange rate and foreign output respectively - increases considerably during the post-1986 period. Both parameters also become statistically significant, reflecting the importance of these factors to the Malaysian GDP during the later period.

On the same note, factors that contribute to the development of inflation in Malaysia also change notably over the period. From the estimation result of the PC equation, inflation in the later period was largely attributed to the 'demand-pull' factor and less from the 'cost-push' factor. For example, the estimated coefficient for $\kappa_5$ - which measures the contribution of the output gap to inflation - turns positive and statistically significant during the 1987-1998 period. This suggests, as the Malaysian economy experienced rapid expansion during this period, the capacity constraint starts to kick in and cause rising price pressure. Looking from another angle, this development also indicates improvement in the process of transmitting monetary policy action to inflation. From the way the Malaysian economy is modelled here, the impact of interest rate changes is transmitted to inflation through its initial impact on the IS equation. As shown in the results, this channel was not in operation during the earlier period. Perhaps, this factor could partly explain the high inflation rate experienced during this period. Besides that, inflation movements during the 1975-1986 period are also attributed to the 1973 and 1980 oil price shocks. Following these events, the estimated coefficient for $\kappa_7$ - which measures the contribution of oil price to inflation - is much higher during the 1975-1986 period, but declines noticeably during the later period. Surprisingly, the estimation results also indicate that the contribution of the exchange rate factor to inflation is weakening as the Malaysian economy increases its trade openness over time. Even though correctly signed, the estimated parameter for $\kappa_6$ is much smaller during the 1987-1998 period, suggesting that inflation dynamics in Malaysia could largely be attributed to the domestic factor.

### 4.3.2 Uncovering Parameters of BNM’s Loss Function

While the small open economy model used in this exercise is able to fit Malaysian data reasonably well, the approach produces mixed outcomes in trying to estimate BNM’s preference parameters. Attempts to uncover BNM’s preference parameters are only
Table 4.6: Estimated Parameters of BNM’s Loss Function
(standard error and p-value in parenthesis)

<table>
<thead>
<tr>
<th></th>
<th>$\lambda_1$</th>
<th>$\lambda_2$</th>
<th>$\lambda_3$</th>
<th>$\pi$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Full sample</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1975Q1-2005Q2</td>
<td>7.816</td>
<td>0.008</td>
<td>1.056</td>
<td>0.110</td>
</tr>
<tr>
<td>LogL = -1102.426</td>
<td>(13.875) (0.287)</td>
<td>(0.014) (0.269)</td>
<td>(2.193) (0.315)</td>
<td>(0.441) (0.402)</td>
</tr>
<tr>
<td><strong>Sub-sample</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1975Q1-1998Q2</td>
<td>1.639</td>
<td>0.099</td>
<td>2.609</td>
<td>3.721</td>
</tr>
<tr>
<td>LogL = -872.899</td>
<td>(0.755) (0.016)</td>
<td>(1.033) (0.462)</td>
<td>(1.521) (0.044)</td>
<td>(2.203) (0.047)</td>
</tr>
<tr>
<td>1975Q1-1986Q4</td>
<td>1.403</td>
<td>0.108</td>
<td>2.963</td>
<td>4.590</td>
</tr>
<tr>
<td>LogL = -452.932</td>
<td>(0.631) (0.014)</td>
<td>(0.456) (0.047)</td>
<td>(1.245) (0.009)</td>
<td>(2.338) (0.026)</td>
</tr>
<tr>
<td>1987Q1-1998Q2</td>
<td>1.916</td>
<td>0.013</td>
<td>0.317</td>
<td>3.871</td>
</tr>
<tr>
<td>LogL = -376.63</td>
<td>(0.466) (0.000)</td>
<td>(0.025) (0.307)</td>
<td>(0.175) (0.037)</td>
<td>(2.108) (0.035)</td>
</tr>
</tbody>
</table>

successful for the period prior to the introduction of the capital controls and fixed exchange rate regime. Parameter estimates for the loss function when using the data for the whole sample period (that includes the 1998Q3-2005Q2) are found to be not statistically significant. Estimates for BNM’s implicit inflation target for this period is also found to be unrealistically low. Unsurprisingly, attempts to estimate the preference parameters using the 1998Q3-2005Q2 sample period alone, could not produce any result at all. Despite several attempts using different starting values, the iteration procedure using this short sample period fails to reach convergence. Hence, no result can be reported for this last sub-period.

There are a few possible reasons for the failure to satisfactorily estimate BNM’s preferences parameters using the sample that includes the 1998Q3-2005Q2 period. Firstly, is the possibility that the standard, linear quadratic loss function (like equation 4.1) cannot adequately represent BNM’s loss function when the capital controls and fixed exchange rate regime was in place. While the use of this model produces reasonable results when applied to the other sample periods, its failure to produce a similar performance for the period when this regime was in effect suggests that the same model could be inadequate or perhaps, inappropriate to represent BNM’s loss function. The introduction of this regime as the stop-gap policy action to recover from the Asian Financial Crisis could induce BNM to deviate from its normal/usual
behaviour of policy-making. This unusual change in the central bank’s behaviour cannot be easily approximated by the standard loss function used here and could not be taken as the usual BNM’s behaviour in conducting monetary policy. The possible change in the BNM’s behaviour in formulating monetary policy during this period can also be seen by analyzing closely the residuals of the estimated interest rate equation during this period. As indicated in Figure 4.1, there are few large spikes in the interest rate residuals during the post 1997 period, suggesting the possible deviations of the interest rate movements during this period from the normal way BNM set its interest rate policy.

Secondly, it is very likely that during this period, BNM was pursuing different policy objectives other than what is assumed here. Given the circumstances at the time, BNM was probably pursuing other unconventional and temporary objectives like managing capital outflow and stabilizing domestic liquidity; restructuring and rebuilding the banking system; and restoring economic conditions. This can be inferred from
BNM's publication below, explaining its policy action after the crisis.

"Beginning mid-1998, the policy focus shifted towards reviving the economy.... The National Economic Recovery Plan (NERP) had six objectives, which included the short-term focus of stabilizing the ringgit; restoring market confidences; and maintaining financial market stability. These were complemented with structural reform objectives of strengthening economic fundamentals, continuing the socio-economic agenda; and restoring adversely affected sectors."

Page 596, Chapter 14: Management of the Economy during the Asian Crisis, Bank Negara Malaysia (1999)

Obviously, all this additional, unconventional and temporary policy objectives could not be represented by a standard loss function as in equation 4.1. Hence, the outcome of this empirical exercise suggests that the standard loss function is only able to represent BNM's behaviour during the "normal" period, and not during the period when the central bank is pursuing other uncommon and temporary agenda.

Thirdly, the operation of this regime may impose different policy constraints to BNM's optimal control set-up. Besides pegging the currency to the US dollar, the capital control provided BNM with monetary independence. This allowed Malaysia's interest rate policy to be set independently from the US monetary policy.\(^{11}\) The restriction on capital movement put away the usual Mundell-Fleming effect on the relationship of deviation between domestic and international interest rates and the determination of exchange rates. Consequently, the model set-up of exchange rate determination through UIP as used in this exercise becomes redundant.

In order to reaffirm the hypothesis that the specification of BNM's loss function after the introduction of the capital control and fixed exchange rate could be very different than the one assumed here, the estimation exercise using the sample period that specifically excludes this regime is also examined. The results are given in Table 4.6. As expected,

\(^{11}\)From the impossible trinity condition (free capital movement, monetary independence, fixed exchange rate regime), a central bank can only choose 2 out of 3 conditions. During September 1998-July 2005, BNM chose the last two and must adopt the capital control for the arrangement to work. See Bank Negara Malaysia (1999), Athukorala (2001), Dornbusch (2001) and Kaplan and Rodrik (2001) for detailed discussion of this issue.
the estimation exercise using the shorter sample period of 1975Q1 to 1998Q2 produces much better results than the one using the whole sample period of 1975Q1-2005Q2. As shown in Table 4.6, parameter estimate for $\lambda_1$ is also much smaller (1.63, against 7.81 for 1975Q1-2005Q2 period) and is also more in-line with the estimation results using the sub-sample period (1.40 and 1.91 for 1975Q1-1986Q4 and 1987Q1-1998Q2 respectively). Most importantly, with a lower standard error, the parameter estimates for the loss function using the 1975Q1-1998Q2 period are found to be statistically significant. This supports the earlier proposition that BNM’s loss function during 1998Q3-2005Q2 period could be very different than the standard specification assumed in this exercise.

4.4 Discussions on Understanding BNM’s Behaviour in Formulating Monetary Policy in Malaysia

Modelling a central bank’s behaviour is not an easy task for economists. Being one of the key economic agents, modelling a central bank’s behaviour is an integrated part in the study of macroeconomic research. In the case of Malaysia, the above results indicate that representing BNM’s policy behaviour as a rational and optimizing economic agents works reasonably well. By using Malaysia’s economic outcomes for the 1975Q1-1998Q2 period, representing BNM’s action using the optimal control theory provides valuable information regarding its policy behaviour. In particular, the results identify BNM’s policy targets and relative preferences, as well as the inflation target that it wants to achieve.

Most essentially, the results indicate that modelling BNM’s policy behaviour does not differ very much to its counterparts in the developed countries. Despite having a different economic structure (and hence different policy constraints), BNM’s policy behaviour can be reasonably represented by using the optimal control approach, which is the standard modelling methodology used in the literature to represent a central bank’s behaviour in formulating monetary policy. Perhaps, the outcome of these results would prompt the use of the same approach to model BNM’s behaviour in future research involving Malaysian data. The above results indicate that this approach works well for the period that excludes September 1998 to July 2005, i.e. when the capital controls and fixed exchange rate regime was in effect.
The results presented in the previous section highlight a few important characteristics regarding BNM’s behaviour in formulating monetary policy in Malaysia. Each of these characteristics are discussed below.

4.4.1 Objective of Monetary Policy in Malaysia

By assuming that BNM’s preference can be represented by the standard loss function, the estimate for BNM’s relative preferences are found to have a plausible size, be correctly signed and are statistically significant. This holds in all cases, except for the 1998Q3-2005Q2 period, when BNM was pursuing several unconventional and temporary agendas.

The results indicate that the objective of monetary policy in Malaysia is not very much different than those pursued by the central banks in the developed economies. Based on its policy action, the results suggest that BNM formulates monetary policy to achieve three common objectives - stabilizing inflation, stabilizing output and smoothing interest rates.

In addition, the positive and statistically significant estimated parameters for the relative preferences on output stabilization and interest rates smoothing (\(\lambda_1\) and \(\lambda_3\)) suggests that BNM is not a central bank which Svensson (1999) categorized as a strict inflation targeter. In contrast, it can be inferred from these empirical results that besides achieving price stability, BNM also takes into account the objective to stabilize output and to smooth interest rates.

The results also reveal important information about the way BNM balances the trade-off between achieving price stability and stabilizing output growth. The estimated parameter on relative preferences to stabilize output (\(\lambda_1\)) is found to be greater than 1, suggesting BNM puts greater weight on attaining output stability ahead of stabilizing inflation. Hence, with \(\lambda_1 > 1\), the results reaffirm the proposition made by Tang (2006) that the objective of monetary policy in Malaysia is the attainment of sustainable economic growth with price stability. In doing so, BNM’s policy preferences are biased towards achieving output stability.
4.4.2 Stabilizing Exchange Rate is not one of BNM’s monetary policy objectives

In all the sample periods, the estimated coefficient for $\lambda_2$ are not statistically significant. These results suggest that smoothing the real exchange rate is not one of BNM’s policy objectives. Given the knowledge that BNM does intervene regularly in the foreign exchange market, the outcome of this result is rather unexpected. Nevertheless, despite the strong reasons to believe that smoothing the real exchange rate is one of the important objectives that BNM pursues in its policy formulation, results of this exercise fail to capture any empirical evidence to support this proposition.

On this regard, Kam, Lees, and Liu (Forthcoming) also attempted the same exercise in the case of central banks in Australia, Canada and New Zealand. By also modelling central bank behaviour using the optimal control theory set-up, they too, do not find empirical evidence to support the proposition that smoothing real exchange rates is one of the policy objectives for the central bank in these countries.

Perhaps, the main reason that contributes to the failure of the empirical exercise to find supportive evidence for this proposition is related to differences in the actual method that central banks use to achieve exchange rate stability and the way that this is being represented in the model. Instead of using interest rates as the instrument to influence the real exchange rate - which is the key assumption in the model of representing central bank behaviour using the optimal control theory - most central banks in practice, prefer to intervene directly in the foreign exchange market (Jurgensen (1983); Bank for International Settlement (2004)).

There are two possible reasons for central banks’ favouring the direct intervention method - speed and accuracy. The mechanism of the interest rate to influence exchange rate movement in the short-run relies on the sensitivity of the short-term capital flows to the interest rate. Change in exchange rates is triggered by the actual demand for domestic currency following the movement of the capital flows. In reality, movement of short-term capital across borders is bound by factors other than interest rates alone. Factors like country risk premium, players’ expectation on future returns, performance of the stock markets, as well as political stability are also important. As a result, the effect of changing interest rates to influence exchange rate movement could be full of
uncertainty, which makes the direct intervention to be a more favourable option to the central banks.

The direct intervention method influences the exchange rate movement through three main channels - monetary policy, portfolio and expectation channels.\textsuperscript{12} The monetary policy channel - that requires the change in interest rate to trigger the adjustment in the exchange rate through the standard Mundell-Fleming mechanism - works when the intervention operation is unsterilized.\textsuperscript{13} Nevertheless, many central banks do not favour the unsterilized intervention due to its negative impact on interest rate stability (Craig and Humpage (2001)). On this regard, Fry (1995) finds that Asia-Pacific countries have attained autonomy in both monetary policy and exchange rate stabilization by means of sterilized intervention in the foreign exchange markets. Also, Takagi and Esaka (2001) argue that sterilized intervention was effective in Asian countries, particularly during the period before the 1997 Asian Financial Crisis. With the sterilized intervention method, exchange rate stability is achieved with interest rate levels left virtually unchanged. Nevertheless, this condition is not consistent with the mechanics assumed under the optimal control theory. The stability of the exchange rate - one of the state variables in the optimal control system - is achieved without the use of the interest rate (control variable). This factor could directly contribute to the failure of the empirical exercise to find evidence that smoothing the exchange rate is one of the central bank’s policy objectives. For the same reason, the knowledge that BNM conducts most of its foreign exchange intervention through the sterilized intervention method (Lin See Yan (1991), Bank Negara Malaysia (1994b, 1999)), could also explain the failure of this exercise to generate positive evidence to support the proposition that smoothing the real exchange rate is one of the BNM’s policy objectives.

Having said that, the truth of the matter lies in the difficulty in identifying the exact role of real exchange rate smoothing to the Malaysian policymakers. If the empirical result using the optimal control theory is taken as the correct specification representing BNM’s

\textsuperscript{12}See Sarno and Taylor (2001) for a detailed description of each channel.

\textsuperscript{13}In short, the mechanics of sterilized intervention is as follows. Central banks operation of buying (to smooth appreciation pressure) or selling (to smooth depreciation pressure) of foreign currency in the foreign exchange market will see the injection or contraction of domestic currency (liquidity) into the foreign exchange market. The injection or contraction of liquidity in the domestic money market leads to constant fluctuations of short-term interest rates. To avoid unwanted interest rate fluctuations, central banks conduct a contra operation in the domestic money market to neutralize the amount of liquidity that it initially injected/contracted in the foreign exchange market. See among others, Taylor (1982); Jurgensen (1983); Craig and Humpage (2001) for details.
policy behaviour, then its regular intervention operation in the (nominal) exchange rate market could have an alternative role to the policymakers. Putting together two sources of information regarding BNM's policy and operational behaviour - the insignificant of parameter $\lambda_2$ as found in this empirical exercise; and the knowledge that BNM conducts regular sterilized intervention operations in the foreign exchange rate market - suggests a useful proposition regarding the role of the real exchange rate stability in the conduct of monetary policy in Malaysia. Smoothing the real exchange rate may not be one of BNM's policy objectives, but it has been used as the means to achieve its other policy objectives that have been identified in this empirical exercise - stabilizing inflation, stabilizing output and smoothing interest rates.

This proposition is also consistent with BNM's official view in justifying its action to minimize excessive exchange rate fluctuation. The quotations below outline the importance of stable exchange rates to the conduct of monetary policy for a small open economy like Malaysia.

"As a matter of policy, the Central Bank's intervention in the foreign exchange market is only to moderate day-to-day fluctuation in the value of ringgit and not to fight the underlying trend dictated by the market."

page 270, Bank Negara Malaysia (1999)

"...Competitiveness needs to be achieved through efficiency and productivity gains rather than relying on currency depreciation. As a matter of policy, Malaysia does not rely on the exchange rate to gain competitive advantage."


More importantly, the last quotation also reiterates BNM's stand for not using the exchange rate to promote exports. This lends support to the proposition that stabilizing real exchange rates is not one of BNM's policy objectives.
4.4.3 Evolution of BNM’s Relative Preferences and Inflation Target

Estimation results using the sample period of 1975Q1-1986Q4 and 1987Q1-1998Q2 indicate considerable changes in BNM’s relative preferences between different objectives and the inflation target. To non-policymakers, two possible reasons could contribute to this outcome. First, changes in BNM’s relative preferences and inflation targets could be attributed to the changes in the key policymaker itself, i.e. the Governor. Second, the change in policymakers’ relative preferences could reflect a change in its policy emphasis. For example, the strengthening of the banking sector and the liberalization of the interest rate structure would cause the central bank to be less concerned about the impact of policy changes on financial stability. This could prompt the central bank to reduce its preferences to smooth interest rate.

While the ideal way to investigate the first reason is to divide the estimation period according to tenure of the BNM’s Governor itself, this option is not being pursued in this exercise. The fact that BNM does not enjoy goal independence, highlights the possibility that its policy directions are heavily influenced by the Government. Hence, the change in BNM’s Governor is less likely to cause significant changes in the way BNM pursues its policy objectives. In contrast, the way that the estimation period is divided in this empirical exercise, is more inclined to cater for the second reason. The change in BNM’s relative preferences over time could be more likely attributed to the change in its policy emphasis, in line with the evolution of the Malaysian economy.

4.4.3.1 Evolution of BNM’s policy preferences to stabilize output

The estimated value for parameter $\lambda_1$ increases during the later period, suggesting BNM’s higher relative preferences to stabilize output to be close to its potential level. A higher estimated value for $\lambda_1$ could reflect BNM’s continuous effort in trying to

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14In the case of the US Federal Reserve, this factor was investigated by Ozlale (2003), and Dennis (2004, 2006), by dividing the estimation period under the chairmanship of Arthur Burns, Paul Volker and Alan Greenspan.

15Page 109, Bank Negara Malaysia (1999) states: "...BNM is independent within the Government, but not of the Government." This suggests that BNM has operational independence, but its policy objective(s) is set by the Government. Having said that, the way BNM prioritizes its designated policy objective(s) is unknown to the non-policymakers.
moderate the accelerated economic growth experienced during this period. In the aftermath of the mid-1980 recession, the Malaysian economy staged a strong recovery and recorded a decade of uninterrupted growth until the outbreak of the 1997 Asian Financial Crisis. During this period, its GDP grew constantly to over 8% every year. This prolonged growth created a new challenge to the policymaker. The risk of rising inflation became an important issue together with the need to ensure economic growth remained sustainable. The three quotes from a series of BNM’s Annual Reports below, reflects its long-standing concerns about this issue during the course of this period.

"The primary thrust of macro-economic policy in 1991 was on the management of rising price pressures to ensure that the rapid pace of economic expansion in recent years would not precipitate an inflationary spiral in the country. The maintenance of price stability was particularly important as there were increasing signs of overheating in the domestic economy, characterized by rising wage pressure amidst a general tightening of the labour market, and the buoyant and sustained expansion in domestic demand."


"The challenge of economic management in 1994 continued to be sustaining the growth momentum, while at the same time maintaining price stability. It was recognized that the price pressures and the imbalance in the current account of the balance of payments reflected not only excess demand conditions, but also supply constraints."

Page 19, Bank Negara Malaysia (1994a) Annual Report

"During 1996, the monetary policy strategy was undertaken against the background of continued resource constraints reflected in higher wages and persistent inflationary pressures despite a moderation in exports and growth."


To reinforce this point, the estimation result of the PC indicates that the contribution of the output gap to overall inflation in Malaysia becomes more important as the economy progresses. From Table 4.5, the estimated parameter for $\kappa_5$ of the PC equation turns
positive and statistically significant during the 1987-1998 period. Hence, the strategy to achieve price stability could not only rely on an orthodox instrument like price control, but also needs to focus on the source of the price pressure. In the Malaysian case, price pressure during the 1987-1998 period mostly originated from the demand side (demand-pull inflation). Due to this factor and as suggested by the estimation results of its loss function, BNM’s policy preferences during this period gave more attention to stabilizing output. The strategy to make output operate close to its full potential level minimizes the risk of an excess demand in the economy. Consequently, with a more sustainable economic growth, it will directly reduce the risk of demand-pull inflation.

4.4.3.2 Evolution of BNM’s relative preferences to smooth interest rates

In contrast, BNM’s relative preferences to smooth interest rates declines markedly in the later period. This outcome is consistent with the advancement of the Malaysian banking system and financial sector. For example, the success of the banking system reforms in the late 1970s and the first half of the 1980s made Malaysian banking institutions stronger and more resilient to face competitive pressure (Bank Negara Malaysia (1994b, 1999)). As maintaining banking system stability is also one of BNM’s main tasks, this advancement reduced BNM’s concern that its monetary policy action would generate negative impact to the overall stability of the banking system.

In addition, the successful interest rate liberalization in late 1978 made the economy more responsive to the interest rate changes. This can be seen from the parameter estimate of $\gamma_3$ in the IS equation. During the 1975-1986 period, the estimate for $\gamma_3$ is wrongly signed and is not statistically significant. The situation reversed in the 1987-1998 period, signifying the positive impact of the interest rate liberalization to the Malaysian economy. For the policymakers, this change indicates vast improvement in its monetary transmission process. As central banks are generally reluctant to reverse policy action in order to maintain reputation and credibility (Goodhart (1999)), the knowledge that its policy action is now being transmitted more effectively, could reduce BNM’s concern of making policy mistakes. On top of that, BNM’s progression to move away from non-market based monetary policy instruments (like direct controls on interest rates, credit controls and high Statutory Reserves/Liquid Assets Requirement) in favour of market based instruments (like direct borrowing/lending and open market
operation) has enabled the central bank to influence market interest rates more effectively (Bank Negara Malaysia (1999) and Bank for International Settlement (1999)). Consequently, these factors made BNM less reluctant to change interest rates in the later period.

4.4.3.3 Lower implicit inflation target

The change in BNM's behaviour over the period is also reflected in the evolution of its implicit inflation target. The estimation results indicate that BNM's inflation target during the 1987Q1-1998Q2 period was around 3.9%, which is lower than the 4.6% estimated for the earlier period. The change in the implicit inflation target over these two periods could be due to two factors - policy outcomes attributed to the economic circumstances and a possible change in BNM's policy behaviour.

First, the higher estimated inflation target during 1975Q1-1986Q4 could reflect the outcome of the policymakers' difficulty during the period to bring actual inflation near to its targeted level. The impact of the first and second oil price shocks experienced in 1973 and 1979 caused inflation during the subsequent periods to be highly volatile. In general, experiences indicate that inflation originating from the cost-push factor is much more difficult to contained compared with the demand-pull factor. Hence, the "failure" of BNM to pin-down inflation during the aftermath of the first and second oil price shocks could 'inflate' the estimation of its implicit inflation target for the period.

The second possible reason to explain this outcome is related to the possible change in BNM's policy behaviour itself. The higher inflation target for the 1975-1986 period could reflect BNM’s stance during the period to accept a higher inflation rate. Due to falling output following the oil price shocks as well as the severe economic recession experienced in the mid-1980s, perhaps the main focus of the policy was to stabilize output. In contrast, the lower inflation target reflects that BNM was more stringent in its policy-making to achieve price stability during the post-1986 period. In line with the new challenge faced by the policymakers to ensure sustainable growth of the Malaysian economy, BNM sets a lower inflation target for its policy. Unsurprisingly, against the background of robust economic growth experienced during the later period, the lower inflation target requires BNM to be more aggressive in taking policy action. This is generally consistent with the earlier suggestion that BNM was more concerned about
stabilizing output (higher $\lambda_1$) and less concerned about smoothing interest rates (lower $\lambda_3$) during the post-1986 period.

4.5 Conclusion

In conclusion, the results of this chapter provide important insights towards understanding Bank Negara Malaysia’s (BNM’s) behaviour in formulating monetary policy in Malaysia. By employing the standard approach used in the literature to model central banks’ behaviour, this chapter models BNM’s policy behaviour as the solution to the optimal control problem. The results indicate that this standard approach represents BNM’s policy behaviour reasonably well. However, this representation is limited to the sample that excludes the September 1998-July 2005 period. During the period when the capital control and the fixed exchange rate regime was in place, this standard approach fails to generate any results.

By assuming that BNM’s preferences can be represented by the standard loss function, the results suggest that the objective of monetary policy in Malaysia is not very different than those pursued by the central banks in developed economies. For the estimation period prior to September 1998, BNM’s policy objectives were identified as to stabilize inflation, output and interest rates. The results also reveal important information about the way BNM balances the trade-off between price stability and output growth. Estimates of its relative preferences parameters suggest BNM puts greater weight on attaining output stability ahead of stabilizing inflation. This finding also reaffirms the proposition made by Tang (2006) that the objective of monetary policy in Malaysia is the attainment of sustainable economic growth with price stability.

Despite prior beliefs that smoothing the real exchange rate could be one of BNM’s key policy objectives, this could not be substantiated empirically. Based on this result, this chapter proposes another role for exchange rate smoothing in the conduct of monetary policy in Malaysia. BNM uses the stable real exchange rate environment as a means to achieve its other policy objectives.

Results using different sample periods suggest the parameters of BNM’s loss function evolve over time. The change in BNM’s relative preferences over the period could be
attributed to the change in its policy emphasis, in line with the evolution of the Malaysian economy. The results show that BNM's relative preference to smooth output increases in the later period, suggesting BNM’s desire to contain the economic overheating problem experienced during the first half of the 1990s. In addition, the improvement in the overall monetary transmission mechanism as well as with the more resilient banking system during the post-1986 period, explains the marked decline in BNM’s relative preference to smooth interest rates. Besides changing its relative preferences over different policy objectives, the results also suggest BNM has a lower implicit inflation target during the later period.

After gaining a general understanding about the way BNM behaves in formulating monetary policy in Malaysia, we use this knowledge to ask another important question regarding BNM's policy behaviour. What would happen to the outcomes of the Malaysian economy if BNM was to behave differently than what we have understood so far? To answer this, we need to conduct counter-factual policy simulations. This is done best using a dynamic stochastic general equilibrium (DSGE) model representing the Malaysian economy. Developing one is the topic of the next chapter.
4.6 Appendix

Figure 4.2: Residuals of Estimated SOEM Equations Across Different Period

(a) 1975Q1 - 2005Q2 and 1975Q1-1986Q4

(b) 1987Q1-1998Q2 and 1975Q1-1998Q2
Chapter 5

An Estimated DSGE Model of the Malaysian Economy: Full Sample Period 1975Q1 to 2005Q2

During recent years there has been a growing literature that uses dynamic stochastic general equilibrium (DSGE) models for analyzing macroeconomic fluctuations and for quantitative policy analysis. The appeal of DSGE models has captured the interest of many researchers, inside and outside academia. Among the academicians, economists use DSGE models in many ways to answer various interesting research questions. Similarly, a large number of central banks use DSGE models for their policy analysis. Despite the large interest in this area, it is fair to say that the current literature on DSGE modelling is largely concentrated on the experience of the developed economies. Among the rare examples of literature that cover the experience of developing economies are the studies involving Latin American countries by Medina and Soto (2005, 2007) for Chile and Castillo, Montoro, and Tuesta (2006) for Peru. Ramayandi (2008) estimates a DSGE model for four ASEAN economies (including Malaysia).

The main attractiveness of DSGE models is that they are derived from first principles. They describe the general equilibrium allocations and prices of the economy in which all the agents dynamically maximize their objectives (utility, profits, etc) subject to budget or resource constraints. These equilibrium equations form the structural features of the economy. Parameters of these structural equations are known as "deep" parameters - they are assumed to be invariant to policy actions. For this reason, DSGE models are seen as powerful tools that provide a coherent framework for policy discussion and
analysis. In principle, they can help to identify sources of fluctuations, answer questions about structural changes, forecast and predict the effect of policy changes, and perform counter-factual experiments. They also establish a link between structural features of the economy and reduced form parameters, something that was not always possible with large-scale macroeconomic models.

The main objective of this chapter is to employ the DSGE modelling framework to the case of the Malaysian economy. The key structural parameters of the Malaysian economy are estimated using the Bayesian methodology. The estimated model is later used to analyze Bank Negara Malaysia’s (BNM) behavior in formulating monetary policy. Naturally, in developing the DSGE model to analyze BNM’s behaviour in formulating monetary policy, empirical results from other studies involving the Malaysian economy should be taken into account. Not only does the knowledge derived from previous studies contribute to the model’s richness, but it also helps to incorporate the salient features about the Malaysian economy in the model’s specifications. Hence, we build the DSGE model in this chapter based on this philosophy. On the monetary transmission channels, empirical studies using Malaysian data by Razi (1998) and Tang (2006) concluded that interest rates, exchange rates and credit channels are the three important channels that transmit BNM’s monetary policy action to the real sector. On areas related to the exchange rate pass through, empirical studies by Webber (1999) and Ito and Sato (2006) found that the impact of exchange rate fluctuations on Malaysia’s CPI was very low, suggesting the presence of incomplete exchange rate pass through in the Malaysian import sector. On the formulation of monetary policy, our results from Chapter 3 conclude that the simple Henderson-McKibbin-Taylor (HMT) rule represents BNM’s policy behaviour reasonably well. We incorporate all these features in the DSGE model presented here.

We choose the DSGE model of a small and open economy developed by Gali and Monacelli (2005) as the starting block to develop a DSGE model of the Malaysian economy. Gali-Monacelli’s model is seen as the best candidate for this purpose as its general design already incorporates most of the empirical knowledge about the Malaysian economy listed in the previous paragraph. More importantly, the set-up used in Gali-Monacelli’s model gives rise to simple, intuitive and tractable log-linearized equilibrium equations. While the model used in this chapter shares many elements with Gali-Monacelli’s model, we introduce a small modification. We put into the model’s specifications the effect of the financial accelerator mechanism described in Bernanke,
Gertler, and Gilchrist (1999) (BGG hereafter). The motivation behind this modification is simple. We seek to improve the model’s properties by specifying formally the role of financial friction as a propagation mechanism. There is ample evidence in the literature to show that financial frictions amplify the magnitude and persistence of fluctuations in economic activities.¹ In the context of the Malaysian economy, evidence about the importance of credit channels in propagating BNM’s monetary policy action is documented in the empirical study by Razi (1998) and Tang (2006).

Based on this evidence - both theoretical and empirical, we explore the effects of specifying explicitly the operation of financial frictions to the empirical properties of our DSGE model. For this purpose, we estimate two model specifications - with and without a financial accelerator mechanism. Estimating these two model specifications allows us to statistically evaluate the importance of a financial-accelerator mechanism using the posterior odds ratio (or Bayes factor). To show the operation of a financial accelerator as a propagation mechanism, we also compare the impulse responses and variance decompositions of key macroeconomic variables generated by the two model specifications.

The model is estimated using the data set for the 1975Q1-2005Q2 period. The estimation results provide useful information about the structural parameters of the Malaysian economy. Estimates of structural parameters like consumer preferences, behaviour of retailers in setting prices as well as the degree of the financial accelerator mechanism for the Malaysian economy are revealed.

This chapter is organized as follows. It starts with the discussion on the model set-up. This covers the definitions of key variables and derivation of equilibrium equations of our model. Section 5.2 describes the Bayesian methodology utilized to estimate the model. Then, Section 5.3 and 5.4 discuss the estimation results. The last section concludes.

5.1 The Open Economy DSGE Model

Design of the DSGE model in this chapter builds extensively on the model developed by Gali and Monacelli (2005), but is modified to include the financial accelerator mechanism. With this modification, this model shares many salient features to the open economy DSGE model used in Devereux, Lane, and Xu (2006). The economy under purview is small and open, with nominal price rigidities following a staggered pricing. There are four major actors in this economy - households, entrepreneurs, retailers and the central bank.

This section starts with definitions of consumption composites, prices indexes, terms of trade and real exchange rate. These definitions act as the building block for the model set-up. Before proceeding, some note on the notations. Throughout this chapter, a variable in capital letter denotes the variable in its original form, while those in the small caps denotes the corresponding variables written in log and as percentage deviations from a corresponding non-stochastic steady state.

Definitions

5.1.1 Consumption Composites and Price Indexes

Consumption index, \( C_t \), is a bundle comprising domestically produced goods and imported goods,

\[
C_t = \left[ (1 - \gamma)^{\frac{1}{\eta}} (C_{H,t})^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} (C_{F,t})^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}
\]  

(5.1)

where \( C_{H,t} \) denotes the composite consumption index for the domestic goods, \( C_{F,t} \) denotes the composite consumption index for the imported goods. Parameter \( \gamma \in [0, 1] \) measures the preference bias to the foreign good (degree of openness) and \( \eta > 0 \) measures the elasticity of substitution between domestic and foreign goods.

The consumption index for each category of generic goods is aggregated using the standard CES function,
\[ C_{H,t} = \left( \int_0^1 C_{H,t}(h) \frac{e^{1-\varepsilon}}{1-\varepsilon} dh \right)^{\frac{1}{1-\varepsilon}} \quad C_{F,t} = \left( \int_0^1 C_{F,t}(f) \frac{e^{1-\varepsilon}}{1-\varepsilon} df \right)^{\frac{1}{1-\varepsilon}} \]

with \( h \in [0,1] \) and \( f \in [0,1] \) denotes the good variety. Parameter \( \varepsilon > 0 \) is the elasticity of substitution between generic goods within each category. To minimize expenditure, the optimal allocation for \( C_{H,t} \) and \( C_{F,t} \) across generic goods within each category is given by the standard isoelastic demand function;\(^2\)

\[ C_{H,t}(h) = \left( \frac{P_{H,t}(h)}{P_{H,t}} \right)^{-\varepsilon} C_{H,t} \quad C(f) = \left( \frac{P_{F,t}(f)}{P_{F,t}} \right)^{-\varepsilon} C_{F,t} \]

where \( P_{H,t} \) and \( P_{F,t} \) is the associated aggregate price index (expressed in domestic currency) for each good category.\(^3\)

Following the same steps, the optimal consumption demand for the domestic and foreign produced goods can be derived respectively as,

\[ C_{H,t} = (1 - \gamma) \left( \frac{P_{H,t}}{P_t} \right)^{-\eta} C_t \quad \text{(5.2)} \]

\(^2\)Which is derived from consumers solving the following problem:

\[
\max_{C_t(i)} C_t \left( \int_0^1 C_t(i) \frac{e^{1-\varepsilon}}{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}} \quad \text{subject to } P_tC_t - \int_0^1 P_t(i) C_t(i) di = 0
\]

with \( C_t(i) \) and \( P_t(i) \) is the respective good and its associated price. The FOC for good \( i \) is given by,

\[ C_t(i) \frac{1}{1} \left( \int_0^1 C_t(i) \frac{e^{1-\varepsilon}}{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}} - \zeta P_t(i) = 0 \]

with \( \zeta \) is the Lagrange multiplier for the minimum expenditure constraint. By computing another generic good \( i^* \) and taking the ratio, get the expression

\[ \left( \frac{C_t(i)}{C_t(i^*)} \right)^{-\frac{1}{\varepsilon}} = \left( \frac{P_t(i)}{P_t(i^*)} \right) \]

Then, substituting this into the CES consumption index for \( C_t(i) \), get the demand function for good \( i \), \( C_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\varepsilon} C_t \).

\(^3\)Both aggregate price index will be derived later in Section 5.1.5 (see equation (5.23) and (5.25)).
\[ C_{F,t} = \gamma \left( \frac{P_{F,t}}{P_t} \right)^{-\eta} C_t \] (5.3)

and the implied consumer price index (CPI) for the domestic economy is given by the expression,

\[ P_t = \left[ (1 - \gamma) P_{H,t}^{1-\eta} + \gamma P_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}} \] (5.4)

### 5.1.2 Inflation, Terms of Trade, Real Exchange Rate and Incomplete Pass-through

There are three categories of inflation in this model. First, is the CPI inflation \( \pi_t \). It measures the price condition of the consumption goods, which is a mixture of domestically produced and imported goods. Using the definition for the consumer price index from equation 5.4, the expression for the CPI inflation is \( \pi_t \equiv \log \left( \frac{P_t}{P_{t-1}} \right) = p_t - p_{t-1} \). Second, is the domestic inflation \( \pi_{H,t} \), which measures the price condition of domestically produced goods. It is measured by the expression \( \pi_{H,t} \equiv \log \left( \frac{P_{H,t}}{P_{H,t-1}} \right) = p_{H,t} - p_{H,t-1} \), with \( P_{H,t} \) the domestic price index. Third, is the foreign good inflation \( \pi_{F,t} \equiv \log \left( \frac{P_{F,t}}{P_{F,t-1}} \right) = p_{F,t} - p_{F,t-1} \), which measures the movement of foreign goods in the domestic economy. By log-linearizing the definition of the consumer price index given by equation (5.4), the relationship between the three categories of inflation is;

\[ \pi_t = (1 - \gamma) \pi_{H,t} + \gamma \pi_{F,t} \] (5.5)

The terms of trade is defined as \( TOT_t \equiv \frac{P_{F,t}}{P_{H,t}} \). It measures the relative price of foreign produced goods to domestic produced goods (expressed in domestic currency). The expression \( p_t = p_{H,t} + \gamma tot_t \) provides the link between the CPI, domestic price index and term of trade. Write this in the growth form,

\[ \pi_t = \pi_{H,t} + \gamma \triangle tot_t \] (5.6)
where $tot_t = p_{F,t} - p_{H,t}$. The above equation indicates the role of degree of openness of the economy ($\gamma$) in influencing the country’s CPI. As the economy becomes more open, the bigger the influence of the change in the term of trade to the movement of CPI inflation.

Let $S_t$ be the nominal exchange rate (defined as the price of foreign currency in terms of the domestic currency. Hence, $\uparrow S$ denotes depreciation). The definition for the real exchange rate is $RER_t = S_t \frac{P^*_t}{P_t}$ ($\uparrow RER$ denotes depreciation), with $P^*_t$ the aggregate price index in the foreign country.

Assuming the law of one price, the price of foreign goods ($P_{F,t}$) in the domestic economy (expressed in the domestic currency) will move on a one-to-one basis with the price level of its country of origin ($P^*_t$), i.e. $P_{F,t} = S_t P^*_t$. However, under the case of incomplete exchange rate pass-through, the law of one price does not hold. For example, the existence of monopolistic domestic importers that practice Local Currency Pricing, could cause the price of the foreign goods in the domestic market to temporarily deviate from the price level in the country of origin.\(^4\) The wedge between these two prices is known as the law of one price gap (LOPG) and is given by the expression $LOPG_t = \frac{S_t P^*_t}{P_{F,t}}$, or in the log-linear form as $\log pt = s_t + p_t^* - p_{F,t}$. Obviously, in the case when the law of one price holds, $LOPG_t = 1$. For estimation purposes, the LOPG is assumed to be exogenous and follows the AR(1) process,

$$lopqt = \rho_{LOPG} lopqt-1 + \varepsilon_{LOPG}$$  \hspace{1cm} (5.7)

where $\rho_{LOPG} \in [0, 1]$ is the AR(1) coefficient and $\varepsilon_{LOPG} \sim iid (0, \sigma^2_{LOPG})$ is the LOPG shocks.

Following Monacelli (2005), the expression that links the real exchange rate, terms of trade and the effect of deviation from the law of one price (in log-linear forms) is,

$$rer_t = (1 - \gamma) tot_t + lopqt$$  \hspace{1cm} (5.8)

\(^4\)Factors that contribute to the incomplete exchange rate pass-through are well documented in the literature. Campa and Goldberg (2006) is the leading literature on this area. Monacelli (2005) discusses the impact of the incomplete exchange rate pass-through on the formulation of monetary policy.
Equation 5.8 shows that the possible deviation from the Purchasing Power Parity (PPP) comes from two factors. First, from the heterogeneity of the consumption baskets between the domestic and the foreign economy (captured by $(1 - \gamma) tot_t$). From equation 5.1, parameter $\gamma$ measures the degree of preference bias to the foreign goods. Hence, as $\gamma \to 1$, composite consumption between the domestic and the foreign economy will coincide and the contribution of $tot$ to the movement of $rer$ is negligible. Second, movement of the real exchange rate is influenced by the effect of incomplete exchange rate pass-through, which is captured by $logp_t$. As LOPG increases, the effect of the increase in the foreign price ($P^*_t$) is transmitted less slowly to the price of foreign goods in the domestic economy ($P_{F,t}$). This contributes to the smaller rise in the CPI inflation ($P_t$) compared to $P^*_t$, and hence, leads to the depreciation of the domestic economy’s real exchange rate.

Note that for simplicity, in this model, the assumption of the law of one price holds for the export goods. Hence, there is a complete exchange rate pass-through for the domestic produced goods sold abroad, i.e. $P^*_t = \frac{P_{H,t}^{f}}{S_t}$ (where $P_{H,t}^{f}$ is the price of domestic produced goods sold in the foreign country). This simplification is consistent with the notion that the domestic economy is small in size compared to the rest of the world. Hence, in marketing its product abroad, the country is a price taker in the world market. In the case of Malaysia, this simplicity is also consistent with the finding by Toh and Ho (2001) that exchange rate pass-through of Malaysian exports is very large (about 80% for the sample period 1975-1996).

**The Economic Actors**

5.1.3 **Households**

Households maximize the following expected discounted sum of utilities over paths of consumption and labour,

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U(C_t, C_{t-1}, L_{H,t}) \right\}$$
where $E_t$ is the mathematical expectation conditional on information available in period $t$, $\beta \in [0, 1]$ is the exogenous discount parameter. The utility function that represents the preference of the representative household $i$ is,

$$U(C_t, C_{t-1}, L_t) = \log \left[ \frac{1}{1 + \Psi} \right]$$

where $C_t$ is the composite consumption index and $L_{H,t}$ is the labour supply chosen by household $i$. $\Upsilon C_{t-1}$ is the external (exogenous) habit stock, with constant parameter $\Upsilon \in [0, 1]$ capturing the degree of habit persistence in the economy. The introduction of habit formation in the model helps in generating persistence in the consumption dynamics following the monetary policy shocks. Parameter $\Psi > 0$ is the inverse elasticity of labour supply.

Households’ budget constraint is given by,

$$\tilde{W}_{H,t}L_{H,t} + R_{t-1}D_{t-1} + R^*_t \Psi^B (Z_{t-1}, A_{t-1}^{UIP}) S_tB_{t-1} + \Pi_t + T_t \leq P_tC_t + D_t + S_tB_t$$

Households derive income by supplying labour, $L_{H,t}$ at a nominal wage rate $\tilde{W}_{H,t}$. They receive transfers ($T_t$) from the left-over equity of entrepreneurs who die and leave the economy (see section 5.1.4.4 below). Households also receive profits ($\Pi_t$) made by the retail firms which operate in the monopolistically competitive market (see section 5.1.5 below). They can also hold two types of financial assets: place deposits $D_t$ (denominated in domestic currency) with a domestic financial intermediary which pays a fixed nominal return $R_t$; or buy a one-period non-contingent foreign bond $B_t$ (denominated in foreign currency) which gives a risk adjusted nominal return $R^*_t \Psi^B (Z_t, A_t^{UIP})$.

In holding the foreign bonds, households are subject to the country’s risk premium. Introduction of this friction is necessary to alleviate the problem of net foreign assets in the steady-state being non-stationary (Schmitt-Grohe and Uribe (2003)). Following Adolfson, Laséen, and Villani (2008), the expression for the debt-elastic risk premium is given by

$$\Psi^B (Z_t, A_t^{UIP}) = \exp \left[ -\psi^B (Z_t, A_t^{UIP}) \right]$$

See Schmitt-Grohe and Uribe (2003) for detailed quantitative analysis on the different approaches to overcome this problem. One approach, like the one applied here, is to introduce imperfect financial markets. Besides the debt-elastic risk premium, another method to introduce the financial market friction is through introducing a portfolio adjustment cost to hold foreign bonds. Another approach is to assume the existence of complete asset markets, like the one used in Gali and Monacelli (2005).
where $Z_t = \frac{S_t B_t}{Y_t P_t}$ is the real outstanding net foreign assets position of the domestic economy. $\psi^B > 0$ is the parameter that represents elasticity of the risk premium. The term $A_{t}^{UIP}$ is the debt-elastic risk premium shocks, which follows the AR(1) process,

$$A_{t}^{UIP} = \rho_{UIP} A_{t-1}^{UIP} + \varepsilon_{t}^{UIP}$$

where $\rho_{UIP} \in [0, 1]$ is the AR(1) coefficient and $\varepsilon_{t}^{UIP} \sim iid \left(0, \sigma^2_{UIP}\right)$ is the random shocks.

**Optimum Allocation**

Households choose the paths of $\{C_t, L_{H,t}, D_t, B_t\}_{0}^{\infty}$ to maximize expected lifetime utility subject to the budget constraint. Solving the household’s optimization problem, yields the following set of optimality conditions;

$$\tilde{W}_{H,t} P_t \equiv W_{H,t} = L_t \psi (C_t - \Upsilon C_{t-1})$$

$$R_t = \frac{1}{\beta} E_t \left[ \frac{(C_t - \Upsilon C_{t-1}) P_t}{(C_{t+1} - \Upsilon C_t) P_{t+1}} \right]$$

$$R^*_t \psi^B (Z_t, A_{t}^{UIP}) = \frac{1}{\beta} E_t \left[ \frac{(C_t - \Upsilon C_{t-1}) P_t}{(C_{t+1} - \Upsilon C_t) P_{t+1}} S_t \right]$$

where $W_{H,t}$ is the real wages (relative to the CPI). The first equation above refers to the intra-temporal condition relating to the labour supply which equates real wages to the household’s marginal rate of substitution (MRS) between consumption and leisure. The remaining two equations above correspond to the familiar Euler equations that determine the optimal path of consumption, by equating the marginal benefits of savings to its corresponding marginal (opportunity) costs. With this optimal consumption path, it will also determine the household’s savings decision in the form of holding the domestic deposits and foreign bonds respectively. Hence, combining these two equations provides a version of the (risk-adjusted) uncovered interest parity (UIP) condition. The UIP condition will place a restriction on the relative changes of the domestic and
foreign interest rates and pin-down the movement of the nominal exchange rates for the domestic economy.

In log-linear forms, equations that determine consumption, labour supply and the real UIP condition are:

\[ c_t - \Upsilon c_{t-1} = E_t (c_{t+1} - \Upsilon c_t) - (1 - \Upsilon) (r_t - E_t \pi_{t+1}) \quad (5.10) \]

\[ l_{H,t} = \frac{1}{\Psi} \left[ w_{H,t} - \frac{1}{1 - \Upsilon} (c_t - \Upsilon c_{t-1}) \right] \quad (5.11) \]

\[ \text{rer}_{t+1} - \text{rer}_t = (r_t - E_t \pi_{t+1}) - \left( r^*_t - E_t \pi^*_{t+1} \right) + \psi_t z_t + A_{t}^{UIP} \quad (5.12) \]

### 5.1.4 Entrepreneurs

Introduction of the financial accelerator mechanism requires modification to the original set-up of Gali-Monacelli’s model. It involves introducing capital as another factor input in the production function, as well as introducing the entrepreneur as a new economic agent. Capital plays two main roles in this modified model. Through investment expenditure, accumulation of capital acts as another source of demand for goods in the economy. Also, fluctuations in the capital price plays a vital role in determining the external finance premium, which plays a key role in the BGG’s financial accelerator mechanism.

The set-up for the entrepreneur’s behaviour closely follows the approach used in BGG. Entrepreneurs are involved in two main economic activities. First, they manage firms that produce wholesale (intermediate) goods. Second, entrepreneurs produce capital goods. They also own all the capital. In producing and owning capital, entrepreneurs are subject to a financing constraint. This forms the financial accelerator effect in this model. To ensure the financial accelerator effect always binds, entrepreneurs are assumed to have a finite horizon. A fraction \((1 - \varsigma)\) of entrepreneurs "die" and exit business in each period. Parameter \(\varsigma \in [0, 1]\) represents the proportion of entrepreneurs
that survive. Following BGG, this assumption is introduced to guarantee that entrepreneurs always face a financing constraint and will avoid the situation when they are able to accumulate enough net worth to be self-financing. In addition, it also captures the realistic phenomenon of ongoing births and deaths of firms in the economy.

5.1.4.1 Production of Wholesale Goods

Entrepreneurs operate in a competitive market. They produce wholesale goods $Y_{H,t}$ and sell them to retailers at a market clearing wholesale price $P_{H,t}^W$. In producing the wholesale goods, entrepreneurs combine two factors of production - capital ($K_t$) and labour ($L_t$). The labour input is a composite of household labour ($L_{H,t}$), and entrepreneur labour ($L_{E,t}$),

$$L = L_{H,t}^\Omega L_{E,t}^{1-\Omega}$$

with parameter $\Omega$ measuring the proportion of household to entrepreneur labour in the economy. Following BGG, and for simplicity, the supply of entrepreneur labour is assumed to be constant and is normalized to 1.

The gross nominal rental rate for capital is $\tilde{R}_{G,t}$. The nominal wage for the household and entrepreneur labour input is $\tilde{W}_{H,t}$ and $\tilde{W}_{E,t}$ respectively. All firms are assumed to have a common production technology to produce the wholesale goods, given by the standard Cobb-Douglas production function,

$$Y_{H,t} = A_t^Y K_t^\alpha L_{H,t}^{(1-\alpha)\Omega}$$

where parameter $\alpha \in [0, 1]$ is the proportion between the capital and labour input of the given production technology. Variable $A_t^Y$ is a productivity factor common to all firms in the economy. The productivity factor evolves as follows,

$$A_t^Y = \rho_Y A_{t-1}^Y + \varepsilon_t^Y$$ (5.13)

where $\rho_Y \in [0, 1]$ is the AR(1) coefficient and $\varepsilon_t^Y \sim iid(0, \sigma_{\varepsilon_Y}^2)$ is the random shocks. In log-linear form, the equation that represents the production function is;
In every period, entrepreneurs choose a combination of factors of production to minimize costs subject to the technology constraint. More formally, each producer solves the following cost minimization problem,

\[
\min_{L_{H,t}, K_t} \tilde{R}_{G,t} K_t + \tilde{W}_{H,t} L_{H,t} + \tilde{W}_{E,t}
\]

subject to the technology constraint given by the Cobb-Douglas production function defined previously. The solution to the above problem provides the implicit demand function for capital and labour. The following equations are demand functions for the respective factor inputs. They equate the factor cost to its value of marginal product;

\[
\begin{align*}
\tilde{R}_{G,t} &= \alpha \frac{Y_{H,t}}{K_t} P_{H,t}^W \\
\tilde{W}_{H,t} &= (1 - \alpha) \Omega \frac{Y_{H,t}}{L_{H,t}} P_{H,t}^W \\
\tilde{W}_{E,t} &= (1 - \alpha) (1 - \Omega) Y_{H,t} P_{H,t}^W
\end{align*}
\]

To explicitly demonstrate the effect of the LOPG and real exchange rate movements in influencing the cost of the factor inputs (and hence the real marginal cost of domestic produced goods), simple manipulations on the above expressions are necessary. First, write the above demand functions in the real form, by dividing both sides by \( P_t \) (the CPI) and introduce \( P_{H,t} \) (the domestic price index) on the RHS. Next, by using the fact that producers in the wholesale market are price takers and that profit maximization behaviour leads them to set production quantity \( Y_{H,t} \) at the level where the real wholesale price equals the marginal cost of production, we can substitute \( \frac{P_{W,t}}{P_{H,t}} = MC_{H,t} \). Following these two steps the above factor demand equations can be written as,

\[
\frac{\tilde{R}_{G,t}}{P_t} \equiv R_{G,t} = \frac{Y_{H,t}}{K_t} MC_{H,t} \frac{P_{H,t}}{P_t}
\]
\[
\frac{\bar{W}_{H,t}}{P_t} \equiv W_{H,t} = (1 - \alpha) \Omega \frac{Y_{H,t}}{L_{H,t}} MC_{H,t} \frac{P_{H,t}}{P_t}
\]

\[
\frac{\bar{W}_{E,t}}{P_t} \equiv W_{E,t} = (1 - \alpha) (1 - \Omega) Y_{H,t} MC_{H,t} \frac{P_{H,t}}{P_t}
\]

where \( R_{G,t}, W_{H,t}, W_{E,t} \) are the respective real price of factor inputs expressed in terms of CPI and \( MC_{H,t} = \frac{P_{H,t}}{P_t} \) represents the real marginal costs in terms of domestic prices. In log-linear form, equations for the corresponding demand function of factor inputs are;

\[
r_{G,t} = y_{H,t} + mc_{H,t} - k_t - \left( \frac{\gamma}{1 - \gamma} (rer_t - lopg_t) \right) \tag{5.15}
\]

\[
w_{H,t} = y_{H,t} + mc_{H,t} - l_{H,t} - \left( \frac{\gamma}{1 - \gamma} (rer_t - lopg_t) \right) \tag{5.16}
\]

\[
w_{E,t} = y_{H,t} + mc_{H,t} - \left( \frac{\gamma}{1 - \gamma} (rer_t - lopg_t) \right) \tag{5.17}
\]

where, equations 5.15, 5.16 and 5.17 above are written by using the expression \( p_t = p_{H,t} + \gamma tot_t \) and \( rer_t = (1 - \gamma) tot_t + lopg_t \) (see Section 5.1.2) to \( \frac{P_{H,t}}{p_t} \). This is done to explicitly demonstrate the effect of RER and LOPG in affecting the cost of producing domestic goods. Then, to get the expression for the real marginal cost, simply substitute equations 5.15 and 5.16 into equation 5.14 and rearrange,

\[
m_{C_{H,t}} = \frac{(1 - \alpha)(1 + \Omega)}{\alpha + (1 - \alpha)\Omega} y_{H,t} + \frac{1}{\alpha + (1 - \alpha)\Omega} [\alpha r_{G,t} + (1 - \alpha)w_{H,t}]
\]

\[
+ \frac{1}{\alpha + (1 - \alpha)\Omega} \left[ \frac{\gamma}{1 - \gamma} (rer_t - lopg_t) \right] - \frac{1}{\alpha + (1 - \alpha)\Omega} A_Y
\]

From the above expression, notice the role of RER and LOPG in affecting the movement of the real marginal cost. Depreciation in the real exchange rate (\( \uparrow \)RER) contributes
positively to the cost of production, while an increase in the LOPG has the opposite effect. In the open economy set-up, the contribution of these two variables depend on the degree of openness of the economy, measured by parameter $\gamma$. As $\gamma \to 1$, the more open the economy and the bigger the impact of external factors on the domestic marginal cost. Other standard results of the closed-economy set-up also hold. Marginal cost is an increasing function to domestic output ($y_{H,t}$) and is inversely related to the productivity factor ($A^{Y}_{t}$).

5.1.4.2 Investment and Capital Production

Entrepreneurs produce capital and sell it in the competitive market at a nominal price $\tilde{Q}_{t}$. To produce new capital, entrepreneurs combine two factors of production; existing capital ($K_{t}$) and investment ($INV_{t}$). Variable $INV_{t}$ is a composite of home and foreign consumption goods, both purchased from the retailers. For simplicity, entrepreneurs are assumed to choose the investment input mix in exactly the same fashion as the households choose their consumption basket. Thus, entrepreneurs’ demand function is the same as households’. Hence, with this assumption, the expression for $INV_{t}$ is analogous to equation (5.1);

$$INV_{t} = \left[ (1 - \gamma) \frac{\eta}{\pi} (C_{H,t})^{\frac{\eta-1}{\pi}} + \gamma \frac{\eta}{\pi} (C_{F,t})^{\frac{\eta-1}{\pi}} \right]^\frac{\pi}{\eta-1}$$

Note also that with this assumption, the Investment Price Index is the same as the Consumer Price Index. Hence, the cost for a unit of investment is $P_{t}$.

The expression for the capital accumulation equation is,

$$K_{t+1} = \Phi \left( \frac{INV_{t}}{K_{t}} \right) K_{t} + (1 - \delta)K_{t}$$

where $\delta$ is the capital depreciation rate. $\Phi(.)$ is an increasing and concave production function capturing the presence of adjustment costs in the production of capital, given as follows,

$$\Phi \left( \frac{INV_{t}}{K_{t}} \right) = \frac{INV_{t}}{K_{t}} - \frac{\psi_{t}}{2} \left( \frac{INV_{t}}{K_{t}} - \delta \right)^{2}$$
where $\psi_I > 0$ is the parameter measuring capital adjustment cost. The adjustment cost is necessary to allow movement in the price of capital. As explained in BGG, asset price variability contributes to volatility in the entrepreneurial net worth and contributes to the financial accelerator effect. Note that $\Phi(\cdot)$ has the following properties in the steady-state. First, $\Phi'(\frac{INV}{K}) = 1$, which will ensure the real price of capital ($Q_t$, see below) will be equal to unity in the steady-state (i.e. $\bar{Q} = 1$). Second, $\Phi\left(\frac{INV}{K}\right) = \delta$, which implies that in the deterministic steady-state condition (i.e. no steady-state growth), investment just replaces the depreciated capital.\(^6\) In log-linear forms, the equation for capital accumulation is,

$$k_{t+1} = \delta inv_t + (1 - \delta)k_t$$  \hspace{1cm} (5.18)

In deciding how much new capital to produce, entrepreneurs choose investment level $INV_t$, to maximize profits. To do so the entrepreneur solves the following problem,

$$\max_{INV_t} \tilde{Q}_t \Phi\left(\frac{INV_t}{K_t}\right) K_t - P_t INV_t$$

The optimality condition for the entrepreneur’s investment decision is given by the expression,

$$\tilde{Q}_t \Phi'(\frac{INV_t}{K_t}) - P_t = 0$$

Now, to express the price of capital in real term, define $Q_t = \frac{\tilde{Q}_t}{P_t}$. Then, transform the above optimality condition as,

$$Q_t = \frac{1}{\Phi'\left(\frac{INV_t}{K_t}\right)}$$

or in the log-linear approximation,

$$q_t = \psi_I \left( inv_t - k_t \right)$$  \hspace{1cm} (5.19)

\(^6\)This is a standard assumption used in the literature for capital production with capital adjustment cost. See among others, Bernanke, Gertler, and Gilchrist (1999); Smets and Wouters (2003); Gertler, Gilchrist, and Natalucci (2007). This assumption leads to the condition $\frac{INV}{K} = \delta$ holds in the steady-state that is used to log-linearize the capital accumulation equation below.
where $\psi_I = \left( -\frac{q''}{q'} \right) \left( \frac{\ln N}{K} \right)$ is the elasticity of the price of capital to the capital adjustment cost. The above expression is the familiar Tobin’s-Q relation, which relates the price of capital to the price of investment, adjusted for the capital adjustment cost. Hence, the higher the capital adjustment cost, the more costly for entrepreneurs to produce new capital, which translates into a higher capital price.

5.1.4.3 Return on Investment

Let $R_{K,t}$ denotes the gross real return to investment for entrepreneurs. The expression for the gross return on investment received by entrepreneurs is,

$$R_{K,t} = \frac{\{R_{G,t} + (1 - \delta) Q_t\} K_t}{Q_{t-1} K_t}$$

which implies, in log-linear approximation;

$$r_{K,t} + q_{t-1} = \left( 1 - \frac{1 - \delta}{\overline{R}_K} \right) r_{G,t} + \frac{(1 - \delta)}{\overline{R}_K} q_t$$

where $\overline{R}_K$ is the return on investment in the steady-state.

The above equation shows that there are two determinants to the return on the entrepreneur’s investment. First, is the real rental revenue received from the production of the intermediate (wholesale) goods ($R_{G,t}$). Secondly, after taking into account capital depreciation, the return on capital also depends on the current value of the existing capital stock. Hence, movement in $Q_t$ produces capital gains or losses that directly affects total return on capital. Movement in $Q_t$ also influences the entrepreneur’s net worth position and their ability to borrow. This is discussed next.

5.1.4.4 Financial Friction and Net Worth

Entrepreneurs finance the production activities and owning of capital using the combination of their net worth ($N_{t+1}$) and by borrowing funds from the financial intermediary ($F_{t+1}$). Hence, the entrepreneur’s budget constraint is,
\[ Q_t K_{t+1} = N_{t+1} + F_{t+1} \]

With the financial accelerator mechanism, when borrowing funds from a financial intermediary, entrepreneurs need to pay gross real interest rate \( R_t \frac{P_t}{P_{t+1}} \) and the external finance premium that depends on the borrower’s leverage ratio. Following the approach used by BGG, there is an agent-principal problem in the credit market that makes external finance more expensive to entrepreneurs than the internal funds. The external finance premium depends on the entrepreneur’s financial position. This is given by the expression,

\[ \text{External Finance Premium} = \left( \frac{N_{t+1}}{Q_t K_{t+1}} \right)^{-\chi} \]

where \( \chi > 0 \) is the parameter measuring the elasticity of the external finance premium to the leverage ratio \( \frac{N_{t+1}}{Q_t K_{t+1}} \). See BGG for a comprehensive discussion and a detailed derivation on the optimal contract that motivates the positive relationship between the external finance premium and the borrower’s leverage ratio. In short, as \( \frac{N_{t+1}}{Q_t K_{t+1}} \) falls the higher is the leverage ratio of the borrowers. With a higher leverage ratio, the lenders require a higher premium from borrowers to commensurate the higher risk of default from the increase incentive to misreport the project outcome.

Entrepreneurs are risk neutral and choose the level of capital \( K_{t+1} \), as well as the associated level of fund borrowing, \( F_{t+1} \), to maximize profit. At the optimum, entrepreneurs equate the expected marginal return from capital investment to its expected marginal financing cost. Accordingly, the entrepreneur’s optimality condition is,

\[ E_t (R_{K,t+1}) = E_t \left[ \left( \frac{N_{t+1}}{Q_t K_{t+1}} \right)^{-\chi} R_t \frac{P_t}{P_{t+1}} \right] \]

or in log-linear form,

\[ E_t r_{K,t+1} = r_t - E_t \pi_{t+1} - \chi (n_{t+1} - q_t - k_{t+1}) \quad (5.21) \]
The next step is to derive the evolution of the entrepreneur’s net worth. The entrepreneurs net-worth, $N_{t+1}$, consists of the entrepreneurial equity, $V_t$, held by the proportion of entrepreneurs ($\varsigma$) who are still in business during the period and the share of the entrepreneur’s real wage income $W_{E,t}$ from supplying labour for the production of household goods, i.e.

$$N_{t+1} = \varsigma V_t + W_{E,t}$$

The remaining entrepreneurs who exit the economy, are assumed to transfer their equity as a lump sum to households, with $T_t = (1 - \varsigma)V_t$.\(^7\) Note that, following BGG, the model assumes that the share of entrepreneur’s income from supplying labour for production purposes is small. With this assumption, parameter $1 - \Omega$ (share of entrepreneurs labour input in the production process, see sub-section 5.1.4.1) is set at 0.01. Hence, with the small share of entrepreneur wage income, the dynamics of the entrepreneur’s net worth is largely determined by the movement of its equity value. In fact, the introduction of the entrepreneur wages in the BGG model is mainly due to a technical reason - to pin-down the net-worth position in the steady state. Also, with wage income, entrepreneurs always have a non-zero net-worth in the initial state to start the business.

Entrepreneurial equity, in turn, is given by

$$V_t = \left[ R_{K,t} Q_{t-1} K_t - \left( \frac{N_t}{Q_{t-1} K_t} \right)^{-\chi} R_{t-1} P_{t-1}^{1-\chi} F_t \right]$$

where $F_t = Q_{t-1} K_t - N_{t-1}$ is the amount borrowed. In words, entrepreneurial equity is the realized return on capital less repayment of loans. There are two principle sources for the movement of the entrepreneur’s equity position. First, as mentioned earlier, is from the changes in the capital return, $R_{K,t}$, that affects the entrepreneur’s revenue stream. The second source that affects the entrepreneur’s equity comes from the change

\(^7\)Note that this is a small departure from the original approach used in BGG. In their model, BGG assumes entrepreneurs who exit the economy spend their remaining equity in form of consumption goods, that requires the introduction of additional variable in the model for entrepreneur consumption. Here, instead of introducing a new notation for entrepreneur’s consumption, it is lumped into household consumption. This does not affect the overall results.
in the loan repayment burden. An increase in the interest rate, for example, reduces the entrepreneur’s net worth through higher debt burden. This raises the external finance premium, that subsequently increases the amount of outstanding loan. With higher liability due to higher external finance premium, the entrepreneur’s net worth is further reduced. These factors will affect the entrepreneur’s ability to borrow, which subsequently affect the demand and supply of capital in the economy.

The log-linear approximation for the equation governing the dynamics of the entrepreneur’s net-worth is,

$$n_{t+1} = \zeta R_K \left\{ \left( \Gamma_5 + 1 \right) r_{K,t} - \Gamma_5 \left( r_{t-1} - \pi_t \right) - \chi \Gamma_5 \left( q_{t-1} + k_t \right) + \chi \left( \Gamma_5 + 1 \right) n_t \right\}$$

$$+ \left( \Gamma_5 + 1 \right) \frac{W_E}{K} w_{E,t}$$

(5.22)

where $\Gamma_5 = \frac{K}{N} - 1$, and $\frac{K}{N}$ is the capital net-worth ratio in the steady-state. $\frac{W_E}{K}$ is the entrepreneur’s wages-capital ratio in the steady-state.

### 5.1.5 Retailers, Price Determination and Inflation Dynamics

To introduce nominal price rigidities, the model assumes that all consumption goods are distributed to the end-users by retailers who practice Calvo-type staggered price setting. These retailers are monopolistically competitive. They earn non-zero profit that is distributed back to the households. There are two types of retailers in this economy. Home good retailers, which distribute home produced goods to domestic households and capital producers. They also export the home produced goods for consumption abroad. The second type of retailers distribute foreign goods for domestic users. The mechanics of how both types of retailers set their price is discussed below. Based on their price setting behaviour, the price dynamic for the home and foreign produced goods will also be derived accordingly.
5.1.5.1 Home Good Retailers

Home good retailers redistribute goods produced by the home good producers. They buy the good from producers at the wholesale price $P_{W,t}$. For simplicity, retailers do not incur any cost to redistribute their products to the end users. Let $P_{H,t} (z)$ be the price set by home good retailer $z$, for the period $t$. Retailer’s re-optimized price is denoted $P_{H,t}^{NEW}$. It is assumed that all retailers face the same decision problem, hence their optimized price is common across the board, i.e. $P_{H,t} (z) = P_{H,t}^{NEW}$. At each period, the exogenous probability for home goods retailers to re-optimize their price level is $(1 - \theta_H)$. Following Calvo (1983), this probability is assumed to be independent of the price level chosen by the retailers in the previous periods and on the last time the retailers changed their price. This time independent probability is necessary to simplify the aggregation problem. Thus, at each period, a measure of $(1 - \theta_H)$ home goods retailers re-optimize their prices by setting $P_{H,t} (z) = P_{H,t}^{NEW}$. Meanwhile, the remaining retailers do not re-optimize their price. This happens with a probability $\theta_H$. Following Gali and Gertler (1999), these retailers updated their price according to the last period CPI inflation as follows;

$$P_{H,t} (z) = P_{H,t-1} (z) (\pi_{t-1})^\kappa$$

where parameter $\kappa \in [0, 1]$ measures the degree of inflation indexation (or degree of the “backward-lookingness”), and $\pi_{t-1} = log \left( \frac{P_{t-1}}{P_{t-2}} \right)$ is the CPI inflation.\(^8\) Accordingly, the expected duration for a price to adjust to its optimum level is given by,

$$(1 - \theta_H) + 2\theta_H (1 - \theta_H) + 3\theta_H^2 (1 - \theta_H) + \ldots + t\theta_H^{t-1} (1 - \theta_H) = \frac{1}{1 - \theta_H}$$

Thus, for example, if $\theta_H = 0.75$ per quarter, retailers do not reset their optimum price for an average duration of 1 year.

Under the assumed price-setting structure, the aggregate price level for the home good is given by,

\(^8\)The inflation indexation is introduced in order to generate the Phillips Curve that contains both the forward-looking and backward-looking elements. This combination is necessary to better fit the data. See Gali and Gertler (1999) for a detailed discussion.
\[ P_{H,t} = \left( 1 - \theta_H \right) \left( P_{H,t}^{NEW} \right)^{1-\epsilon} + \theta_H \left( P_{H,t-1} \left( \pi_{t-1} \right)^{\kappa} \right)^{1-\epsilon} \]  \hspace{1cm} (5.23)

Let \( Y_{H,t} (z) \) be the composite good sold by retailer \( z \) at period \( t \). The aggregate goods sold by all home goods retailers for consumption, investment and export purposes is given by the CES function,

\[ Y_{H,t} = \left( \int_0^1 Y_{H,t} (z)^{\frac{\epsilon-1}{\epsilon}} \, dz \right)^{\frac{\epsilon}{\epsilon-1}} \]

and each firm faces a demand schedule of the form,

\[ Y_{H,t+s} (z) \leq \left( \frac{P_{H,t}^{NEW}}{P_{H,t+s}} \left( \pi_{t+s-1} \right)^{\kappa} \right)^{-\epsilon} Y_{H,t+s} \]

In setting the price level, firm \( z \) solves the problem of maximizing the present discounted value of profits;

\[
\max_{P_{H,t}^{NEW}} \sum_{s=0}^{\infty} \beta^s \theta_H E_t \left\{ Y_{H,t+s} (z) \left[ P_{H,t}^{NEW} \left( \pi_{t+s-1} \right)^{\kappa} - P_{H,t+s} \frac{P_{H,t+s}^{W}}{P_{H,t+s}} \right] \right\}
\]

subject to the sequence of demand constraints. Note that \( \frac{P_{H,t+s}^{W}}{P_{H,t+s}} = MC_{H,t+s} \) is the home retailer’s real marginal cost. Since all retailers source their supply from the competitive intermediate good producers and they do not incur any additional cost to differentiate their products, each retailer has a common real marginal cost equal to the real wholesale price.\(^9\) Parameter \( \beta \) is the exogenous discount factor.\(^10\) The FOC of the above optimization problem is,

\[
\sum_{s=0}^{\infty} \beta^s \theta_H E_t \left\{ Y_{H,t+s} \left[ P_{H,t}^{NEW} \left( \pi_{t+s-1} \right)^{\kappa} - \frac{\epsilon}{\epsilon-1} P_{H,t+s} MC_{H,t+s} \right] \right\} = 0
\]

\(^9\)The wholesale price is determined by the marginal cost for the intermediate goods producers, discussed in sub-section 5.1.4.1.

\(^{10}\)As it is assumed that households are the owners of the distributing (retailer) firms in this model, retailers will distribute back all profits to households. Hence, the stream of retailer’s future profit is discounted based on household’s discount factor, \( \beta \).
Then, using the above FOC expression, the optimal price is,

\[ P_{NEW}^{H,t} = \mu \sum_{s=0}^{\infty} \beta^s \theta_H^s E_t \{ Y_{H,t+s} [P_{H,t+s} MC_{H,t+s}] \} \]

where \( \mu = \frac{\varepsilon}{\varepsilon - 1} \) is the retailer’s desired gross mark-up over wholesale price. The equation above indicates the determinant of the retailer’s optimal price under the environment of staggered pricing. Given the possibility that its price may remain fixed for multiple periods, retailers take into account two factors in setting price for period \( t \) - the expected future path of the real marginal cost and the movement of the inflation rate.

To get the expression for domestic inflation, first log-linearize the optimal price equation above,

\[ p_{NEW}^{H,t} \approx (1 - \beta \theta_H) [p_{H,t} + mC_{H,t}] + (\beta \theta_H) [E_t \{ p_{NEW}^{H,t+1} \} - \kappa \pi_{t-1}] \]

where \( mC_{H,t+s} = p_{H,t+s}^W - p_{H,t+s} \). Also, log-linearized the domestic price equation (from equation (5.23)) to get,

\[ \pi_{H,t} = (1 - \theta_H) [p_{NEW}^{H,t} - p_{H,t-1}] + \theta_H \kappa \pi_{t-1} \]

Now, with a simple substitution and rearrangement, the expression for domestic inflation is,

\[ \pi_{H,t} = \frac{1}{1 + \beta \kappa} [\beta E_t \{ \pi_{H,t+1} \} + \kappa \pi_{t-1} + \Lambda^H mC_{H,t}] \quad (5.24) \]

where parameter \( \Lambda^H = \frac{(1 - \beta \theta_H)(1 - \theta_H)}{\theta_H} \) measures the degree of price rigidity of the home good. Note that parameter \( \Lambda^H \) is decreasing in \( \theta_H \). The above expression shows that given the staggered price-setting structure of the retail goods, domestic inflation is determined by three determinants - expectation of the future domestic inflation, lag CPI inflation and the current real marginal cost of producing domestic intermediate goods.
5.1.5.2 Foreign Goods Retailers

For the foreign goods, the law of one price is assumed to hold at the wholesale level. Hence, import retailers purchase the products from foreign producers at the wholesale price $P_{F,t}^W = S_t P_t^*$ (expressed in the local currency). With the assumption that these retailers operate in a monopolistic competitive structure, they resell these imported products at the retail price $P_{F,t}$. At the retail level, LOPG does not necessarily hold. The possible divergence between the retail price of foreign goods in the domestic economy and the price of the foreign good in its country of origin ($P_{F,t} \neq S_t P_t^*$), introduces the effect of the incomplete exchange rate pass-through into the model.

Similar to the home good retailers, retailers for the imported goods fix their price in a staggered fashion. Let $P_{F,t}(z)$ be the price set by the imported good retailer $z$, for the period $t$. Import retailers re-optimize their price by choosing $P_{F,t}(z) = P_{F,t}^{NEW}$ with a fixed probability $(1 - \theta_F)$. The remaining import retailers who do not re optimize (which happens with probability $\theta_F$), simply update their price based on the last period CPI inflation;

$$P_{F,t}(z) = P_{F,t-1}(z) (\pi_{t-1})^\kappa$$

Under the assumed price-setting structure, the aggregate price level for the foreign good is given by

$$P_{F,t} = \left( (1 - \theta_F) \left( P_{F,t}^{NEW} \right)^{1-\varepsilon} + \theta_F \left( P_{F,t-1} (\pi_{t-1})^\kappa \right)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}} \quad (5.25)$$

Like home good retailers, import retailers set their optimal price by solving this problem;

$$\max_{P_{F,t}^{NEW}} \sum_{s=0}^{\infty} \beta^s \theta_F E_t \left\{ Y_{F,t+s}(z) \left[ P_{F,t}^{NEW} (\pi_{t+s-1})^\kappa - P_{F,t+s} \frac{P_{F,t}^W}{P_{F,t+s}} \right] \right\}$$

subject to the demand constraint, $Y_{F,t+s}(z) \leq \left( P_{F,t+s}^{NEW} (\pi_{t+s-1})^\kappa \right)^{-\varepsilon} Y_{F,t+s}$, with total aggregate demand for the foreign goods of $Y_{F,t} = \left( \int_0^1 Y_{F,t}(z)^{\frac{\varepsilon-1}{\varepsilon}} \, dz \right)^\frac{\varepsilon}{\varepsilon-1}$. Like before,
\[
\frac{p_{F,t}^W}{p_{F,t+s}} = MC_{F,t+s}
\]
is the real marginal cost for the import retailers. Import retailer’s optimal price is,

\[
P_{F,t}^{NEW} = \mu \frac{\sum_{s=0}^{\infty} \beta^s \theta_F E_t \{Y_{F,t+s} [P_{F,t+s}MC_{F,t+s}]\}}{\sum_{s=0}^{\infty} \beta^s \theta_F E_t \{(\pi_{t+s-1})^s\}}
\]

To get the expression for foreign inflation, log-linearize the equation above,

\[
p_{F,t}^{NEW} \approx (1 - \beta \theta_F) [p_{F,t} + mc_{F,t}] + (\beta \theta_F) [E_t \{p_{F,t+1}^{NEW}\} - \kappa \pi_{t-1}]
\]

where \(mc_{F,t} = p_{F,t}^W - p_{F,t}\). Also, by using the definition that \(p_{F,t}^W = s_t + p_t^*\), then the link between import retailer’s real marginal cost and LOPG can also be written as,

\[
mc_{F,t} = s_t + p_t^* - p_{F,t} \equiv lopg_t
\]

Log-linearizing equation (5.25),

\[
\pi_{F,t} = (1 - \theta_F) [p_{F,t}^{NEW} - p_{F,t-1}] + \theta_F \kappa \pi_{t-1}
\]

Now, with a simple rearrangement, the expression for foreign good inflation is,

\[
\pi_{F,t} = \frac{1}{1 + \beta \kappa} [\beta E_t \{\pi_{F,t+1}\} + \kappa \pi_{t-1} + \Lambda^F lopg_t]
\]

where parameter \(\Lambda^F = \frac{(1-\beta \theta_F)(1-\theta_F)}{\theta_F}\) measures the degree of price rigidity for the foreign good due to incomplete exchange rate pass-through. \(\Lambda^F\) is decreasing in \(\theta_F\). Like its domestic counterpart, foreign good inflation is also determined by three determinants - expectation of the future foreign good inflation, lag CPI inflation and the current LOPG (which represent the real marginal cost for purchasing foreign goods at the wholesale level).

**CPI Inflation**

Lastly, by substituting equation (5.24) and (5.26) to equation (5.5), the specification of the CPI inflation for this small open economy is given by expression,
\[
\pi_t = \frac{1}{1 + \beta \kappa} \left[ \beta E_t \{ \pi_{t+1} \} + \kappa \pi_{t-1} + (1 - \gamma) \Lambda^H m_{c_H,t} + \gamma \Lambda^F \text{lopg}_t \right] \quad (5.27)
\]

It is clear from the above equation that the determinant of the CPI inflation in this economy is a combination of domestic and foreign factors. On the domestic side, the cost of the factor inputs for producing intermediate goods determines the real marginal cost. Similarly, the impact of the foreign factor is transmitted through the measure for the law of one price gap (LOPG), \(\text{lopg}_t\). The relative importance between the domestic and foreign factors in influencing the overall dynamics of the CPI inflation is determined by the parameter \(\gamma\), the degree of economic openness.

### 5.1.6 The Central Bank

Results of Chapter 3 highlighted three main characteristics of BNM’s reaction function - BNM is forward-looking, does not react to the exchange rate movement and practices interest rate smoothing. Based on these results, monetary policy in this DSGE model is represented by a forward looking HMT type interest rate rule,

\[
r_t = (1 - \rho) \left[ \beta \pi_{t+1} + \Theta y_{t+1} \right] + \rho r_{t-1} + \varepsilon_t^{MP} \quad (5.28)
\]

where \(\varepsilon_t^{MP} \sim iid (0, \sigma_{mp}^2)\) is the monetary policy shocks.

### 5.1.7 Market Clearing Condition

#### 5.1.7.1 Foreign Sector

The consumption demand of the foreign country has the same structure as the one described in section 5.1.1. Analogous to equation 5.3, the optimal demand for the home good abroad (imported goods for the recipient country) is,

\[
C^*_t = Y_t^* \left( \frac{P^*_{H,t}}{P^*_t} \right)^{-\eta} \quad (5.29)
\]
where $Y^*_t = C^*_t$ is the total foreign output (exogenously given). Law of one price is assumed to hold for the export sector with the price of the home good sold abroad is $P^*_H/t = \frac{P^*_H}{P_t}$. This allows the demand for the home good abroad to be written as,

$$C^*_H/t = \gamma \left( \frac{P^*_H}{P_t} \right)^{-\eta} \left( \frac{P_t}{S_t P_t} \right)^{-\eta} Y^*_t.$$  

Then, using the definition of the real exchange rate, $\text{RER}_t \equiv S_t \frac{P^*_t}{P_t}$, the export demand of the home good is,

$$C^*_H/t = \gamma \left( \frac{P^*_H}{P_t} \right)^{-\eta} \left( \frac{1}{\text{RER}_t} \right)^{-\eta} Y^*_t.$$ \hfill (5.29)

The dynamics of the foreign sector is represented by a simple AR(1) process,

$$y^*_t = \mu^*_y y^*_{t-1} + \varepsilon^*_y,$$

$$i^*_t = \mu^*_i i^*_{t-1} + \varepsilon^*_i,$$

$$\pi^*_t = \mu^*_\pi \pi^*_{t-1} + \varepsilon^*_\pi.$$ \hfill (5.30)

where $\mu_i \in [0, 1]$, $i = y^*_t, i^*_t, \pi^*_t$ is the respective AR(1) coefficient and $\varepsilon^*_i \sim iid (0, \sigma^2_i)$ is the respective random shocks.

### 5.1.7.2 Aggregate Resource Constraint

In each period, the home final good ($Y_{H,t}$) is used for consumption, investment and export activities. The demand comes from domestic households for consumption purposes ($C_{H,t}$). Entrepreneurs utilize home final goods for investment purposes ($INV_{H,t}$). Lastly, demand for home final goods comes from the foreign country ($C^*_{H,t}$). Hence, in aggregate, total demand for the home good is $Y_{H,t} = C_{H,t} + INV_{H,t} + C^*_{H,t}$. Using their respective demand function from equations (5.2) and (5.29), the market clearing condition for the home final goods can be written as,

$$Y_{H,t} = \left( \frac{P_{H,t}}{P_t} \right)^{-\eta} \left[ (1 - \gamma) [C_t + INV_t] + \gamma \left( \frac{1}{\text{RER}_t} \right)^{-\eta} Y^*_t \right]$$

or in log-linear form,
\[ y_{H,t} = \frac{C}{Y_H} (1 - \gamma) c_t + \frac{INV}{Y_H} (1 - \gamma) \text{inv}_t + \gamma y_t^* + \eta \gamma \left( \frac{2 - \gamma}{1 - \gamma} \right) \text{rer}_t - \frac{\eta \gamma}{1 - \gamma} \text{lom}_t \quad (5.31) \]

A financial intermediary lends funds to entrepreneurs. To finance its operation, the financial intermediary collects deposits from domestic households at a cost \( R_t \). For simplicity, the financial intermediary operates in a competitive manner with zero profit. The risk premium that it charges entrepreneurs, is fully utilized to cover monitoring/auditing cost. In addition, it is also assumed that the financial intermediary does not borrow funds from abroad. Hence, in equilibrium, the amount of funds available for the financial intermediary to finance the borrowing demand from the entrepreneur is,

\[ D_t = F_t \]

i.e. total deposits placed by households is equal to total loans extended to the entrepreneurs. Entrepreneurs then transform this loan into capital.

5.1.7.3 Evolution of net foreign assets

The evolution of the aggregate net foreign asset for the economy (used to calculate the country risk premium in the UIP equation) is,

\[ Z_t = R^*_{t-1} \Psi^B (Z_{t-1}, A^{UIP}_{t-1}) Z_{t-1} + Y_{H,t} - (C_t + INV_t) \]

where \( Z_t = \frac{S_t B_t}{Y_{P_t}} \) is the economy’s aggregate net foreign assets. The above equation determines the dynamic of net foreign assets, \( Z_t \), as a function of the current account position, \( Y_{H,t} - (C_t + INV_t) \) and the flow of interest payments generated by \( Z_{t-1} \). The current account position reflects the net movement of the physical goods (exports minus imports) between the domestic economy and the rest of the world. In return, the domestic economy will accumulate net foreign assets which affects the country’s debt-elastic risk premium. In log-linear form, the equation that governs the country’s net foreign asset position is,
\[ z_t = \frac{1}{\beta} z_{t-1} + y_{H,t} - (c_t + inv_t) - \frac{\gamma}{(1-\gamma)} (r_{er,t} - \gamma l_{opg,t}) \quad (5.32) \]

### 5.1.8 Solving the model

For the purpose of estimation, a log-linear approximation to the model's optimality conditions around a non-stochastic steady-state value is employed. The complete representation of the system of equations to be estimated is summarized in Table 5.1. The system consists of 22 equations and 22 variables \( y_H, c, inv, \pi, rer, lopg, r, r_G, r_K, q, k, n, l_H, mc, w_H, w_E, z, y^*, i^*, \pi^*, A^{UIP}, A^Y \) and seven exogenous shocks \( \varepsilon^Y, \varepsilon^{UIP}, \varepsilon^{MP}, \varepsilon^{LOPG}, \varepsilon^{i*}, \varepsilon^{y*}, \varepsilon^{\pi*} \). All the seven exogenous shocks are assumed to be i.i.d process.

A variety of numerical techniques are available to solve this linear rational expectations model. Among others are methods proposed by Blanchard and Kahn (1980), McKibbin and Sachs (1991), Uhlig (1999), Klein (2000) and Sims (2002). See among others, Dave and DeJong (2007) for a review on this topic. The approximate solution takes the form of state-space representation,

\[ X_{t+1} = \Lambda_1 X_t + \Lambda_2 v_{t+1} \]
\[ Y_t = \Phi X_t + w_t \]

where \( X_t \) is the vector of state variables, \( Y_t \) is the vector of observed variables, \( \Lambda_1 \) and \( \Lambda_2 \) are solution matrices of the rational expectation model and \( \Phi \) is the matrix of parameters defining the link between the state and observed variables. \( v_{t+1} \) and \( w_t \) are the vector of uncorrelated shocks. The above state-space representation of the DSGE model can be estimated with the Kalman filter. See chapter 13 of Hamilton (1994) for a detail discussion on this area.

The above log-linearized DSGE model is solved and estimated using DYNARE v3.65.\textsuperscript{11}

\textsuperscript{11}DYNARE is a set of MATLAB codes to solve, simulate and estimate DSGE models. See http://www.cepremap.cnrs.fr/dynare/ for details.

131
Table 5.1: Summary of Log-linearized System of Equations

**Demand Side**

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate Demand: ( y_{H,t} = \frac{C}{R_H} (1 - \gamma) c_t + \frac{I}{R_I} (1 - \gamma) inv_t + \gamma y^*_t + \eta \gamma \left( \frac{\delta - \gamma}{1 - \gamma} \right) rer_t - \frac{\eta}{1 - \gamma} logq_t )</td>
<td>Consumption: ( c_t - \Upsilon c_{t-1} = E_t (c_{t+1} - \Upsilon c_t) - (1 - \Upsilon) (r_t - E_t \pi_{t+1}) )</td>
</tr>
</tbody>
</table>
| Investment: \( r_{K,t} + q_t - 1 = \left( 1 - \frac{(1 - \delta)}{R_K} \right) r_{G,t} + \frac{(1 - \delta)}{R_K} q_t \) | \( q_t = \psi_t (inv_t - k_t) \)
| \( E_t F_{K,t+1} = r_t - E_t \pi_{t+1} - \chi (n_{t+1} - q_t - k_{t+1}) \) |                                                                 |
and Sims (2002). Then, the Bayesian estimation method is used to estimate the parameters of the model. The methodological discussion of the Bayesian method as well as the results of the estimation exercise of the DSGE model is presented in the next section.

5.2 Estimation Strategy

There are several techniques that have been used in the literature to parametrize and evaluate the DSGE model. Canova (2007), Dave and DeJong (2007) and Ruge-Murcia (2007) review the use of different techniques to confront DSGE models to data. These techniques range from the calibration method, to estimation exercises using various techniques. Among the examples of DSGE models that use the calibration method are the work by Kydland and Prescott (1982, 1996); McKibbin and Sachs (1991); Bernanke, Gertler, and Gilchrist (1999) and Gali and Monacelli (2005). The different estimation techniques that have been used in the literature to estimate DSGE models are the GMM method (e.g. Christiano and Eichenbaum (1992)), the minimum distance method that is based on discrepancy among VAR and DSGE model impulse response functions (e.g. Rotemberg and Woodford (1997); Christiano, Eichenbaum, and Evans (2005); Meier and Muller (2006)) and the Full Information Maximum Likelihood (FIML) method (e.g. Leeper and Sims (1994); Kim (2000) and Ireland (2004)). In recent years, the Bayesian method has become an increasingly popular technique to estimate DSGE models. Examples in the literature that use this method include DeJong, Ingram, and Whiteman (2000); Smets and Wouters (2003) and Lubik and Schorfheide (2005).

The Bayesian method has also been applied to estimate the DSGE model in an open economy setting. For example, Lubik and Schorfheide (2005) apply the Bayesian method to estimate the open economy DSGE model for the large economy of the US and the Euro area. Using the same estimation method, this approach has been extended to the case of smaller economies of developed countries. Among the examples include Kam, Lees, and Liu (Forthcoming) and Justiniano and Preston (2006) which estimate the model for Australia, New Zealand and Canada; and Adolfsson, Laseen, and Lindé (2008) for Sweden. Conversely, as stated before, examples of published work involving developing countries are limited. Medina and Soto (2005, 2007) and Castillo, Montoro,
and Tuesta (2006) apply the Bayesian approach to estimate a DSGE model for Chile and Peru respectively.

Conceptually, the application of Bayesian estimation on a DSGE model is a bridge between the calibration and the maximum likelihood methods. In this regard, Lubik and Schorfheide (2005) list three main characteristics of the Bayesian approach in the context of estimating the DSGE model. First, the Bayesian approach is a system-based methodology that fits the DSGE model to a vector of time series. As opposed to GMM estimation which is based on particular (partial) equilibrium relationships (such as the Euler equation in consumption), the Bayesian approach takes advantage of the general equilibrium philosophy - all the theoretical restrictions implied by the model for the likelihood function and the full dimensions of the data are taken into account for estimation. Second, the estimation of the Bayesian approach is based on the likelihood function generated by the DSGE model, rather than, for instance, the discrepancy between DSGE model responses and vector autoregression (VAR) impulse responses. Third, the Bayesian approach involves the introduction of prior distributions on the model's parameters.

There are several advantages of using this approach in the DSGE framework. For instance, An and Schorfheide (2007) elaborate in detail how the three characteristics listed above, are instrumental in making the Bayesian approach cope with the potential problem of model misspecification and possible lack of parameter identification in estimating the DSGE model. While the Bayesian approach does not solve the model misspecification and parameter identification problems per se - the common challenges face by any estimation method - An and Schorfheide (2007) argue that it provides admonition about the problems to the user.\[^{12}\] Fernandez-Villaverde and Rubio-Ramirez (2004) highlight another important strength of the Bayesian approach as the estimation tool for the DSGE model. They find that the Bayesian estimation has a strong small sample behaviour that outperforms the results of the DSGE model estimated using the Maximum Likelihood approach. Most importantly, they also show that even in the case of misspecified and/or non-nested models, results from Bayesian estimation are asymptotically consistent. Lastly, the Bayesian approach provides a platform for researchers to easily perform model comparisons that best fit the data. To do so, the posterior odds ratio is constructed using the information gathered from the posterior

\[^{12}\text{See also Canova and Sala (2006) and Del Negro, Schorfheide, Smets, and Wouters (2007) for detailed discussion regarding identification and misspecification problems in the DSGE model.}\]
distribution of the competing models. In the case of equal prior probabilities across models, the posterior odds ratio is simply the ratio of marginal likelihoods between the competing models. Among the examples of literature that utilize this method is Rabanal and Rubio-Ramirez (2005). They compare the fit of four competing specifications of a closed economy DSGE model and Lubik and Schorfheide (2005) compare a closed and open economy version of a DSGE model.

5.2.1 Bayesian Estimation

This sub-section provides a sketch on the application of the Bayesian methodology in the DSGE framework. Unlike the Classical approach which assumes there exists a fixed, true value for the parameters, the fundamental difference of the Bayesian approach is the assumption that the parameter of interest is not fixed, but a random variable with a probability distribution. To briefly illustrate the mechanics of the Bayesian estimation, let $\Theta_M$ denotes the vector of parameters for the specific model $M$, and $Y_T$ is the vector of observed data with $T$ the sample size. Also let $p (\Theta_M | M)$ be the prior density of the parameters and $p (\Theta_M | Y_T, M)$ the posterior density of the parameters conditional on the observed data. $L (\Theta_M | Y_T, M) \equiv p (Y_T | \Theta_M, M)$ is the likelihood function describing the density of the observed data conditional on the model and its parameters. The likelihood function is recursive and can be written as:

$$p (Y_T | \Theta_M, M) = p (y_0 | \Theta_M, M) \prod_{t=1}^{T} p (y_t | Y_{T-1}, \Theta_M, M)$$

The Bayesian estimation works as follows. The aim is to obtain the posterior density $p (\Theta_M | Y_T)$ of the model’s parameters by using the information of the prior density and the likelihood function. Combining the prior density and likelihood function using the Bayes theorem, the posterior density can be written as:\textsuperscript{14}

$$p (\Theta_M | Y_T) = \frac{p (\Theta_M \cap Y_T)}{p (Y_T)} \equiv \frac{p (Y_T | \Theta_M) \times p (\Theta_M)}{p (Y_T)}.$$ Equation for the posterior density (equation 5.33) utilizes this property.

\textsuperscript{13}An and Schorfheide (2007) provide a detail overview of the Bayesian methodology in the DSGE framework. See also Chapter 12 of Hamilton (1994) and Chapter 9 of Canova (2007) and reference in them for technical discussions of the Bayesian estimation.

\textsuperscript{14}In general form, Bayes theorem states that $p (\Theta | Y_T) = \frac{p (\Theta \cap Y_T)}{p (Y_T)}$. Similarly, expressed on the opposite condition, $p (Y_T | \Theta) = \frac{p (\Theta \cap Y_T)}{p (\Theta)} \iff p (\Theta \cap Y_T) = p (Y_T | \Theta) \times p (\Theta)$.

Hence, $p (\Theta | Y_T) = \frac{p (\Theta \cap Y_T)}{p (Y_T)} \equiv \frac{p (Y_T | \Theta) \times p (\Theta)}{p (Y_T)}$. Equation for the posterior density (equation 5.33) utilizes this property.
\[
p(\Theta_M \mid Y_T, M) = \frac{p(Y_T \mid \Theta_M, M) \times p(\Theta_M \mid M)}{p(Y_T \mid M)}
\]

where \(p(Y_T \mid M)\) is the marginal data density conditional on the specific DSGE model that it tries to fit;

\[
p(Y_T \mid M) = \int_{\Theta_M} p(Y_T \mid \Theta_M, M) \times p(\Theta_M \mid M) \, d\Theta_M
\]

The objective of the Bayesian approach is to reconstruct the parameter’s posterior density and use it to characterize the parameter’s statistical moments. The central part of doing this is to exploit the parameter’s posterior kernel equation,

\[
K(\Theta_M \mid Y_T, M) \equiv p(\Theta_M \mid Y_T, M) \propto p(Y_T \mid \Theta_M, M) \times p(\Theta_M \mid M)
\]

The construction of the parameter’s posterior distribution involves two main steps. First, is the estimation of the posterior kernel using the information from the likelihood function. The recursive likelihood function of the model is estimated using the Kalman filter. Second, is to use the posterior kernel to characterize the shape of the parameter’s posterior distribution. However, as the parameter’s posterior distribution is nonlinear and is a complicated function of the parameters \(\Theta_M\), its explicit form is unknown. Hence, the simulation exercise by generating random draws from the parameter’s posterior distribution is needed. To do so, these random draws are generated using the Markov Chain Monte Carlo (MCMC) method, such as the Metropolis-Hastings (MH) algorithm.

To perform model comparison, say between model \(M\) and \(N\), the Bayesian approach utilizes the information from the model’s posterior distribution. Let \(p(M)\) and \(p(N)\) be the prior distribution for each model. The posterior distribution for each model, generated from the same data set \(Y_T\), is given by the expression,

\[
p(M \mid Y_T) = \frac{p(M)p(Y_T \mid M)}{p(M)p(Y_T \mid M) + p(N)p(Y_T \mid N)}
\]

\[
p(N \mid Y_T) = \frac{p(N)p(Y_T \mid N)}{p(M)p(Y_T \mid M) + p(N)p(Y_T \mid N)}
\]
where \( p(Y_T \mid M) \), \( p(Y_T \mid N) \) is the marginal data density (given by equation 5.34).\(^{15}\)

The posterior odds ratio (or Bayes factor), \( K \), is calculated as follows:

\[
K \equiv \frac{p(M \mid Y_T)}{p(N \mid Y_T)} = \frac{p(M)}{p(N)} \times \frac{p(Y_T \mid M)}{p(Y_T \mid N)}
\]

Without any prior beliefs about which model is more likely to fit the data, it can be assumed that \( p(M) = p(N) \). Hence, the Bayes factor is normally expressed as:

\[
K = \frac{p(Y_T \mid M)}{p(Y_T \mid N)}
\]

Jeffreys (1961) and Kass and Raftery (1995) give the scale for interpreting \( K \). From Kass and Raftery (1995) (page 777), this scale is summarized as follows:

<table>
<thead>
<tr>
<th>( \log_e K )</th>
<th>K</th>
<th>Evidence favouring model M</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 2</td>
<td>1 to 3</td>
<td>Not worth more than a bare mention</td>
</tr>
<tr>
<td>2 to 6</td>
<td>3 to 20</td>
<td>Positive</td>
</tr>
<tr>
<td>6 to 10</td>
<td>20 to 150</td>
<td>Strong</td>
</tr>
<tr>
<td>&gt;10</td>
<td>&gt;150</td>
<td>Very strong</td>
</tr>
</tbody>
</table>

The Bayesian estimation in this chapter was performed using DYNARE v3.65. The following options were used to run the estimation process.

- Christopher Sims 'csminwel' algorithm as the optimizer for computing the mode of parameter’s posterior density. This value is then used to initiate the simulation using the MCMC method.

- Metropolis-Hastings (MH) algorithm to generate draws from the posterior density.

The following options were used for the MH algorithm:

\(^{15}\)The practical difficulty to calculate the Bayes factor is to obtain the marginal data density. One of the common methods to do this (and the one used in this chapter) is to use the Modified Harmonic Mean Estimator (see Geweke (1999)), which involves the simulation of the marginal density using the MH algorithms. See Canova (2007) and An and Schorfheide (2007) for detailed discussion on the alternative estimator to calculate the marginal data density.
- 2 parallel Markov chains
- 500,000 draws for each chain, with the first 30% of draws discarded as burn-in
- The scale coefficient for the variance-covariance matrix of the random walk chain was set to give the acceptance rate between 20-30%.

5.2.2 Choice of Priors and Fixed Parameters

The choice of priors for the Bayesian estimation in this chapter is guided by two main considerations - the restrictions imposed on the theoretical grounds as well as the specifications and results from other studies. The theoretical restrictions on the parameter values like the interval boundaries and the non-negativity constraints affects the choice of the probability distribution used as the prior. Beta distribution is used when the parameters are constrained on the unit-interval while Gamma and Normal distribution is chosen for parameters that are restricted to be on the positive domain. After deciding a suitable prior distribution, the next step is to find a suitable value for the prior mean and standard deviation of each parameters. In doing so, results from other empirical studies are used.

Table 5.2 summarizes the prior distribution of the estimated parameters. The main challenge of finding the parameter's priors for the estimation exercise is the lack of published studies that use a DSGE modelling framework involving Malaysia's data that can be used as a reference. There is only one known published study that applies this modeling framework to the Malaysia's data - Ramayandi (2008). Ramayandi estimated Gali-Monacelli's small open economy DSGE model for 5 ASEAN countries using the Maximum Likelihood (ML) method. Even though Ramayandi used a shorter sample period for his estimation of structural parameters on the Malaysian economy - quarterly data of 1991 to 2004 - information from his point estimates is useful in guiding us to set the priors for most of the parameters in this exercise. Summary of his results is given in Table 5.6 (place in Appendix). Hence, by utilizing the information from Ramayandi's estimation results on the deep parameters for the Malaysian economy, fairly tight priors are imposed on the deep parameters $\Upsilon$, $\Psi$, $\eta$, $\kappa$, $\theta_D$, $\theta_F$.

The introduction of the financial accelerator mechanism in the DSGE model requires finding a suitable prior for parameter $\chi$, the elasticity of the external finance premium.
<table>
<thead>
<tr>
<th>Description</th>
<th>Domain</th>
<th>Density</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Υ</td>
<td>Habit Persistence</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.50</td>
</tr>
<tr>
<td>Ψ</td>
<td>Inv. Elasticity of Lab. Supply</td>
<td>$\mathbb{R}^+$</td>
<td>Gamma</td>
<td>2</td>
</tr>
<tr>
<td>η</td>
<td>Elasticity Subst. Home/Foreign Goods</td>
<td>$\mathbb{R}^+$</td>
<td>Gamma</td>
<td>0.50</td>
</tr>
<tr>
<td>κ</td>
<td>Price Indexation</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.50</td>
</tr>
<tr>
<td>$\theta_D$</td>
<td>Calvo pricing - domestic goods</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.80</td>
</tr>
<tr>
<td>$\theta_F$</td>
<td>Calvo pricing - imported goods</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.80</td>
</tr>
<tr>
<td>ρ</td>
<td>HMT rule - smoothing</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.50</td>
</tr>
<tr>
<td>$\beta_\pi$</td>
<td>HMT rule - inflation</td>
<td>$\mathbb{R}^+$</td>
<td>Normal</td>
<td>1.20</td>
</tr>
<tr>
<td>$\Theta_y$</td>
<td>HMT rule - output</td>
<td>$\mathbb{R}^+$</td>
<td>Normal</td>
<td>1.00</td>
</tr>
<tr>
<td>$\mu_y^*$</td>
<td>AR(1) : Foreign output</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.50</td>
</tr>
<tr>
<td>$\mu_i^*$</td>
<td>AR(1) : Foreign int. rate</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.50</td>
</tr>
<tr>
<td>$\mu_\pi^*$</td>
<td>AR(1) : Foreign inflation</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.50</td>
</tr>
<tr>
<td>$\rho_{UIP}$</td>
<td>AR(1) : UIP shocks</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.50</td>
</tr>
<tr>
<td>$\rho_{LOPG}$</td>
<td>AR(1) : LOP shocks</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.50</td>
</tr>
<tr>
<td>$\rho_Y$</td>
<td>AR(1) : Technology shocks</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.50</td>
</tr>
<tr>
<td>$\sigma_{MP}$</td>
<td>Std. dev. MP shocks</td>
<td>$\mathbb{R}^+$</td>
<td>Inverse Gamma</td>
<td>0.05</td>
</tr>
<tr>
<td>$\sigma_y^*$</td>
<td>Std. dev. foreign output shocks</td>
<td>$\mathbb{R}^+$</td>
<td>Inverse Gamma</td>
<td>0.05</td>
</tr>
<tr>
<td>$\sigma_i^*$</td>
<td>Std. dev. foreign int. rates shocks</td>
<td>$\mathbb{R}^+$</td>
<td>Inverse Gamma</td>
<td>0.05</td>
</tr>
<tr>
<td>$\sigma_\pi^*$</td>
<td>Std. dev. foreign inflation shocks</td>
<td>$\mathbb{R}^+$</td>
<td>Inverse Gamma</td>
<td>0.05</td>
</tr>
<tr>
<td>$\sigma_{UIP}$</td>
<td>Std. dev. UIP shocks</td>
<td>$\mathbb{R}^+$</td>
<td>Inverse Gamma</td>
<td>0.05</td>
</tr>
<tr>
<td>$\sigma_{LOPG}$</td>
<td>Std. dev. LOP shocks</td>
<td>$\mathbb{R}^+$</td>
<td>Inverse Gamma</td>
<td>0.05</td>
</tr>
<tr>
<td>$\sigma_Y$</td>
<td>Std. dev. technology shocks</td>
<td>$\mathbb{R}^+$</td>
<td>Inverse Gamma</td>
<td>0.05</td>
</tr>
<tr>
<td>$\chi$</td>
<td>Financial Accelerator</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.07</td>
</tr>
</tbody>
</table>

There is a wide range of values that has been used and found in the literature. BGG set this parameter to 0.02 (or 200 basis points), referring to the historical average of the risk spread between the prime lending rate and the 6-month Treasury bill in the US.
Devereux, Lane, and Xu (2006) used the same value when calibrating their model using the Korean data. Gertler, Gilchrist, and Natalucci (2007) set this parameter at 0.035, a higher value than used by Devereux, Lane, and Xu (2006) with the argument that the capital market in Korea is less developed relative to the US. In contrast, results of a few estimation exercises found a higher value for this parameter than those used in the calibration approach. Meier and Muller (2006) estimated a closed economy DSGE model with a financial accelerator for the US economy using the minimum distance method. Using the sample period of 1980-2003, they estimated this parameter to be around 0.06. Using the FIML method and the same sample period, Christensen and Dib (2008) found a higher point estimate of 0.09 for the US economy.

For this chapter, priors for parameter $\chi$ is set to be Beta distribution with mean 0.07 and standard deviation 0.02. Using the same approach used by BGG, the value for the prior mean is chosen based on the historical average of interest rate risk-spread in Malaysia. For the period 1975-2005, the average risk-spread between the commercial bank’s average lending rate and the 3-month Treasury bill rate is about 550 basis points (or 0.055). Considering that Malaysia’s capital market is less developed than the US and Korea, setting the prior mean higher than the calibrated value used by BGG, Devereux, Lane, and Xu (2006) and Gertler, Gilchrist, and Natalucci (2007) is reasonable. In addition, by taking into account the estimation results of Meier and Muller (2006) and Christensen and Dib (2008) which found estimated values of this parameter are higher than the one used in the calibration exercise, we also expect the value for $\chi$ in Malaysia to be higher than 0.055. Hence, to allow for a possible large range for this parameter, we put a fairly loose prior for $\chi$, by setting the prior distribution’s standard deviation to 0.02.

The remaining priors are fairly standard. Based on the estimation results of BNM’s reaction function in Chapter 3, prior mean for parameter $\beta_\pi$ and $\Theta_y$ is set at 1.2 and 1.0 respectively. However, in order to investigate the possible differences of the HMT rule coefficients estimated as a single equation (as conducted and presented in Chapter 3) and those estimated from the system of equations used in here, a loose priors is set for the HMT-rule parameters $\rho$, $\beta_\pi$ and $\Theta_y$. We also set fairly uninformative priors for the shocks parameters. Priors for all the AR(1) coefficients of the shocks takes mean value of 0.5 and standard deviation of 0.25. The standard error of the shocks follows the Inverse-Gamma distribution, with all shares a common mean of 0.05 and infinite standard deviation.
As in other studies that estimate DSGE models, some parameters are fixed because the data used in the estimation exercise contain little information about them. For the estimation exercise in this chapter, few parameters in the model are set to the common value used in the literature. Household discount parameter, $\beta$, takes the value of 0.985. The share of capital in the production function, $\alpha$, is set at 0.35. The depreciation rate parameter, $\delta$, is 0.025, which implies an annual depreciation rate of 10%. The degree of retailer’s monopoly power, $\varepsilon$, is set at 6, which implies a gross steady-state price markup ($\mu$) of 1.20. The parameter measuring capital adjustment cost $\psi$, is set at 0.5.\footnote{BGG noted that there is no firm consensus in the literature about the value for this parameter. They suggest a value between 0 to 0.5 is a reasonable assumption for the capital adjustment cost. Hence, BGG and Devereux, Lane, and Xu (2006) set this parameter at 0.25, while Gertler, Gilchrist, and Natalucci (2007) use 0.5.} Following Schmitt-Grohe and Uribe (2003), the parameter for the elasticity of the risk premium ($\psi^B$) is set to 0.01.

Most of the parameters for the financial accelerator mechanism are the same as in BGG. The probability that an entrepreneur will survive for the next period, $\varsigma$, is set at 0.9728, implying that the expected working life of an entrepreneur is 36 years. The proportion of the household labour relative to the entrepreneur labour, $\Omega$, is fixed at 0.99. The only departure from the BGG’s set-up is on the choice of the capital to net-worth ratio ($\frac{K}{N}$) in the steady state. BGG fixed this ratio at 2, which they state is consistent with the 200 basis points risk-spread between the prime lending rate and 6-month treasury bill rate for the US’s data. Devereux, Lane, and Xu (2006) suggest that the use of a higher ratio than BGG’s set-up is more consistent with the higher leverage observed in emerging market economies. For this reason, in their calibrated DSGE model on Korea, they set this ratio at 3. Following their suggestion, the same value is chosen for this exercise. The higher capital-net worth ratio is also in line with the larger risk-spread seen in Malaysia’s data. As mentioned earlier, the average risk-spread in Malaysia was about 550 basis points, much larger than the one seen in the US’s data.

### 5.2.3 Data and Estimation Period

Like in the earlier chapters, the estimation exercise uses quarterly data series of output gap, CPI index, 3-month interbank nominal interest rate and index of the Real Exchange
5.3 Estimation Results for Full Sample Period: 1975Q1 to 2005Q2

The main objective of this estimation exercise is to estimate the structural or deep parameters of the Malaysian economy. In doing so, two model specifications were estimated - with a financial accelerator (FA) and without a financial accelerator (NFA). In the NFA model, the effect of credit friction is switched off by fixing parameter $\chi$ to zero. There are two reasons why we estimate these two model specifications. First, is to investigate how the estimation of the deep parameters for the Malaysian economy are affected by the choice of these two specifications. Second, is to investigate which of these two model specifications are better in describing the Malaysian economy. The outcome of this investigation will also verify the findings of Razi (1998) and Tang (2006) that the credit channel has an important role in the Malaysian economy. Discussion on the differences in the estimation results between FA and NFA model specifications will be discussed in Section 5.4.

This section starts with the general overview of the estimation results of FA and NFA models for the whole sample period - 1975Q1 to 2005Q2. It follows with discussion comparing the estimation results of the FA and NFA model with the results of another open economy DSGE model for Malaysia by Ramayandi (2008).

5.3.1 Estimates

Table 5.3 summarizes the estimation results for the FA and NFA model specifications. It presents the posterior mean and the 95% confidence interval for the estimated parameters. Besides this statistical information, additional information on the estimation results is presented in Figure 5.1 to 5.2, which plots the prior (in Grey) and posterior (in Black) distributions for some of the estimated parameters. The dotted line (in Black) in the figures is the mode value of the posterior distribution.
<table>
<thead>
<tr>
<th></th>
<th>Model with Fin. Accelerator</th>
<th>Model without Fin. Accelerator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>95% CI</td>
</tr>
<tr>
<td>$\Upsilon$</td>
<td>0.565</td>
<td>[0.471, 0.661]</td>
</tr>
<tr>
<td>$\Psi$</td>
<td>0.720</td>
<td>[0.443, 1.007]</td>
</tr>
<tr>
<td>$\eta$</td>
<td>0.465</td>
<td>[0.333, 0.576]</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>0.626</td>
<td>[0.497, 0.761]</td>
</tr>
<tr>
<td>$\theta_D$</td>
<td>0.716</td>
<td>[0.666, 0.766]</td>
</tr>
<tr>
<td>$\theta_F$</td>
<td>0.738</td>
<td>[0.691, 0.783]</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.607</td>
<td>[0.530, 0.685]</td>
</tr>
<tr>
<td>$\beta_\pi$</td>
<td>2.251</td>
<td>[1.990, 2.523]</td>
</tr>
<tr>
<td>$\Theta_y$</td>
<td>1.303</td>
<td>[1.002, 1.599]</td>
</tr>
<tr>
<td>$\mu_{y^*}$</td>
<td>0.881</td>
<td>[0.815, 0.948]</td>
</tr>
<tr>
<td>$\mu_{i^*}$</td>
<td>0.728</td>
<td>[0.675, 0.783]</td>
</tr>
<tr>
<td>$\mu_{\pi^*}$</td>
<td>0.904</td>
<td>[0.871, 0.938]</td>
</tr>
<tr>
<td>$\rho_{UIP}$</td>
<td>0.751</td>
<td>[0.638, 0.866]</td>
</tr>
<tr>
<td>$\rho_{LOPG}$</td>
<td>0.843</td>
<td>[0.797, 0.890]</td>
</tr>
<tr>
<td>$\rho_Y$</td>
<td>0.885</td>
<td>[0.822, 0.948]</td>
</tr>
<tr>
<td>$\sigma_{MP}$</td>
<td>0.012</td>
<td>[0.010, 0.014]</td>
</tr>
<tr>
<td>$\sigma_{y^*}$</td>
<td>0.008</td>
<td>[0.007, 0.009]</td>
</tr>
<tr>
<td>$\sigma_{i^*}$</td>
<td>0.016</td>
<td>[0.014, 0.018]</td>
</tr>
<tr>
<td>$\sigma_{\pi^*}$</td>
<td>0.008</td>
<td>[0.007, 0.010]</td>
</tr>
<tr>
<td>$\sigma_{UIP}$</td>
<td>0.020</td>
<td>[0.015, 0.024]</td>
</tr>
<tr>
<td>$\sigma_{LOPG}$</td>
<td>0.020</td>
<td>[0.015, 0.025]</td>
</tr>
<tr>
<td>$\sigma_Y$</td>
<td>0.013</td>
<td>[0.010, 0.016]</td>
</tr>
<tr>
<td>$\chi$</td>
<td>0.032</td>
<td>[0.010, 0.053]</td>
</tr>
</tbody>
</table>

LogL: -2403.56       LogL: -2422.44

143
Figure 5.1: Prior and Posterior Distributions: FA Model 1975Q1-2005Q2

\[\begin{align*}
\gamma &
\begin{array}{c}
\begin{array}{c}
\text{(a)} \\
\text{Prior}
\end{array}
\begin{array}{c}
\text{(b)} \\
\text{Posterior}
\end{array}
\end{array}
\end{align*}
\]
Figure 5.2: Prior and Posterior Distributions: NFA Model 1975Q1-2005Q2
Three interesting observations are evident from the figures depicting prior and posterior distribution of the estimated parameters. First, all the posterior distribution of the estimated parameters seems to be well behaved. Besides having a bell-shaped curve, they display another important feature of normal distribution - their posterior mode and mean are very close to each other. Second, in almost all parameters, their posterior distributions are less diffuse than their respective priors. Third, except for parameter \( \eta \), these prior and posterior distributions are generally well apart and do not overlap with each other. Hence, the three observations on the behaviour of posterior distributions of the estimated parameters suggest the data contains informative information to update the initial priors that we set in most of the model’s parameters.

The estimates of the structural parameters are also found to be plausible and generally comparable to the values found in the literature. This applies to both model specifications. Also, based on the 95% confidence interval of the estimated parameters, the results indicate that all estimated parameters are significantly different from zero. In a way, this outcome indicates that the simple open economy DSGE model presented in Section 5.1 is able to fit the data and represent the Malaysian economy reasonably well. Next, we analyze the point estimates of the structural parameters for the Malaysian economy in more detail.

Estimates for pricing behaviour parameters are comparable to those commonly found in the literature. Estimates for the degree of price indexation \( (\kappa) \) are centered around 0.6, suggesting a fairly high degree of inflation persistence in the Malaysian economy. The Calvo pricing parameters - \( \theta_D \) and \( \theta_F \) - are estimated to be between 0.7 to 0.8. This is very close to the standard value of 0.75 used in many calibration exercises in the DSGE literature (example Bernanke, Gertler, and Gilchrist (1999), Gali and Monacelli (2005), Gertler, Gilchrist, and Natalucci (2007)). The close estimated values for parameter \( \theta_D \) and \( \theta_F \) also indicate retailers of the home and foreign goods have almost the same behaviour in setting the retail price. Based on the estimates for these two parameters, the average duration of the price contracts for both types of goods is estimated to be around 4.3 quarters. This is very much in line with the estimated duration in the Philippines and Singapore reported by Ramayandi (2008).

Estimates of parameters describing household's preferences are mixed. The estimate for the degree of habit persistence \( (\Upsilon) \) of 0.6 is relatively low compared to the estimates of around 0.7-0.9 reported in Adolfson, Laséen, and Villani (2007) for the Euro
area, Kam, Lees, and Liu (Forthcoming) for Australia, Canada and New Zealand; Liu (2006) for New Zealand and Ramayandi (2008) for Indonesia, Thailand and Philippines. Estimates measuring the elasticity of substitution between domestic and foreign goods ($\eta$) are around 0.5-0.6. This is close to the values found in many of the open-economy DSGE literature, among others by Lubik and Schorfheide (2005), Justiniano and Preston (2006) and Adolfson, Laséen, and Villani (2007). The less than unitary estimate for $\eta$ indicates substitution between domestic and foreign goods is inelastic. This suggests consumption preferences in Malaysia are biased towards domestic produced goods. Meanwhile, estimates for the inverse elasticity of labour supply ($\Psi$) are centered around 0.7-1.0. Interestingly, these estimates are on the low side, compared to the values of 1.5 to 2 found in Kam, Lees, and Liu (Forthcoming) and Justiniano and Preston (2006) for Australia, Canada and New Zealand; Liu (2006) for New Zealand; and 1 to 4 found by Ramayandi (2008) in the ASEAN countries. The finding that the estimate of $\Psi$ is less than 1 indicates that the labour supply in Malaysia is elastic. This implies, in general, a one percentage change in wage will induce a more than proportional change in labour supply. This prediction is largely consistent with development in the Malaysian labour market during the estimation period. The large employment creation, particularly in the export-oriented manufacturing sector, and the subsequent increase in real wages during the post-1980 period were instrumental in reducing the unemployment level in Malaysia (page 20, Athukorala (2001)). Consequently, this induced a higher labour force participation from the Malaysian population. The rate of labour force participation in Malaysia increased consistently from around 60% in 1980, to over 67% in the post-1995 period. In addition, besides the increase of labour force from the native Malaysian population through the increase in participation rate, the large and consistent influx of immigrant workers into the country throughout the 1990s further expanded the pool of labour supply in the Malaysian economy. These developments could explain why the labour supply in Malaysia is found to be more elastic, particularly if compared to the other ASEAN countries as reported in Ramayandi (2008).

Another interesting observation about the above estimation results is the point estimate for the parameter measuring the elasticity of external finance premium ($\chi$). Surprisingly, the estimate for parameter $\chi$ is smaller than what we anticipated. Posterior

mean of 0.03 for \( \chi \) is much lower than the average risk-spread of 0.055 found in the Malaysian data. Having said that, the estimated value for \( \chi \) for the Malaysian economy is still higher than the calibrated value of 0.02 used by BGG (for the US economy) and very close to the value of 0.035 used in Devereux, Lane, and Xu (2006) and Gertler, Gilchrist, and Natalucci (2007) (for the case of Korea economy). In a way, this outcome is consistent with the fact that the Malaysian capital market is less developed than in the US.

Lastly, the estimated autoregressive coefficients for shocks - \( \rho_{UIP}, \rho_{LOPG}, \rho_Y \) - range between 0.7 to 0.9. The size of these parameters are plausible and suggest shocks that hit the economy are fairly persistent. Likewise, the estimated standard deviation of the shocks also have reasonable values.

5.3.1.1 BNM’s reaction function

Estimates for the HMT interest rate rule parameters are also fairly standard and provide a good description about the way monetary policy is conducted during the estimation period. In particular, the estimated BNM’s reaction function shows strong responses to both inflation and output gap, as well as the tendency for policy inertia. The estimate for \( \beta_\pi \) is found to be around 2.1-2.2 while \( \Theta_y \) is about 1.3-1.5. The estimate for \( \rho \) which measures the degree of interest rate smoothing is about 0.6.

An interesting observation from the above results is the fact that they are dissimilar to the results we found in Chapter 3. Recall that in Chapter 3, we represent BNM’s reaction function with the same HMT interest rate rule and the estimation exercise was conducted as a single equation. However, in this chapter, the same interest rate rule is estimated under a different estimation approach. As part of the equations in the DSGE model, the parameters of HMT interest rate rule are estimated simultaneously with other parameters in the system of equations. Interestingly, the use of a different estimation approach produces a different estimation results for the BNM’s reaction function. Comparing the results between the two approaches, we find the estimate for the feedback coefficient on inflation is much higher when the HMT rule is estimated as a system of equations. Estimates for \( \beta_\pi \) of around 2.1-2.2 generated in the DSGE model are twice the size of the estimate of the single equation estimation (\( \beta_\pi = 1.1 \) in Chapter 3). The higher estimate for \( \beta_\pi \) implies BNM responds much more forcefully
to inflation than what we conceived before. Similarly, the estimate for the interest rate smoothing parameter ($\rho$) of around 0.6 in this chapter is lower than the value of around 0.8 found in Chapter 3. This suggests BNM’s behaviour in setting the interest rate is less persistent than what we envisaged earlier. In contrast, estimates for BNM’s response to the output gap ($\Theta_y$) of between 1.3-1.5 is close to the value of 1.2 reported in Chapter 3.

The differences in the HMT parameter estimates between the two estimation approaches highlighted above, provide an important admonition about the use of estimated reaction functions as a tool to analyze BNM’s policy behaviour. Results of the estimated reaction function are influenced by the way the HMT interest rate rule is estimated. Obviously, different estimation results lead to different analysis and understanding about the subject matter. While both methods are equally useful in describing BNM’s reaction function - in revealing the variables that policymakers respond to - the differences in the parameter estimates of HMT rule provides different qualitative information about describing BNM’s policy behaviour. For example, the estimate for $\beta_\pi$ in the DSGE model is found to be twice the size of the estimate of the single equation, which leads us to deduce BNM responds much more forcefully to the inflation movement. Similarly, the difference in the estimate for $\rho$ gives a different description about the degree of interest rate smoothing that BNM practices when executing its policy action. Hence, a new question arises. Since they produce different results, which of these two approaches is better in producing the estimates of BNM’s reaction function?

We do not have a definitive answer to the above question. Instead of trying to argue and select which method is better in generating the estimates of BNM’s reaction function, we take the view that the results of both methods should not be looked at in isolation. Both methods have their own strengths and weaknesses. Estimation of the reaction function as a single equation as conducted in Chapter 3, has the advantage of simplicity, ease to generate and the ability to fit the data very well. But, as is generally known, the simplicity of a single equation estimation raises fundamental questions about the validity of assuming the variables that interest rates rule respond to, are exogenous. In contrast, while estimation of the reaction function as part of the system of equations like in the DSGE model overcomes the fundamental question about exogeneity of the variables included in the HMT interest rate rule, the estimation of a system of equations has other fundamental questions to answer. Not only is the
estimation result for the system of equations more complex and difficult to generate, but also the possible invalid cross equation restrictions in them can cause other problems like a more severe misspecification and identification problem, which can also distort the estimation outcomes. Due to these reasons, finding the absolute answer on which of the estimation methods produce a better outcome is not easy. Thus, our estimation results of BNM’s reaction function as reported in Chapter 3 and this chapter, should be used to complement each other as a tool to analyze BNM’s behaviour in formulation of monetary policy in Malaysia.

In a way, the stand that we take on this issue is consistent with the suggestion made in Fukac and Pagan (2008). Given uncertainty about the model, they advocate looking at the estimation results of the single equation methods in combination with the estimation results generated from the DSGE model. According to Fukac and Pagan, the single equation and system measures of fits were complements, and not substitutes. Thus, it is wise to look at the building blocks as well as the complete model.

5.3.2 Comparing estimation results with the other DSGE model for Malaysia

Interestingly, except for parameter $\Psi$, our estimations of the deep parameters of the Malaysian economy are not much different to the estimates of those reported in Ramayandi (2008). As stated before, Ramayandi estimated a DSGE model for Malaysia by applying Gali-Monacelli’s open economy DSGE model without capital. Ramayandi used the ML estimation method and covered a shorter sample period of 1991-2004. Since this is the only known study that attempts to estimate the deep parameters for the Malaysian economy, the similarities of ours and Ramayandi’s results are quite reassuring. Comparing the results between the two studies also highlight four interesting observations about the estimation of the DSGE model involving Malaysian data.

First, the introduction of capital into the original Gali-Monacelli’s open economy DSGE model as used in Ramayandi (2008), does not change significantly the estimation outcome of the deep parameters. As stated before, the main extension of our DSGE model is the introduction of capital into the original Gali-Monacelli’s open economy DSGE model. This extension also allows the financial accelerator mechanism to
operate. The similarities between ours and Ramayandi’s estimates of the deep parameters suggest this extension is not very crucial in influencing the estimation outcome. While this extension may enrich the models structure, it does not lead to the estimates of the deep parameters behaving differently. In other words, this outcome suggests the absence of capital from the the original Gali-Monacelli’s open economy DSGE model does not make the model seriously misspecified to the extent that it affects the outcome of parameter estimates. To further validate this point, we try to replicate Ramayandi’s estimation results by re-estimating our DSGE model with the same sample period as used in Ramayandi (2008). The results are presented in Table 5.6 (placed in the Appendix). Unsurprisingly, except for parameter $\Psi$, results for most of the estimated parameters from our DSGE model using the Bayesian method for the 1991Q1-2004Q4 period, are very close to the original results reported by Ramayandi. This outcome suggests both models are equally capable of representing Malaysia’s economy and fit the data fairly well.

Another interesting observation from this exercise is the difference in the point estimate for parameter $\Psi$. Based on our estimation results, the introduction of capital into the DSGE model produces a lower estimate for the parameter on inverse elasticity of labour supply ($\Psi$). In our extended open economy DSGE model for Malaysia, estimates for this parameter $\Psi$ decline to around 0.7-1.0, compared to the estimate of around 2 reported by Ramayandi. A lower value for parameter $\Psi$ means the labour supply in our DSGE model is more elastic than what is estimated in Ramayandi’s model. There is a theoretical explanation to this lower estimate for $\Psi$. Intuitively, moving away from a single into a dual factor inputs, allows the substitution effects to operate in the model. In equilibrium, substitution effects cause larger changes in the equilibrium wage and this triggers a bigger adjustment in the quantity of labour supply to achieve market clearing. This mechanism may explain why labour supply is found to be more elastic in our DSGE model with capital, compared with Ramayandi’s estimation results for Malaysia and ASEAN countries.

Third, the difference in the sample period does not significantly change the estimation outcome. The fact that ours and Ramayandi’s estimation results are generated by a different sample period, suggest estimates of the deep parameter in our DSGE model for Malaysia are not very sensitive to the choice of estimation sample. This outcome also suggests most of the deep parameters of the Malaysian economy could be constant over time. As will be seen and discussed in Chapter 6, estimates for the deep parameters
for Malaysia for the sub-sample periods are also found to be fairly constant across the
different sample periods.

The last interesting observation on the similarities of ours and Ramayandi’s estimation
results is regarding the performance of the estimation method. As mentioned
by Fernandez-Villaverde and Rubio-Ramirez (2004), Bayesian estimation has a strong
small sample behaviour which outperforms the results of the ML approach. Based
on this knowledge and given the relatively short sample period used by Ramayandi’s
estimation, we expect the estimation results from the Bayesian method, would be
different from those generated by Ramayandi’s ML estimates. However, this turns
out to be not really the case. As presented in Table 5.6, both estimation methods
produce an almost similar outcome. This suggests, that for the size of the sample pe-
riod that we are dealing with, the outcome of the Maximum Likelihood approach in
estimating the DSGE model could be as good as the Bayesian method.

5.4 Comparing Results between FA and NFA DSGE
Models

As stated earlier, one of the objectives of this chapter is to investigate the role of
the financial accelerator in affecting the empirical properties of our model. In doing
so, we estimate the open economy DSGE model with two model specifications - with
and without a financial accelerator mechanism. As credit frictions are an important
feature in a developing economy, the outcome of this investigation will indicate the
effects of leaving out the financial accelerator mechanism in the standard open economy
DSGE model on the estimation of the structural parameters in Malaysia. Hence, the
discussion in this section starts with a comparison on the point estimates of these two
model specifications. Then, dynamic features of the estimated model using the impulse
response function and variance decomposition are analyzed. Lastly, by calculating the
Bayes factor, it also indicates which of these two model specifications fit the Malaysian
data better.
5.4.1 Parameter estimates

A general observation on the estimation results indicates that the point estimates for most of the structural parameters in the FA and NFA model specifications are quite similar to each other. However, small differences occur to the parameter estimates for the inverse elasticity of labour supply ($\Psi$). Interestingly, the FA model produces a slightly lower estimate of 0.7 (1.0 in NFA) for this parameter. As we explained in sub-section 5.3.2, this suggests in the presence of the financial accelerator mechanism, household’s labour supply is more elastic to the changes in the real wages.

Another interesting outcome is the observation that the use of different model specifications does not affect the behaviour of BNM in conducting monetary policy. By referring to results in Table 5.3, it is clear that the estimated parameters of the HMT rule in the FA and NFA model are very similar to each other. This observation suggests that the presence of the financial accelerator mechanism does not alter the way BNM sets the interest rates. This outcome is quite surprising. As stressed by BGG, financial friction introduces additional rigidities to the real sector, particularly affecting the ability of entrepreneurs to adjust the investment level. The presence of a financial accelerator contributes to the propagation mechanism, which effectively amplifies the effect of shocks to the movement of output and inflation. Thus, policymakers need to respond more aggressively to changes in these variables than they would if there were no financial accelerator. Due to this factor, we would expect BNM’s behaviour in setting interest rates to be different in the FA and NFA model. After taking into account the propagation mechanism, the presence of a financial accelerator mechanism in the FA model is expected to produce a more forceful monetary policy action from the policymakers - most probably in the form of higher parameter estimates for $\beta_\pi$ and $\Theta_y$ in the FA model compared to the NFA model. This turns out not to be the case.

The effect of the financial accelerator as the propagation mechanism can be clearly demonstrated by comparing the impulse response function and variance decomposition generated by the FA and NFA model specifications. This will be discussed next.
5.4.2 Impulse Response Function and Variance Decomposition

As mentioned before, the use of FA and NFA model specification does not much affect the estimation results of the structural parameters. However, the presence of credit frictions affects the dynamic response of the estimated models to shocks. The difference in the model dynamics is reflected in the comparison of the impulse response function between the FA and NFA model. As can be seen in Figure 5.3, a positive monetary policy shocks causes nominal interest rates to increase. In the FA and NFA model, interest rates rise in almost the same magnitude. However, as also found in BGG, the same interest rate rise leads to different responses to other variables in the model. The impulse response functions of variables in the FA model reacted with a bigger magnitude than those in the NFA model. This is consistent with the BGG’s proposition that the presence of a financial accelerator mechanism amplifies the effect of monetary policy shocks.

The clearest evidence to indicate the operation of the financial accelerator mechanism can be seen on the response of investment to the monetary policy shocks. As presented in Table 5.4, the contribution of monetary policy shocks to the dynamics of invest-

Figure 5.3: FA vs. NFA Specification: Comparison of IRF 1975Q1-2005Q2

Monetary Policy Shocks
Table 5.4: Comparison of Variance Decomposition: FA vs. NFA model (in %)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Model</th>
<th>Shocks (1 s.d.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\varepsilon_t^{UIP}$</td>
</tr>
<tr>
<td>Output</td>
<td>FA</td>
<td>12.7</td>
</tr>
<tr>
<td></td>
<td>NFA</td>
<td>22.8</td>
</tr>
<tr>
<td>Inflation</td>
<td>FA</td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td>NFA</td>
<td>6.8</td>
</tr>
<tr>
<td>Interest Rates</td>
<td>FA</td>
<td>15.3</td>
</tr>
<tr>
<td></td>
<td>NFA</td>
<td>17.1</td>
</tr>
<tr>
<td>RER</td>
<td>FA</td>
<td>32.8</td>
</tr>
<tr>
<td></td>
<td>NFA</td>
<td>33.0</td>
</tr>
<tr>
<td>Investment</td>
<td>FA</td>
<td>8.2</td>
</tr>
<tr>
<td></td>
<td>NFA</td>
<td>8.0</td>
</tr>
<tr>
<td>Net Worth</td>
<td>FA</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>NFA</td>
<td>10.0</td>
</tr>
</tbody>
</table>

The monetary policy shock is bigger in the FA than in the NFA model. Also note that the monetary policy shock is the biggest contributor to the dynamics of the entrepreneur’s net-worth. The financial accelerator mechanism takes effect when monetary policy shocks affect the entrepreneur’s net-worth position through the rise in the borrowing cost. As entrepreneurs face a credit constraint, a fall in their net-worth position reduces their borrowing ability. Hence, as can be seen in the impulse response function following monetary policy shocks, investment activities decline a lot more in the FA model than when the financial accelerator is not in operation.

To further illustrate the role of the financial accelerator in propagating the effect of other shocks, Figures 5.4 to 5.6 (placed in the Appendix) put together the impulse response function of the key variables to six other shocks - LOPG, UIP, technology, foreign output, foreign inflation and foreign interest rates. Like the case for the monetary policy shock, in general, most of the these variables respond more forcefully to other shocks when the financial accelerator is in operation. This outcome is consistent with the proposition made by BGG that endogenous developments in credit markets work to propagate and amplify shocks to the economy.
5.4.3 Model Fit

Table 5.5 presents standard deviations and autocorrelations for the data and those implied by the model. The model implied statistics are constructed using the parameter estimates reported earlier. The model is then used to generate 10,000 series of simulated data to compute the moment of interest. By comparing the actual and the model’s moments for interest rates, inflation and output, it can be seen that both model specifications perform reasonably well in replicating the features of the Malaysian data. However, the model is not able to mimic the RER data. Both model specifications over-predict the volatility and persistence of the real exchange rate. These limitations could be attributed to the inadequacy of the simple risk-adjusted UIP condition that represents the real exchange rate movement.

Another important characteristics about the fitting performance of the estimated model with the FA and NFA specifications, is the differences in the value of the simulated moments. Standard deviations for the simulated data in the FA model are higher than those produced by the NFA model, indicating that movement of variables in the model in the presence of financial friction is more volatile than in the model without this feature. Furthermore, simulated data from the FA model displays a higher degree of persistence. The different degree of volatility and persistence between the two model specifications are consistent with the assertion made by BGG on the effect of the financial accelerator mechanism to the model’s properties. As stressed by BGG, the financial accelerator mechanism amplifies the effect of exogenous (like monetary and

<table>
<thead>
<tr>
<th>Standard Deviation</th>
<th>Actual</th>
<th>DSGE Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FA</td>
<td>NFA</td>
</tr>
<tr>
<td>Interest Rates</td>
<td>0.025</td>
<td>0.031 0.023</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.020</td>
<td>0.027 0.022</td>
</tr>
<tr>
<td>RER</td>
<td>0.033</td>
<td>0.111 0.101</td>
</tr>
<tr>
<td>Output</td>
<td>0.029</td>
<td>0.038 0.035</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Autocorrelation Coefficients</th>
<th>Actual</th>
<th>DSGE Model</th>
</tr>
</thead>
<tbody>
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<td>FA</td>
<td>NFA</td>
</tr>
<tr>
<td>Interest Rates</td>
<td>0.930</td>
<td>0.904 0.835</td>
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<tr>
<td>Inflation</td>
<td>0.890</td>
<td>0.888 0.868</td>
</tr>
<tr>
<td>RER</td>
<td>0.350</td>
<td>0.725 0.668</td>
</tr>
<tr>
<td>Output</td>
<td>0.670</td>
<td>0.696 0.492</td>
</tr>
</tbody>
</table>
technology) shocks that hit the economy. Consequently, as displayed in the impulse response function in the previous section, this amplification contributes to higher volatility in the variables like investment and output. Furthermore, the financial accelerator serves as additional friction in the model and acts to reduce the ability of some variables (like investment and net-worth) to adjust more instantaneously. The end result from the adjustment delay is the increase in persistence of the key variables in the FA model.

5.4.4 Model Selection

In choosing the two model specifications that best fit the Malaysian data, information from the model’s log marginal likelihood is used. The log marginal likelihood for each model was generated using the Modified Harmonic Mean Estimator and is reported in the last row of Table 5.3. The results indicate that the model with the financial accelerator performs better than the alternative model in fitting the data. The difference between the log marginal likelihood of the two models, is 18.9. Hence, based on the scale suggested by Kass and Raftery (1995), there is very strong evidence that the data favours the FA model against the NFA model.

The outcome that the data strongly supports the inclusion of the financial accelerator mechanism in the DSGE model for Malaysia is expected. As seen from the results in Table 5.3, parameter $\chi$ is estimated away from zero. The non-zero estimate for the parameter measuring the elasticity of external finance premium supports the notion that credit friction is one of the important features for a developing economy like Malaysia. The outcome that the DSGE model with the financial accelerator performs better in fitting the Malaysian data is also consistent with the proposition made by Razì (1998) and Tang (2006) about the importance of the credit channel as one of the monetary transmission channels in Malaysia. Due to this reason, estimation results using the DSGE model with a financial accelerator is taken as the better representation of the Malaysian economy and will be used in the subsequent analysis of this thesis.
5.5 Conclusion

In this chapter, we employ the DSGE modelling framework to the case of the Malaysian economy. The model is developed based on the DSGE model of Gali and Monacelli (2005) for a small open economy, but modified to include the effect of a financial accelerator mechanism along the line of Bernanke, Gertler, and Gilchrist (1999). Using a Bayesian methodology, we estimate the model for the 1975Q1-2005Q2 period. We find estimates of the structural parameters for the Malaysian economy to be plausible and generally comparable to the values reported in the literature.

The estimation exercises also reveal a few interesting outcomes. We find estimates of BNM's reaction function in this chapter are fairly different to the results that we reported in Chapter 3. This finding provides an important caveat about analyzing BNM's policy behaviour based on its estimated reaction function. Results of estimated BNM's reaction function are influenced by the way the HMT interest rate rule is estimated. To investigate the impact of financial frictions on the empirical properties of our DSGE model, we also estimate the model with two specifications - with and without a financial accelerator mechanism. The results indicate estimates for most of the structural parameters between the two model specifications are very similar to each other. However, results of posterior odds ratio comparing both models indicate the model with a financial accelerator performs better than the alternative model in fitting the Malaysian data. This reaffirms the notion that credit friction is one of the important features for a developing economy like Malaysia. Analysis using the impulse-response functions and variance decomposition between the two model specifications demonstrate how the operation of a financial accelerator mechanism amplifies and propagates the effects of transitory shocks to economic activities.

In the next chapter, we extend the discussions about estimation results that we present in this chapter, to investigate two issues regarding the estimation of DSGE model. First, is about the stability of structural parameters over time. For this, like in the previous chapters, estimations using sub-sample periods will be conducted. In doing so, we analyze the estimates of the model's parameters for three sub-sample periods - 1975Q1-1986Q4, 1987Q1-1998Q2 and 1998Q3-2005Q2. Comparing the estimation outcomes for sub-sample periods will indicate whether the structural parameters for a developing economy like Malaysia are stable over time. Second, is regarding the
possible identification problems faced by the estimated parameters in the DSGE model. Identification problem is one of unresolved issues surrounding the estimation of the DSGE model. Moreover, in the case where the DSGE models are estimated using Bayesian methods, potential identification problems largely remain hidden due to the use of tight priors. As a result, it is often unclear to what extent the reported estimates reflect information in the data instead of subjective beliefs or other considerations reflected in the choice of prior distribution for the parameters. On this regard, in the next chapter, we will focus on detecting the possible identification problem in our Bayesian estimation of the DSGE model for Malaysia. The outcome of this investigation reveals whether there are any benefits from estimating instead of calibrating the structural parameters of the DSGE model that we present in this chapter.
5.6 Appendix

Steady-state conditions

It is assumed that in the steady-state, the following conditions holds;

- All prices equal unity, i.e. $\bar{P} = \bar{P}_H = \bar{P}_F = \bar{P}^* = 1$ and all corresponding inflation rates equal zero, i.e. $\bar{\pi} = \bar{\pi}_H = \bar{\pi}_F = \bar{\pi}^* = 0$.

- Complete exchange rate pass-through, with law of one price gap (LOPG), $\text{lopg} = 0$. Thus, $\bar{P}_F = S \bar{P}^*$. Then, the nominal exchange rate in the steady-state is $\bar{S} \equiv \frac{\bar{P}_F}{\bar{P}^*} = 1$. Also, $\text{REER} = 1$.

- Productivity factor, $\bar{A} = 1$.

- Home good real marginal cost, $\bar{P}^w_H \equiv \bar{MC}_H = \frac{1}{\bar{\mu}} = \frac{\epsilon - 1}{\bar{\epsilon}}$.

- Domestic deposit and holding of foreign bonds is zero, $\bar{D} = \bar{B} = 0$. With this assumption, the net foreign asset in the steady-state is also zero, $\bar{Z} \equiv \frac{\bar{S} \bar{B}}{\bar{P}} = 0$.

- From household’s Euler equation, the gross domestic interest rate in the steady state, is $\frac{1}{R} = \beta$.

- The link between level of investment and capital, is $\text{TINV} = \delta \bar{K}$.

- From entrepreneur optimality condition, $\bar{R}_K = \left( \frac{\bar{\nu}}{\bar{Q} R} \right)^{-\chi} \bar{R}$. Then, by using $\frac{1}{R} = \beta$, the return on capital in the steady-state, is $\bar{R}_K = \left( \frac{\bar{\nu}}{\bar{R}} \right)^{-\chi} \frac{1}{\beta}$.

- The relationship between return on capital and capital rent is derived from $\bar{R}_K = \frac{[\bar{R}_G] + (1 - \delta) \bar{Q}}{\bar{Q}}$. Then by using $\bar{R}_K = \left( \frac{\bar{\nu}}{\bar{R}} \right)^{-\chi} \frac{1}{\beta}$ and $\bar{Q} = 1$, the rental on capital in the steady-state is $\bar{R}_G = \left( \frac{\bar{\nu}}{\bar{R}} \right)^{-\chi} \frac{1}{\beta} - (1 - \delta)$.

- The output-capital ratio is derived from $\bar{R}_G = \alpha \bar{\nu} \bar{K} \bar{P}_H \bar{P}_u \bar{P}$ . Then use $\bar{P}^w_H \equiv \bar{MC}_H = \frac{1}{\bar{\mu}}$, $\bar{P} = \bar{P}_H = 1$, the output capital ratio in the steady-state is $\frac{\bar{\nu} \bar{K}}{\bar{R}_G} = \bar{R}_G \bar{K}$.

- Entrepreneur’s wages to capital ratio is $\frac{\bar{W}_E}{\bar{K}} = (1 - \alpha) (1 - \Omega) \bar{R}_G \bar{K}$.

- Investment to output ratio, is $\frac{\text{TINV}}{\bar{Y}_H} = \delta \frac{\bar{K}}{\bar{Y}_H}$.

- Consumption to output ratio, is $\frac{\bar{C}}{\bar{Y}_H} = 1 - \frac{\text{TINV}}{\bar{Y}_H}$.
Table 5.6: Estimated DSGE model for Malaysia: Comparison with Ramayandi (2008)
Sample Period: 1991Q1-2004Q4

<table>
<thead>
<tr>
<th>Parameter</th>
<th>FA Model</th>
<th>NFA Model</th>
<th>Ramayandi (2008)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
</tr>
<tr>
<td>$\Upsilon$</td>
<td>0.5484</td>
<td>0.1869</td>
<td>0.5194</td>
</tr>
<tr>
<td>$\Psi$</td>
<td>0.8528</td>
<td>0.2332</td>
<td>1.1956</td>
</tr>
<tr>
<td>$\eta$</td>
<td>0.5752</td>
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<tr>
<td>$\kappa$</td>
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<td>0.0919</td>
<td>0.6467</td>
</tr>
<tr>
<td>$\theta_D$</td>
<td>0.8111</td>
<td>0.0298</td>
<td>0.8524</td>
</tr>
<tr>
<td>$\theta_F$</td>
<td>0.8368</td>
<td>0.0260</td>
<td>0.8652</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.3750</td>
<td>0.1042</td>
<td>0.4446</td>
</tr>
<tr>
<td>$\beta_\pi$</td>
<td>2.1617</td>
<td>0.1647</td>
<td>2.1379</td>
</tr>
<tr>
<td>$\Theta_y$</td>
<td>0.9648</td>
<td>0.1527</td>
<td>1.0580</td>
</tr>
<tr>
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<td>0.8244</td>
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<td>0.8333</td>
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<td>$\mu_\pi^*$</td>
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<td>$\rho_{UIP}$</td>
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<td>0.0734</td>
<td>0.7332</td>
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<td>$\rho_{LOPG}$</td>
<td>0.8422</td>
<td>0.0430</td>
<td>0.8043</td>
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<td>$\rho_Y$</td>
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<td>$\sigma_{MP}$</td>
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<td>0.0008</td>
<td>0.0088</td>
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<td>$\sigma_y^*$</td>
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<td>0.0006</td>
<td>0.0069</td>
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<tr>
<td>$\sigma_i^*$</td>
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<td>$\sigma_\pi^*$</td>
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<td>0.0072</td>
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<td>0.0021</td>
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</tr>
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<td>$\sigma_{LOPG}$</td>
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</tr>
<tr>
<td>$\sigma_Y$</td>
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</tr>
<tr>
<td>$\chi$</td>
<td>0.0566</td>
<td>0.0179</td>
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</tr>
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</table>

LogL: -1197.62   LogL: -1204.66   LogL: Not Available

* Note: In Ramayandi (2008), parameters for the HMT rule and foreign block were not estimated as part of the DSGE model. Parameters for HMT rule are estimated as a single equation, while parameter for the foreign block come from his VAR(1) estimates. Since these estimates were not estimated as part of the DSGE system, they are not reported here.
Figure 5.4: FA vs. NFA Specification: Comparison of IRF 1975Q1-2005Q2 (continue)

Technology Shocks

Output

Inflation

Interest Rates

REER

Consumption

Investment

Marginal Cost

Labour

Capital

UIP Shocks

Output

Inflation

Interest Rates

REER

Consumption

Investment

Marginal Cost

Labour

Capital
Figure 5.5: FA vs. NFA Specification: Comparison of IRF 1975Q1-2005Q2 (continue)

LOPG Shocks

Output

FA
NFA

Inflation

Foreign Inflation Shocks

Output

fa
NFA

Inflation

Interest Rates

Consumption

Labour

Capital

Investment

Marginal Cost

Labour

Capital

163
Figure 5.6: FA vs. NFA Specification: Comparison of IRF 1975Q1-2005Q2 (continue)

Foreign Output Shocks

Foreign Interest Rates Shocks

164
Chapter 6

An Estimated DSGE Model of the Malaysian Economy: Sub-sample Periods and Possible Identification Problems

This chapter extends the discussion about the estimation of the DSGE model of the Malaysian economy from Chapter 5, by looking at two on-going issues surrounding the estimation of the model. The first issue concerns stability of parameters. How stable over time are the so-called “structural parameters” of DSGE models? If in the previous chapters we find empirical evidence suggesting the conduct of monetary policy evolves over time, it will be equally interesting to see whether the estimates of structural parameters for the Malaysian economy follow the same suit. The second issue is related to the identification problems. Are the estimated parameters of our DSGE model adequately identified? Since identification problems are likely to cause the estimated parameters to be biased and inaccurate, it is important to know how well the structural parameters that we estimated pick-up the information from the data. In particular, in the case where the DSGE models are estimated using Bayesian methods, potential identification problems largely remain hidden due to the use of tight priors. As a result, it is often unclear to what extent the reported estimates reflect information in the data instead of subjective beliefs or other considerations reflected in the choice of prior distribution for the parameters.
To investigate the first issue, the DSGE model presented in Chapter 5 will be re-estimated using sub-sample periods. In doing so, we analyze the estimates of the model's parameters for three sub-sample periods - 1975Q1-1986Q4, 1987Q1-1998Q2 and 1998Q3-2005Q2. Comparing the estimation results for sub-sample periods will indicate whether the structural parameters for a developing economy like Malaysia are stable over time. On the second issue, we conduct two analysis to detect the possible identification problem in our estimated DSGE model. First, we examine carefully properties of prior and posterior distributions of the estimated parameters. Then, we complement this analysis by conducting another diagnostic procedure. We look at the robustness of the estimated parameters with a looser prior. The outcome of this investigation reveals the extent of identification problems that our estimated DSGE model faces.

We divide this chapter into three parts. Section 6.1 discusses the estimation results for the sub-sample periods and Section 6.2 investigates the possible identification problems faced by the structural parameters that we estimate. The last section provides a brief conclusion.

6.1 Estimation Results for Sub-sample Period

This section explores the behaviour of the estimated parameters of a DSGE model of the Malaysian economy using the sub-sample period. The main objective of estimating the model using the sub-sample period, is to investigate the stability of the estimated structural parameters across a different time period. Fernández-Villaverde and Rubio-Ramírez (2007) raise this issue, by questioning how stable over time are the so-called "structural parameters" of the DSGE models. In their model estimated using the US data, they allow for parameter drifting and rational expectations of the agents with respect to this drift. Using this approach, they found strong evidence to indicate that the estimated parameters for the monetary reaction functions and parameters characterizing the pricing behavior of firms and households are not stable over time. Their results raises doubts on the assumption that the DSGE parameters are constant over the period.

The estimation exercise in this section tries to shed some lights on the above issue in the context of estimating the DSGE model for a developing economy like Malaysia.
However, in this exercise, we do not introduce a dedicated parameter drifting mechanism like the approach used in Fernández-Villaverde and Rubio-Ramírez (2007). Instead, investigation about the stability properties of structural parameters for the Malaysian economy is only limited to run the estimation using different sub-sample periods and see how the estimated parameters behave across different estimation periods. Due to this limitation, the results of this investigation should be taken as preliminary. A more systematic approach like the one used by Fernández-Villaverde and Rubio-Ramírez (2007) to address this issue, is an interesting extension for future research.

For this purpose, we re-estimate the DSGE model with a financial accelerator that we presented in Chapter 5. The re-estimation of the model with the Bayesian method is conducted using the same prior specifications as the full sample period (see Table 5.2 in Chapter 5). The estimation results for all three sub-periods - 1975Q1-1986Q4, 1987Q1-1998Q2 and 1998Q3-2005Q2 - are presented in Table 6.1. Like before, besides this statistical information, Figure 6.1 and 6.2 provides the plots of the prior (in Grey) and posterior (in Black) distributions of the estimated parameters. The dotted line (in Black) in the figures is the mode value of the posterior distribution.

6.1.1 Estimates

General observation on Table 6.1 indicates that estimates for most of the structural parameters are fairly constant across different sub-sample periods. The findings that the point estimates for most of these parameters are relatively constant across different sample periods highlight one interesting feature about the behaviour of the deep parameters for the Malaysian economy. In general, they imply that most of the deep parameters are not affected by the transformation of the Malaysian economy in the past 30 years.

While the estimates for most of the structural parameters are relatively constant, small changes are seen on the point estimates for the autoregressive coefficients $\rho_{LOPG}$ and $\rho_Y$ across different sub-sample periods. Estimates for $\rho_{LOPG}$ which are fairly stable at around 0.8 for the sub-sample periods prior to 1998Q3, decreases to around 0.5 when the fixed exchange rate regime was in place. This suggests the LOPG shock is less persistent
Table 6.1: Posterior Distributions: FA Model for Sub-sample Periods

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>95% CI</td>
<td>Mean</td>
</tr>
<tr>
<td>Γ</td>
<td>0.506 [0.420 , 0.592]</td>
<td>0.485 [0.398 , 0.571]</td>
<td>0.488 [0.408 , 0.571]</td>
</tr>
<tr>
<td>Ψ</td>
<td>1.092 [0.677 , 1.509]</td>
<td>1.052 [0.578 , 1.565]</td>
<td>1.062 [0.606 , 1.790]</td>
</tr>
<tr>
<td>η</td>
<td>0.429 [0.311 , 0.555]</td>
<td>0.640 [0.412 , 0.898]</td>
<td>0.570 [0.379 , 0.763]</td>
</tr>
<tr>
<td>κ</td>
<td>0.637 [0.502 , 0.770]</td>
<td>0.563 [0.367 , 0.686]</td>
<td>0.641 [0.507 , 0.784]</td>
</tr>
<tr>
<td>θD</td>
<td>0.689 [0.628 , 0.752]</td>
<td>0.809 [0.754 , 0.876]</td>
<td>0.844 [0.798 , 0.91]</td>
</tr>
<tr>
<td>θF</td>
<td>0.704 [0.644 , 0.765]</td>
<td>0.829 [0.783 , 0.886]</td>
<td>0.827 [0.747 , 0.909]</td>
</tr>
<tr>
<td>ρ</td>
<td>0.505 [0.372 , 0.642]</td>
<td>0.554 [0.405 , 0.734]</td>
<td>0.477 [0.230 , 0.723]</td>
</tr>
<tr>
<td>βπ</td>
<td>1.818 [1.565 , 2.085]</td>
<td>1.721 [0.841 , 2.259]</td>
<td>2.039 [1.647 , 2.453]</td>
</tr>
<tr>
<td>Θy</td>
<td>0.700 [0.381 , 1.013]</td>
<td>1.238 [0.858 , 1.691]</td>
<td>0.816 [0.395 , 1.248]</td>
</tr>
<tr>
<td>μγ*</td>
<td>0.853 [0.753 , 0.957]</td>
<td>0.804 [0.659 , 0.936]</td>
<td>0.738 [0.549 , 0.936]</td>
</tr>
<tr>
<td>μ*</td>
<td>0.542 [0.418 , 0.665]</td>
<td>0.824 [0.737 , 0.915]</td>
<td>0.722 [0.584 , 0.868]</td>
</tr>
<tr>
<td>μπ*</td>
<td>0.869 [0.805 , 0.937]</td>
<td>0.822 [0.713 , 0.936]</td>
<td>0.558 [0.272 , 0.842]</td>
</tr>
<tr>
<td>ρUIP</td>
<td>0.694 [0.487 , 0.904]</td>
<td>0.785 [0.656 , 0.921]</td>
<td>0.706 [0.529 , 0.867]</td>
</tr>
<tr>
<td>ρLOPG</td>
<td>0.870 [0.809 , 0.934]</td>
<td>0.795 [0.683 , 0.889]</td>
<td>0.479 [0.182 , 0.875]</td>
</tr>
<tr>
<td>ρY</td>
<td>0.851 [0.747 , 0.963]</td>
<td>0.571 [0.058 , 0.929]</td>
<td>0.853 [0.620 , 0.993]</td>
</tr>
<tr>
<td>σMP</td>
<td>0.017 [0.013 , 0.021]</td>
<td>0.009 [0.007 , 0.011]</td>
<td>0.010 [0.007 , 0.012]</td>
</tr>
<tr>
<td>σγ*</td>
<td>0.011 [0.009 , 0.013]</td>
<td>0.007 [0.006 , 0.009]</td>
<td>0.009 [0.007 , 0.011]</td>
</tr>
<tr>
<td>σ*</td>
<td>0.025 [0.020 , 0.029]</td>
<td>0.008 [0.007 , 0.010]</td>
<td>0.011 [0.008 , 0.013]</td>
</tr>
<tr>
<td>σπ*</td>
<td>0.011 [0.009 , 0.014]</td>
<td>0.008 [0.006 , 0.009]</td>
<td>0.009 [0.007 , 0.011]</td>
</tr>
<tr>
<td>σUIP</td>
<td>0.024 [0.014 , 0.033]</td>
<td>0.014 [0.010 , 0.018]</td>
<td>0.015 [0.010 , 0.021]</td>
</tr>
<tr>
<td>σLOPG</td>
<td>0.022 [0.015 , 0.029]</td>
<td>0.018 [0.011 , 0.024]</td>
<td>0.074 [0.044 , 0.103]</td>
</tr>
<tr>
<td>σY</td>
<td>0.014 [0.010 , 0.018]</td>
<td>0.034 [0.010 , 0.074]</td>
<td>0.019 [0.011 , 0.026]</td>
</tr>
<tr>
<td>χ</td>
<td>0.040 [0.015 , 0.064]</td>
<td>0.050 [0.024 , 0.077]</td>
<td>0.045 [0.020 , 0.068]</td>
</tr>
</tbody>
</table>

LogL: -823.67  LogL: -951.30  LogL: -589.22
Figure 6.1: Prior and Posterior Distributions: Sub-Sample Period

(a) 1975Q1-1986Q4

(b) 1987Q1-1998Q2
under the fixed exchange rate regime environment. Similarly, compared to the 1975-1986 period, estimates for $\rho_Y$ are lower in the 1987Q1-1998Q2 period, suggesting that the technology shock was less persistent during the era when the Malaysian economy was rapidly expanding.

One interesting feature about the estimation results for the sub-sample periods is that the estimates of the model parameters are less precise than what has been produced by the estimation exercise using the full sample period. This is shown by the larger confidence interval of the parameter estimates. By comparing the 95% confidence interval of the estimated parameters for the full sample (see Table 5.3 in Chapter 5) and those from the sub-sample periods (Table 6.1) we can see that the 95% confidence interval in the latter are generally wider than the former. For example, confidence interval of parameter $\eta$ for the full sample period stands at [0.33, 0.58]. This interval widens to [0.41, 0.90] for 1987Q1-1998Q2 and [0.38, 0.76] for 1998Q3-2005Q2. The same outcome is also observed on the estimates of other structural parameters.
Likewise, estimates for $\rho_{LOPG}$ and $\rho_Y$ in the sub-sample periods are also generated with less accuracy. Confidence interval for $\rho_{LOPG}$ increases steadily from [0.81, 0.93] for 1975Q1-1986Q4, to [0.68, 0.89] for 1987Q1-1998Q2 and further to [0.18, 0.88] for 1998Q3-2005Q2. Similarly, the confidence interval for $\rho_Y$ widens sharply from [0.75, 0.96] for 1975Q1-1986Q4 to [0.06, 0.93] for 1987Q1-1998Q2, before it narrows to [0.62, 0.99] for 1998Q3-2005Q2. Doubts on the precision of the estimates for $\rho_Y$ is compounded by looking at the shape of its posterior distribution. From Figure 6.1(b), it is found that the posterior distribution for $\rho_Y$ for the 1987Q1-1998Q2 has twin peaks - one at a value about 0.3 and another at around 0.8. This could be the reason why its posterior mean for this period settles at a lower value of around 0.6, which is about the mid point between the values of the two peaks.

In a way, reduction in accuracy for the estimation results using the sub-sample periods is expected. Compared to the estimations results for the full sample period, results for the sub-sample periods are generated with a shorter number of observations. Obviously, with a less amount of information used to generate them, makes it more difficult to estimate the parameters. Thus, the increase in uncertainty on the point estimates featured above means that the estimation results for the sub-sample periods should be taken and interpreted cautiously. For example, in arriving at the conclusion that the estimate of structural parameters for the Malaysian economy mostly do not evolve over time, consideration should also be given to the fact that the estimates for the sub-sample periods are generally produced with a lower precision. Hence, while the stability of the structural parameters for the Malaysian economy found above could be genuine, there are also possibilities that such stability could be superficial, simply because the parameter estimates come with a greater uncertainty. In the same context, the instability in the estimates for parameter $\rho_{LOPG}$ and $\rho_Y$ seen above should also be taken with a critical view. Perhaps, variations in the estimates for these two parameters may not represent the actual changes in their behaviour over time, but merely the outcome of the increasing difficulty in estimating them following the shorter sample period.

6.1.1.1 BNM's reaction function

Results in Table 6.1 indicate that coefficients for BNM's reaction function are not constant over time. In particular, when the model is estimated using different sub-
sample periods, there are visible changes on the estimates for BNM’s feedback coefficient for inflation and output gap - $\beta_\pi$ and $\Theta_y$. Estimates for $\beta_\pi$ stand around 1.7-1.8 during the first two sub-periods but increases to around 2 during the period when the capital control and fixed exchange rate regime was in place. A more drastic change happens to the estimates for $\Theta_y$. The point estimate for the feedback coefficient on output gap increases from 0.7 in the 1975Q1-1986Q4 to 1.2 in the 1987Q1-1998Q2 and declines to 0.8 during the 1998Q3-2005Q2 period. Unsurprisingly, variations in the point estimates for $\beta_\pi$ and $\Theta_y$ for the sub-sample periods are largely consistent to our earlier findings in Chapter 3. As reported in that chapter, the estimation results when the HMT rule was estimated as a single equation also change quite widely across the same sub-sample periods. The same observation applies when the HMT rule is estimated as part of the DSGE model using the Bayesian method, which supports the earlier findings that BNM’s reaction function is evolving over time.

Having said that, as in the case of the full sample period reported in Chapter 5, the point estimates of HMT rule in the DSGE model for the sub-sample periods are also fairly different compared to the results of the single equation estimation found in Chapter 3. More interestingly, for this time around, the difference in the estimation results between them are more than the magnitude of the point estimates for the parameters of HMT rule. In some cases, the point estimates for parameter $\beta_\pi$ and $\Theta_y$ between the two methods are not consistent with each other, which lead to contradictory conclusions in describing BNM’s policy behaviour during the period under review. These differences are listed below.

First, the size of the point estimate for $\beta_\pi$ in the 1975-1986 period from the DSGE model is large and is not in-line with the estimation results in Chapter 3. Recall that in that chapter, estimate for $\beta_\pi$ is found to be less than 1, suggesting BNM’s behaviour during that period was violating the Taylor’s principle. The same outcome does not happen when the HMT rule is estimated as part of the DSGE model. The point estimate of $\beta_\pi$ for the 1975-1986 period in Table 6.1 is 1.8, which is well above the estimate of around 0.3-0.5 reported earlier in Chapter 3. In addition, the 95% confidence interval of the estimate with the Bayesian method is [1.56 , 2.08]. Statistically, this implies there is a very remote probability for parameter $\beta_\pi$ to have the point estimate below 1. In other words, the outcome of the estimation using a DSGE model contradicts the finding in Chapter 3 that BNM’s behaviour during the 1975Q1-1986Q4 period was not consistent with the Taylor’s principle.
Second, is the difference in the way BNM responds to the output gap during the period when the Malaysian economy was experiencing rapid expansion. In Chapter 3, the point estimate for $\Theta_y$ during the 1987-1998 period is lower than the estimate for the 1975-1986 period.\footnote{The estimate was 1.13 for 1975-1986 period and 0.57 for 1987-1998 period. Refer to results in Table 3.2 in Chapter 3 for details.} We take this outcome as the empirical evidence to indicate BNM responded less forcefully to the output gap during the second sub-sample period, possibly due to the difficulty of the policymakers to assess the true state of the economy following the robust economic growth experienced during the large part of the 1990’s. In contrast, in the estimation of HMT rule as part of the DSGE model, the opposite observation happens. The point estimate for $\Theta_y$ during the 1987-1998 period is found to be higher than the 1975-1986 period (refer to Table 6.1). This suggests BNM increases the focus of its policy action towards output stabilization during the 1987-1998 period.

The third difference is the estimate of parameter $\beta_\pi$ during the period when the capital control and fixed exchange rate regime was in place. In Chapter 3, we find no statistical evidence to indicate there was a change in the way BNM responded to the inflation outlook during the 1998Q3-2005Q2 period.\footnote{Estimate for the interactive dummy $\partial_\pi$ is not statistically significant. Refer to results in Table 3.2 in Chapter 3 for details.} However, the estimation results of the HMT rule when it is estimated as part of the DSGE model indicates otherwise. From the results in Table 6.1, the estimates for $\beta_\pi$ for the last sub-sample period rises to 2 (from 1.7 in 1987Q1-1998Q2 period), suggesting there was an apparent change in the policymaker’s response to the inflation outlook during this period. In other words, the above result indicates during the period when the capital control and fixed exchange rate regime was in place, interest rate policy was set with an increased focus towards achieving price stability.

The three differences highlighted above, reaffirm the proposition we made in Chapter 5 that the parameters of BNM’s reaction function are influenced by the way the HMT interest rate rule is estimated. In the estimation results using the sub-sample periods, the differences in the estimation results between the single equation method (from Chapter 3) and the DSGE model method (Table 6.1 in this chapter) are more explicit. The differences in the estimation results of BNM’s reaction function between the two estimation methods also lead to different analysis about BNM’s policy behaviour for the sub-sample periods.
6.2 Possible Identification Problems

This section investigates one of the unresolved issues surrounding the estimation of the DSGE model - the possible identification problems on the estimates of the structural parameters. One reason why identification is an important issue is that DSGE models are increasingly being used for analyzing policy-relevant questions, such as the design of optimal monetary policy. Such analysis often hinges crucially on the values assigned to the parameters of the model. However, identification problems likely to cause the estimated parameters to be biased and inaccurate. It is, therefore, important to know how informative the data is to identify the parameter of interest, and whether there are any benefits from estimating instead of calibrating the parameters that we include in the models we use to address policy questions.

Unfortunately, in most empirical DSGE papers the question of parameter identification is not confronted directly. Usually, if some of the parameters are considered to be of lesser interest, and/or with potentially problematic identifiability, their values are calibrated and assumed known, instead of being estimated. Furthermore, in the case where the DSGE models are estimated using Bayesian methods, potential identification problems largely remain hidden due to the use of tight priors. As a result, it is often unclear to what extent the reported estimates reflect information in the data instead of subjective beliefs or other considerations reflected in the choice of prior distribution for the parameters. On this regard, in this section, our analysis will be focused on detecting the possible identification problem in our Bayesian estimation of the DSGE model for Malaysia.

Various aspects regarding identification problems surrounding the DSGE model are discussed in more detailed by Beyer and Farmer (2004), Canova and Sala (2006) and An and Schorfheide (2007). In short, Canova and Sala (2006) list four reasons why identification might not be achieved in the DSGE model. First, is due to what they call observational equivalence. This occurs if the population objective function does not have a unique maximum, which makes the mapping between structural parameters and reduced form statistics not unique. The implication is that different models, with potentially different interpretations, may be indistinguishable from the point of view of the objective function. The second reason is related to under-identification problems. This occurs if the objective function is constant for all values of that parameter in a
selected range. In practice this may arise if a parameter disappears, say for instance, due to the log-linearization of the model or if two parameters enter the objective function in a proportional manner. In the traditional systems of simultaneous linear equations, this phenomenon is popularly known as "partial identification" problem. The third reason happens if the objective function has insufficient curvature (weak identification). In such a case, different values of the parameters around a neighborhood may lead to the same value of the objective function. The last reason is associated with the limited information identification problem. In this case, a parameter may be identified if all the information is employed, but it remains under-identifiable if only partial information is employed. For instance, because only certain responses are employed, this type of identification problems may arise if certain shocks are missing from the model.

As mentioned by An and Schorfheide (2007), it is difficult to detect directly identification problems in the large DSGE model since the mapping of the structural parameters into the state-space representation is highly non-linear. Nevertheless, as identification problems can arise owing to a lack of informative data, the feature of the prior and posterior distribution from the Bayesian estimation can provide a hint on the possible existence of this problem. When the data does not consist of much information about the estimated parameter, the almost overlapping prior and posterior distribution indicates that the prior distribution is not updated in the direction of the parameter space. Hence, a direct comparison of priors and posteriors can provide valuable insights into how much the data can provide information about the parameter of interest (An and Schorfheide (2007)).

Having said that, in certain occasions, merely comparing the prior and posterior distribution is not enough to satisfactorily detect the possible identification problem of the estimated parameters. This is particularly so for parameters that are constrained in a certain domain. When the parameter space is not variation free - for reasons like stability, non-explosiveness conditions or theoretically motivated non-negativity constraints - the prior of non-identified parameters may be marginally updated even if the likelihood has no information (Poirer (1998)). In this case, the finding that prior and posterior distributions differ does not guarantee that the observed data is informative to identify the parameter. A tightly specified prior can also produce a well behaved posterior distribution, even if the data has little information (Canova and Sala (2006)). Due to this reason, Canova and Sala (2006) suggest the use of another diagnostic procedure to detect the possible identification problem. This diagnostic procedure
involves tracking the stability of the estimated parameters under a sequence of prior distributions with increasing spreads (i.e. loosening the priors by increasing the prior standard deviation).

In this section, we use the combination of both methods mentioned above to detect the possible identification problem for the parameter estimates in our model. The outcome of this investigation for the estimations results for the full sample (from Chapter 5) and sub-sample periods (from Section 6.1) are orderly discussed in the two sub-sections below.

6.2.1 Possible identification problem: Full sample period

We start the investigation by looking at the behaviour of prior and posterior distribution of the estimated parameters for the full sample period that we presented in Chapter 5. For easy reference, we reproduce them here. By referring to Figure 6.3 below, a classic sign of possible identification problem is shown on parameter $\eta$. While the estimate for $\eta$ seems reasonable, note that its respective prior and posterior distribution is almost overlapping with each other. In contrast, signs of possible identification problems are less prevalent in other parameters. From their respective prior and posterior distributions, one can see that the distance between the respective prior and posterior distribution for these parameters are duly apart. At this stage, this suggests the possible identification problems on the parameters other than $\eta$, are less prevalent.

In a way, the possible identification problem that we encounter for parameter $\eta$ is not really uncommon in the empirical literature. The difficulty in estimating the parameter on the elasticity of substitution between domestic and imported goods is a well known problem for the researchers. Reflecting the large uncertainty surrounding this parameter, diverse estimates have been reported in various studies. Adolfson (2007) looks at this issue in more detail and she claims that estimates for this parameter are largely influenced by the choice of variables used in the estimation exercise. In particular,

\footnote{Iskrev (2008) suggests another method to detect the possible identification problem in the DSGE model, using the analytical evaluation of the Fisher Information matrix. Admittedly, the method proposed by Iskrev is more rigorous than the two approaches that we used in this chapter. However, it is much more difficult to be conducted and it is not attempted here. Perhaps, this alternative method can be employed in future research.}
Adolfson finds the estimates obtained from the disaggregated time series and trade data usually are a lot larger than those resulting from the aggregate macroeconomic data. For example, in the case of the Euro area data, Lubik and Schorfheide (2005) do not match their DSGE model against any trade (import or export) data and report an estimate of around 0.4. On the other hand, from the same data, Adolfson, Laséen, and Villani (2007) show that by including imports among the observed variables in their estimation procedure leads to totally different results. When the import data is included, they get a much higher estimate of 5 for this parameter compared to about 0.5 when imports are excluded. The uncertainty around the same parameter also apply in our case. Perhaps, in the context of estimating the DSGE model for Malaysia, the estimation exercise that includes the trade data as one of the observed variables can be explored in the future to get improved estimates for this parameter. This is an interesting area for future extension and research. In the mean time, we will use the estimates for $\eta$ that we have here with caution.
Table 6.2: Posterior Estimates with More Diffuse Priors: 1975Q1-2005Q2

<table>
<thead>
<tr>
<th></th>
<th>Original</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prior SD</td>
<td>Post. Mean</td>
<td>Prior SD</td>
</tr>
<tr>
<td>Υ</td>
<td>0.05</td>
<td>0.565</td>
<td>0.10</td>
</tr>
<tr>
<td>Ψ</td>
<td>0.50</td>
<td>0.720</td>
<td>0.60</td>
</tr>
<tr>
<td>η</td>
<td>0.10</td>
<td>0.465</td>
<td>0.15</td>
</tr>
<tr>
<td>κ</td>
<td>0.10</td>
<td>0.626</td>
<td>0.15</td>
</tr>
<tr>
<td>θ_D</td>
<td>0.10</td>
<td>0.716</td>
<td>0.15</td>
</tr>
<tr>
<td>θ_F</td>
<td>0.10</td>
<td>0.738</td>
<td>0.15</td>
</tr>
<tr>
<td>χ</td>
<td>0.02</td>
<td>0.032</td>
<td>0.03</td>
</tr>
</tbody>
</table>

LogL: -2403.56  LogL: 2411.22  LogL: -2441.34

After investigating the behaviour of the prior and posterior distributions of the estimated parameters for the full sample period, next, we conduct another diagnostic procedure to detect the possible identification problems in our estimated DSGE model. Following the suggestion by Canova and Sala (2006), this diagnostic analysis looks at the robustness of the estimated parameters with a looser prior. This is done by re-estimating the original model but with the use of a larger prior standard deviation for the parameters concerned. For our purpose, the structural parameters that have been re-estimated are - Υ, Ψ, η, κ, θ_D, θ_F and χ. Recall that except for χ, we initially imposed tight priors on these structural parameters based on the information derived from Ramayandi (2008) estimation results. In this diagnostic analysis, we increase the prior standard deviation for these structural parameters in two stages, which we named as Alternative 1 and Alternative 2. In producing the estimation results for this diagnostic procedure, the Bayesian estimation under the two alternative priors are conducted by keeping the prior specifications for the remaining parameters unchanged (see Sub-section 5.2.2 of Chapter 5 for details). The point estimates of this robustness exercise is presented in Table 6.2.

The estimation results using looser priors reveal a few more possible identification problems on the estimated parameters of our DSGE model. Besides η, - which we already
detected before to have identification problems - the diagnostic procedure suggested by Canova and Sala (2006) indicates parameter $\Upsilon$ and $\kappa$ may also suffer from a similar problem. This can be seen by the large changes in the value of their posterior mean under the alternative prior standard deviation. The value of the posterior mean for $\Upsilon$, which measures the degree of consumption smoothing, increases consistently when the prior standard deviation is widened in two stages. The posterior mean for $\Upsilon$ jumps from 0.6 (original prior s.d. 0.05) to 0.8 (prior s.d. 0.10), before it increases further towards its upper bound limit of 1 (prior s.d. 0.25). The same case happens to the estimates for parameter $\kappa$. The posterior mean for $\kappa$ is relatively stable at around 0.6-0.7 when the prior standard deviation is widened from 0.10 to 0.15, but it decreases sharply to around 0.3 when the prior standard deviation is widened further to 0.25.

The large change in the point estimates suggests the identification problem faced by parameter $\Upsilon$ and $\kappa$ is quite severe and their estimated values are possibly sensitive to the choice of priors used to generate them. More importantly, the identification problem faced by parameter $\Upsilon$ and $\kappa$ seems to be hidden under tightly specified priors that we initially used under the original specification. Identification problem on these two parameters can only be detected when the prior standard deviation is widened. Hence, the outcome of our results reaffirm the suggestion made by Canova and Sala (2006) about the benefit of conducting the robustness analysis like above as a tool to detect the identification problem in the DSGE model. By simply observing the feature of the prior and posterior distribution of the estimated parameters sometimes are not adequate to detect this problem. This is particularly so, for the estimated parameters whose priors are tightly specified.

Having said that, what will happen if the same diagnostic test is conducted on the parameter which does not initially start with a tight prior? The results of the robustness exercise for parameter $\chi$ could shed some light on this question. Recall that the reason to allow the data to inform us about the degree of financial accelerator mechanism in the Malaysian economy (see Sub-section 5.2.2), we initially impose a fairly loose prior for this parameter. The initial prior standard deviation for $\chi$ is set at 0.02, which is considered fairly large for the prior mean of 0.07. In the robustness exercise to detect the possible identification problem for this parameter, we loosen the initial prior even further. We widened the prior standard deviation in two stages, first to 0.03 and second to 0.05. The results indicate that in both stages, the point estimate for $\chi$ also changes widely. From 0.032 initially, the posterior mean for $\chi$ decreases to 0.010 in the first
stage and decreases further to 0.003 in the second stage. This suggests this parameter may also suffer identification problem. Interestingly, because of its loosely specified initial prior and the well apart prior and posterior distributions, parameter $\chi$ is the least suspected candidate to have this problem. Apparently, this turns out not to be the case. Hence, the point estimate for parameter $\chi$ that measures the degree of financial accelerator in our DSGE model on Malaysia, should also be taken judiciously.

6.2.2 Possible identification problem: Sub-sample periods

We also conduct the same analysis to detect the possible identification problems on the estimation results of our DSGE model for the sub-sample periods. Like before, we start the analysis by trying to find the initial symptom of the identification problem by inspecting the properties of the prior and posterior distributions of the estimated parameters. This follows with a diagnostic analysis by re-estimating the parameters with looser priors.

From inspecting Figure 6.1 and 6.2 that we presented in Section 6.1, two interesting observations on the behaviour of posterior distributions for parameter $\Upsilon$, $\eta$ and $\kappa$ catch our attention. First, in the estimation results of the sub-sample periods, the prior-posterior distribution curve for parameter $\Upsilon$ and $\eta$ is found to be overlapping. This is a clear symptom suggesting estimates of these two parameters are not adequately identified. Second, a symptom of an identification problem also exists for parameter $\kappa$, but it is not common in all the sub-sample periods under review. The overlapping prior-posterior distribution curve for this parameter is only limited to the 1987Q1-1998Q2 period. This indicates the possible identification problem faced by parameter $\kappa$ could be dependent on the choice of estimation period.

Next, we conduct the diagnostic analysis by increasing the prior standard deviation of the selected parameters in each of the estimation exercises involving the sub-sample periods. Again, the involved parameters are - $\Upsilon$, $\Psi$, $\eta$, $\kappa$, $\theta_D$, $\theta_F$ and $\chi$. The results of the robustness exercise for each of the the sub-sample periods are presented in Table 6.3, 6.4 and 6.5 respectively.

Similar to the case for the full sample period, the use of the diagnostic procedure suggested by Canova and Sala (2006) on the estimation results of the sub-sample periods produces few interesting results. These are highlighted below.
### Table 6.3: Posterior Estimates with More Diffuse Priors: 1975Q1-1986Q4

<table>
<thead>
<tr>
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<th>Original</th>
<th>Alternative 1</th>
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<tbody>
<tr>
<td></td>
<td>Prior SD</td>
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<td>Prior SD</td>
</tr>
<tr>
<td>$\Upsilon$</td>
<td>0.05</td>
<td>0.506</td>
<td>0.10</td>
</tr>
<tr>
<td>$\Psi$</td>
<td>0.50</td>
<td>1.092</td>
<td>0.60</td>
</tr>
<tr>
<td>$\eta$</td>
<td>0.10</td>
<td>0.429</td>
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</tr>
<tr>
<td>$\kappa$</td>
<td>0.10</td>
<td>0.637</td>
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<tr>
<td>$\theta_D$</td>
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<td>0.689</td>
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</tr>
<tr>
<td>$\theta_F$</td>
<td>0.10</td>
<td>0.704</td>
<td>0.15</td>
</tr>
<tr>
<td>$\chi$</td>
<td>0.02</td>
<td>0.040</td>
<td>0.03</td>
</tr>
</tbody>
</table>

LogL: -823.67 \quad \text{LogL: -827.72} \quad \text{LogL: -841.41}

### Table 6.4: Posterior Estimates with More Diffuse Priors: 1987Q1-1998Q2

<table>
<thead>
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<th>Alternative 1</th>
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</tr>
</thead>
<tbody>
<tr>
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<td>Prior SD</td>
<td>Post. Mean</td>
<td>Prior SD</td>
</tr>
<tr>
<td>$\Upsilon$</td>
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<td>0.485</td>
<td>0.10</td>
</tr>
<tr>
<td>$\Psi$</td>
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<tr>
<td>$\eta$</td>
<td>0.10</td>
<td>0.640</td>
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<tr>
<td>$\kappa$</td>
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<tr>
<td>$\theta_D$</td>
<td>0.10</td>
<td>0.809</td>
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<tr>
<td>$\theta_F$</td>
<td>0.10</td>
<td>0.829</td>
<td>0.15</td>
</tr>
<tr>
<td>$\chi$</td>
<td>0.02</td>
<td>0.050</td>
<td>0.03</td>
</tr>
</tbody>
</table>

LogL: -951.30 \quad \text{LogL: -954.49} \quad \text{LogL: -963.66}
### Table 6.5: Posterior Estimates with More Diffuse Priors: 1998Q3-2005Q2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Original</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prior SD</td>
<td>Post. Mean</td>
<td>Prior SD</td>
</tr>
<tr>
<td>Υ</td>
<td>0.05</td>
<td>0.488</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>Ψ</td>
<td>0.50</td>
<td>1.062</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>η</td>
<td>0.10</td>
<td>0.570</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>κ</td>
<td>0.10</td>
<td>0.641</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>θ_D</td>
<td>0.10</td>
<td>0.844</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>θ_F</td>
<td>0.10</td>
<td>0.827</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>χ</td>
<td>0.02</td>
<td>0.045</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.05</td>
</tr>
</tbody>
</table>

LogL: -589.22  LogL: -591.46  LogL: -595.66

- Signs of an identification problem faced by parameters Υ, η, and χ are very obvious. In every sub-sample period, estimates for these three parameters are sensitive to the use of looser priors.

- Signs of an identification problem for parameter κ is limited to only two sub-sample periods - 1987Q1-1998Q2 and 1998Q3-2005Q2. The estimate for κ in the 1975Q1-1986Q4 period is fairly robust to the looser priors.

- The robustness analysis reveals a new parameter with the sign of identification problem - the inverse elasticity of labour supply (Ψ). The estimate for this parameter changes quite a lot under more loosely specified priors. However, like parameter κ, signs of an identification problem is only limited to the 1987Q1-1998Q2 and 1998Q3-2005Q sub-sample periods. The estimate for Ψ in the 1975Q1-1986Q4 period is fairly intact to the widening of the prior standard deviation.

- There is no sign of an identification problem for parameter θ_D and θ_F. Their estimates are fairly stable across the board.

The identification problem is related to the ability to draw inference about the model’s parameters from the observed sample. We have encountered a similar problem for parameter η in the case of the full sample period and the recurrence of the same
symptom in each of the sub-sample periods is not really surprising. Possibly, the absence of a trade variable from the list of the observed variables continues to be the reason for the difficulty to identify this parameter when the model is estimated with the sub-sample periods. On the same note, the occurrence of the same symptoms to the estimates of parameter $\Upsilon$, $\chi$ and $\kappa$ in the sub-sample periods are also expected. They reaffirm the results of the robustness analysis conducted in the full sample period that the estimation of these three parameters are also not free from identification problems.

Obviously, results of the diagnostic analysis presented in Table 6.3, 6.4 and 6.5 provide clear evidence to suggest estimates of $\Upsilon$ in the sub-sample periods are not properly identified. The estimates are not robust to a more loosely specified prior. However, a more interesting matter regarding the identification problem for parameter $\Upsilon$ in the sub-sample periods is the fact that its detection is achieved in a more easily and straightforward manner. Unlike the case of the full sample period in which this problem is initially hidden under a well behaved posterior distribution and is only revealed after conducting the robustness analysis, the sign of the identification problem for parameter $\Upsilon$ in the sub-sample periods is more obvious and can be easily detected from looking at the property of its posterior distribution curve. The problem is no longer disguised under a well apart prior-posterior distribution curve. Comparing the two cases, the overlapping prior-posterior distribution curves for $\Upsilon$ in the sub-sample periods indicates that the posterior distribution for this parameter has not been updated in the same manner as in the case of the full sample period. Hence, this suggests the identification problem for parameter $\Upsilon$ becomes more imminent and transparent when the model is estimated with a smaller number of observations. Consequently, this makes the symptom of the identification problem becoming more visible.

In contrast, the opposite case happens to parameter $\chi$. The property of its posterior distribution still fails to provide a correct symptom of the identification problem faced by this parameter. Like the case of the full sample period, the prior-posterior distribution curves for $\chi$ in each of the sub-sample periods are fairly well apart. Only after conducting the robustness analysis do the symptoms of the identification problem emerge. Estimates of this parameter in all the sub-sample periods are not robust to the loosely specified priors. The instability of the estimates in all the sub-sample periods reconfirms our earlier finding that our DSGE model is not able to adequately identify the parameter measuring the financial accelerator mechanism. This happens independently of the estimation sample.
The most interesting result from conducting the diagnostic analysis for the sub-sample periods is the detection of an identification problem faced by the parameter measuring the inverse elasticity of labour supply ($\Psi$). For the record, this is the first instance that any sign of an identification problem emerges for this parameter. In the case of the full sample period, parameter $\Psi$ is found to be totally free from any symptom of an identification problem. Even in the estimation results for the sub-sample periods, the symptom is initially wrapped under a well behaved posterior distribution. Each of $\Psi$ prior-posterior distribution curves in the sub-sample periods is well apart suggesting the non-existence of any identification problem. However, the results of diagnostic analysis for the sub-sample periods indicates otherwise. Under looser priors, estimates of $\Psi$ vary quite distinctly in two sub-sample periods. For the 1987Q1-1998Q2 period, the estimate initially increases from around 1 (original prior s.d. 0.5) to 1.3 (prior s.d. 0.6), before it decreases sharply to around 0.8 (prior s.d. 1). About the same movement is also shown in the estimates for the 1998Q3-2005Q2 period. This suggests parameter $\Psi$ is not actually free from the identification problem. However, the problem is only detected when the model is estimated with a reduction in the sample size.

The above findings demonstrate one important feature regarding the estimation of a DSGE model with Malaysia’s data - the sample size plays an important role in influencing the identifiability of certain structural parameters. Compared with the full sample period, estimation results with shorter data points in the sub-sample periods produce more visible symptoms of identification problems. What happens to parameters $\Upsilon$, $\kappa$ and $\Psi$ in the sub-sample periods indicate how the estimation exercise with a small sample size can aggravate the identification problems in the DSGE model. This outcome is also consistent with one of the findings by Canova and Sala (2006). Their experiment indicates that the use of a small sample period to estimate a DSGE model will compound the identification problems experienced by the parameters.

Besides the sample size, the choice of sample period can also play a role in influencing the identification problem faced by certain structural parameters. This is shown by identification problems on parameters $\kappa$ and $\Psi$ in the sub-sample periods. For both parameters, signs of identification problems in the sub-sample periods are only found in the 1987Q1-1998Q2 and 1998Q3-2005Q2, but they are completely absent in the 1975Q1-1986Q4. In contrast, when the full sample period is used, symptoms of identification problems for $\Psi$ do not arise at all. This outcome highlights another important feature about estimating the DSGE model involving Malaysian data. When one attempts to
estimate the DSGE model using a short sample size, it is important for the researcher to experiment and then select the appropriate sample period. Failure to do so can lead to some structural parameters in the model to be inadequately identified.

The outcome of the above investigation highlights few identification problems in our estimated DSGE model. As stressed by Canova and Sala (2006), the uncritical use of Bayesian methods may sometimes hide identification problems faced by the DSGE model, instead of highlighting them. Hence, the use of a robustness test is beneficial. We conduct this robustness analysis and highlight possible identification problems on the few parameters. While we do not try to find the exact source nor suggest the solution to this problem, the above findings should be used in a different way. They serve as an important admonition about the possible inaccuracy of our estimates of structural parameters for the Malaysian economy.

Identification problems highlighted above also indicate the information content of the four observable variables used in this exercise - real GDP, inflation, interest rate and RER - is not really adequate to identify satisfactorily the structural parameters of consumer preference (Υ and η), the degree of inflation indexation (κ) and the elasticity of external financial premium (χ). Perhaps, the use of additional observable variables like aggregate consumption, banking system loans and trade data in the Bayesian estimation exercise will provide more information to better identify these parameters. However, introducing additional variables to the estimation exercise does not come without a price. The number of observable variables used in the estimation, must match the number of exogenous shocks in the model. In the context of the DSGE model that we used in this chapter, this involves the introduction of new parameters and equations into the model, which increases its dimension and complexities. Perhaps, this extension can be attempted in future research. On a more positive note, the above outcomes also suggest the same observable variables that we used in this chapter contain informative information to successfully estimate some of the structural parameters. Hence, instead of relying on the calibrating method, the structural parameters like Ψ, θ_D and θ_F of our DSGE model can be adequately estimated with the use of the four observable variables listed before.
6.3 Conclusion

This chapter looks at two on-going issues surrounding the estimation of the DSGE model - stability of structural parameters over time and the identification problems of the estimated parameters. To investigate the stability of the structural parameters over time, the DSGE model of the Malaysian economy that we developed and estimated using a full sample period in Chapter 5, is re-estimated using the sub-sample periods. Comparing the estimation results across the three sub-sample periods, there is no evident sign to suggest estimates of structural parameters for the Malaysian economy change over time. While parameter estimates for the HMT interest rate rule exhibit some changes and suggest the evolution of BNM’s policy behaviour over time, estimates of structural parameters like household’s preferences and Calvo pricing are found to be largely intact. Having said that, we also offer a caveat to this finding. Compared to the estimation results for the full sample period that we presented in the previous chapter, estimates of structural parameters using the sub-sample periods are less accurate. Hence, analysis using the estimated DSGE model involving the sub-sample periods should be taken judiciously.

We also highlight another weakness of the estimation results of the structural parameters of the Malaysian economy that we presented. Some of the estimated parameters in our model are detected to suffer from identification problems. While we do not try to offer any solution to the identification problems found in this chapter, we regard the results of this investigation beneficial in other ways. They reveal which of the estimated structural parameters from our model are less susceptible to the identification problems and hence can be used with greater confidence. These results also suggest the four observable variables that we used to estimate the DSGE model with the Bayesian method - real GDP, inflation, interest rate and RER - contain informative information to successfully estimate some of the structural parameters. Hence, instead of relying on the calibrating method, the structural parameters like elasticity of labour supply ($\Psi$) and probability of retailers changing price ($\theta_D$ and $\theta_F$) of our DSGE model can be adequately estimated.

Based on the findings of the last two chapters, in Chapter 7, we use the estimated DSGE model for the 1975Q1-2005Q2 for simulation exercises. Using this model as a workhorse, we do a policy experiment to answer this question - What happens to
Malaysia’s economic outcomes during 1975Q1-2005Q2 if BNM was to change its relative policy preferences between controlling inflation, stabilizing output and smoothing the interest rate? We conduct this policy experiment by varying the parameter of BNM’s loss function. Then, by assuming monetary policy is conducted through the optimal interest rate rule, the estimated DSGE model that we presented in Chapter 5, is used to provide the likely outcomes of this policy experiment.
Chapter 7

Simulating Bank Negara Malaysia’s Behaviour in Formulating Monetary Policy: Policy Experiment using a DSGE Model

Empirical results in previous chapters have provided us with a fairly good understanding about the way Bank Negara Malaysia (BNM) conducts monetary policy in Malaysia. Up to now, we have established the specification of BNM’s reaction function, economic variables that BNM responded to in setting interest rates, policy objectives that BNM tries to pursue, as well as the way BNM prioritizes the multiple objectives that it attempts to achieve. There is also evidence suggesting that in conducting monetary policy, BNM’s behaviour was evolving over time. All in all, BNM’s past policy behaviour and actions have contributed to shaping the outcomes of the Malaysian economy. The next interesting question to ask is, what would happen to Malaysia’s economic outcomes if BNM was to behave differently than what we found empirically?

This chapter conducts a simulation exercise to look at the impact on Malaysia’s economic outcomes for the 1975Q1-2005Q2 period, if BNM was to follow a different policy preference than what we have established and understood from the empirical exercises in Chapter 4. Similar types of counter-factual experiments involving policy behaviour of the US Federal Reserve are discussed in Clarida, Gali, and Gertler (1998), Rotemberg and Woodford (1999) and Soderlind (2004). For our purpose, recall that
estimation results in Chapter 4, reveal the following information about BNM’s policy objectives and relative policy preferences:

- BNM had multiple objectives for monetary policy. Estimates of preference parameters for other policy objectives are statistically significant and greater than one (i.e. $\lambda_1, \lambda_3 > 1$). Hence, compared to the objective of price stability, BNM has a higher preference for output stability and interest rate smoothing.

- No statistical evidence to show BNM puts exchange rate smoothing as one of its policy objectives. The estimate of parameter $\lambda_2$ is small and is not statistically significant.

While the above information may reflect the “actual” BNM’s policy behaviour during the 1975Q1-2005Q2 period, in this chapter, we undertake a different exercise. We try to “replay history” and ask the “what if” question regarding BNM’s policy behaviour. What happens to Malaysia’s economic outcomes during 1975Q1-2005Q2 if BNM had a different set of relative preferences? More specifically, the policy experiment that we conduct in this chapter tries to answer the following questions regarding the alternative way that BNM could prioritize its policy objectives during this period:

- What would happen to Malaysia’s economic outcomes during the period if BNM became an inflation nutter and adopted a strict inflating targeting framework (i.e. $\lambda_1, \lambda_2, \lambda_3 = 0$) ?

- What would be the impact if BNM puts inflation as its first policy priority (i.e. $\lambda_1, \lambda_3 < 1$) and not as what it has been practicing?

- What if BNM puts an equal weights to all its policy objectives (i.e. $\lambda_1, \lambda_2, \lambda_3 = 1$) ?

- What would be the outcomes if BNM’s policy objectives were to include exchange rate smoothing (i.e. $\lambda_2 > 0$) ?

We break this chapter into three main sections. First, a short discussion on the assumptions we make to conduct the simulation exercises. Then, Section 7.2 presents the simulation results of the policy experiment. The last section concludes.
7.1 Assumptions

The main framework of the simulation exercise that we conduct in this chapter is derived from information and knowledge that we gathered in the previous chapters. For example, from Chapter 3 and 5, the Henderson-McKibbin-Taylor (HMT) interest rate rule is known to represent BNM’s reaction function fairly well. This will be used to establish BNM’s reaction function. In Chapter 4, we reveal the policy objectives and relative preferences of BNM by using a linear-quadratic loss function and an optimal interest rate rule. In Chapter 5, we have developed and estimated a small open-economy DSGE, which reveals estimates of structural parameters for the Malaysian economy. This estimated model is used to represent the operation of the Malaysian economy during the 1975Q1-2005Q2 period. Thus, assumptions that we used in these simulation exercises are summarized below:

1. Throughout the 1975Q1-2005Q2 period, BNM treats formulation of monetary policy as a solution to the optimal control problem. BNM sets its policy instrument in such a way as to minimize a specified loss function subject to the dynamics of the Malaysian economy described by a specified model’s equations.

2. BNM’s policy objective is to minimize the following linear quadratic loss function

\[
\text{Loss} = E_t \sum_{j=0}^{\infty} \delta^j \left[ (\pi_{t+j}^a)^2 + \lambda_1 (y_{t+j})^2 + \lambda_2 (rer_{t+j})^2 + \lambda_3 (r_{t+j} - r_{t+j-1})^2 \right]
\]  \hspace{1cm} (7.1)

where \( E_t \) denotes expectation conditional on information available at time \( t \); \( 0 < \delta < 1 \) is the discount factor; \( y_t \) is the output gap; \( \pi_t^a \) is the average inflation (defined as \( \pi_t^a = \frac{1}{4} \sum_{j=0}^{3} \pi_{t-j} \), with \( \pi_t \) is the annual inflation for the quarter); \( r_t \) is the short-term interest rate and \( rer_t \) is the real exchange rate. Parameter \( \lambda_1, \lambda_2, \lambda_3 > 0 \), is the weight of BNM’s policy preference given to the output gap, exchange rate stabilization and interest rate smoothing respectively. These objectives are expressed relative to BNM’s concern for inflation stabilization, which is normalized to one.

3. Monetary policy is conducted according to the HMT interest rate rule

\[ r_t = (1 - \rho) \left[ \beta_n \pi_{t+1} + \Theta_y y_{t+1} \right] + \rho r_{t-1} \]  \hspace{1cm} (7.2)
It is assumed BNM acts optimally to set the interest rates. In doing so, subject to the constraint given by the economic model, value of parameter $\beta$, $\Theta_y$ and $\rho$ is chosen such that the HMT interest rate rule above minimizes the value of the loss function given by equation 7.1. Steps and mechanics to obtain the optimized HMT rule are largely similar to the one we used in Chapter 4. However, note that there is a slight difference in the specifications of the optimized HMT rule that we use here and the one in Chapter 4. In this chapter, we use the optimized “simple”, HMT-type interest rate rule (with three arguments - $\pi_{t+1}$, $y_{t+1}$ and $r_{t-1}$) and not the “fully” (unrestricted) optimal interest rate rule (which responds to ALL state variables). The main reason for our preference in using the optimized HMT rule instead of the unrestricted optimal rule for the simulation exercise in this chapter, is its simplicity. The number of state variables in the DSGE model that we use in this chapter is far greater than the simple small open economy model that we used in Chapter 4. Hence, finding the optimal coefficients for the full-fledged, unrestricted optimal rule with the numerical method is far more difficult to reach convergence.

Having said that, we do not think this simplification will greatly affect the results. As found in Chapter 3 and 5, the HMT rule is known to represent BNM’s reaction function fairly well. Thus, the specification that we used in this chapter is closed to the actual decision rule that BNM adopted during the period. More importantly, as noted by Rudebusch and Svensson (1999), in most cases, the HMT rule with the optimized coefficients (with three arguments) comes close to matching the unrestricted optimal rule (with all state variables as arguments).

The parameter for the optimized HMT rule is searched using a numerical method. Like the Bayesian estimation in Chapter 5, this was performed using the OSR algorithm in DYNARE v3.6. DYNARE uses the MATLAB function “fminsearch” to find the optimized values for the HMT rule that minimize the value of the loss function, subject to the values set on $\lambda$.

4. The estimated DSGE model for the full sample period presented in Chapter 5 is used as the workhorse model representing the operation and dynamics of the Malaysian economy. Summary of the structural equations of the estimated DSGE model as well as the value of the parameters presented in Chapter 5, are reproduced in Table 7.3 and 7.4 (placed in Appendix) for easy reference.
Note that, for the simulation exercise in this chapter, estimates of structural parameters of the DSGE model with a Financial Accelerator for the full sample period (1975Q1-2005Q2) are used. There are two main reasons why we only conduct the simulation exercise using the structural parameters for the full sample period and ignore the estimation results for the sub-sample periods. First, as discussed in Chapter 6, there are no significant changes on the estimates of structural parameters across the different sub-sample periods. As such, there will not be much benefit from the simulation exercise using the estimated DSGE model for the sub-sample periods as the simulated model will generate very similar results. Second, and more importantly, estimates of structural parameters for the sub-sample periods were generated with less accuracy and subject to the greater degree of identification problems. Hence, we feel more comfortable using the estimation results for the full sample period in this simulation exercise.

5. In conducting the simulation exercise, size of the shocks that hit the economy during the 1975Q1-2005Q2 period \( \sigma_{MP}, \sigma_{UIP}, \sigma_{LOPG}, \sigma_{Y}, \sigma_{\pi^*}, \sigma_{i^*}, \sigma_{y^*} \) - are assumed to be fixed. Values of standard deviations for these shocks are derived from the estimated DSGE model presented in Chapter 5.

6. Value for policy preference parameters - \( \lambda_1, \lambda_2, \lambda_3 \) - in the loss function, is set between 0 to 1.5. To reflect different policy preference scenarios, combinations of several values for these parameters are used. As the preference for inflation stabilization is normalized to one, changing the value of parameters \( \lambda_1, \lambda_2, \lambda_3 \) will represent the change in the relative importance of the objective variables. For example, when \( \lambda < 1 \), inflation objective is given a higher priority compared to other policy objectives, while when \( \lambda > 1 \) other policy objectives supersede inflation.

Results of the simulation exercises that we conducted are presented and discussed in the next section.
7.2 Simulation Results

We report the simulation results in two tables. Table 7.1 displays the simulation results when BNM does not have exchange rate smoothing as one of its policy objectives ($\lambda_2 = 0$), while Table 7.2 provides the simulation results when this additional policy objective is in effect ($\lambda_2 > 0$). In part (i) of both tables, there are three different measures of standard deviation - actual data, model’s estimation and model’s simulation - for interest rates, inflation, real exchange rates (RER) and output. These could be used to make a quick comparison about the model’s performance and analyzing the impact to economic outcomes under different policy actions. Part (ii) of both tables reports the parameter values for the estimated (historical) and the optimized HMT rule. Note that, values of estimated and optimized HMT rule are different to each other. Parameter values in the estimated HMT rule are estimated to best fit the historical data and are not constrained to minimize any sort of loss function. In contrast, as stated before, parameter values in the optimized HMT rule are generated from the numerical method to minimize a loss function with a specific value of $\lambda$. The estimated HMT rule is used to represent BNM’s reaction function in the model’s estimation, while the optimized HMT rule is used to represent BNM’s reaction function in the model’s simulation. Since they are generated from two different configurations, estimated and optimized HMT interest rate rule represents a different set of BNM’s policy actions. Obviously, a different set of policy actions produces different economic outcomes. These are represented in two measures of standard deviations (Model’s Estimation and Model’s Simulation) that we report in part (i) of Table 7.1 and 7.2.

Results in column 1 of both tables are the outcome of a special case, a scenario when BNM only has a single policy objective to target inflation. This special case is what Svensson (1999) classified as a strict inflation targeting policy. Even though up to now there is no central bank that officially puts the strict inflation targeting policy into practice, it is interesting to see the effect on the Malaysian economy if BNM was to adopt this policy preference.\footnote{Svensson (1997b) offers five reasons on why s central bank does not put strict inflation targeting into practice. Among others, the reasons are the instrument-instability problem; uncertainties regarding model parameters, data and state of the economy; issues on predictability, credibility and public understanding of monetary policy; and conflicting shocks with the opposite impact to inflation. See Svensson (1997b) for details.} Also, since it involves setting other preference parameters to zero, the outcome from the strict inflation targeting policy is a good starting point
Table 7.1: Simulation Results under Different Policy Preferences: Without Exchange Rate Smoothing (set $\lambda_2 = 0$)

(i) Standard Deviations

<table>
<thead>
<tr>
<th>BNM's Preferences</th>
<th>Scenarios</th>
<th>1a</th>
<th>2a</th>
<th>3a</th>
<th>4a</th>
<th>5a</th>
<th>6a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td></td>
<td>$\lambda_1 = 0$</td>
<td>$\lambda_1 = 1$</td>
<td>$\lambda_1 = 0.5$</td>
<td>$\lambda_1 = 1.5$</td>
<td>$\lambda_1 = 0.5$</td>
<td>$\lambda_1 = 1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\lambda_3 = 0$</td>
<td>$\lambda_3 = 1$</td>
<td>$\lambda_3 = 0.5$</td>
<td>$\lambda_3 = 1.5$</td>
<td>$\lambda_3 = 1$</td>
<td>$\lambda_3 = 0.5$</td>
</tr>
<tr>
<td>Variables</td>
<td>Actual Data</td>
<td>Model's Estimation</td>
<td>Model's Simulation</td>
<td>Actual Data</td>
<td>Model's Estimation</td>
<td>Model's Simulation</td>
<td>Actual Data</td>
</tr>
<tr>
<td>Int. Rates</td>
<td>0.025</td>
<td>0.031</td>
<td>0.015</td>
<td>0.016</td>
<td>0.016</td>
<td>0.018</td>
<td>0.014*</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.020</td>
<td>0.027</td>
<td>0.007*</td>
<td>0.008</td>
<td>0.009</td>
<td>0.012#</td>
<td>0.008</td>
</tr>
<tr>
<td>RER</td>
<td>0.033</td>
<td>0.111</td>
<td>0.105#</td>
<td>0.102</td>
<td>0.101</td>
<td>0.098</td>
<td>0.105#</td>
</tr>
<tr>
<td>Output</td>
<td>0.029</td>
<td>0.038</td>
<td>0.038#</td>
<td>0.034</td>
<td>0.036</td>
<td>0.035</td>
<td>0.037</td>
</tr>
</tbody>
</table>

* Lowest volatility across different scenarios
# Highest volatility across different scenarios

(ii) Parameters of HMT rule

<table>
<thead>
<tr>
<th>BNM’s Preferences</th>
<th>Scenarios</th>
<th>1a</th>
<th>2a</th>
<th>3a</th>
<th>4a</th>
<th>5a</th>
<th>6a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td></td>
<td>$\lambda_1 = 0$</td>
<td>$\lambda_1 = 1$</td>
<td>$\lambda_1 = 0.5$</td>
<td>$\lambda_1 = 1.5$</td>
<td>$\lambda_1 = 0.5$</td>
<td>$\lambda_1 = 1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\lambda_3 = 0$</td>
<td>$\lambda_3 = 1$</td>
<td>$\lambda_3 = 0.5$</td>
<td>$\lambda_3 = 1.5$</td>
<td>$\lambda_3 = 1$</td>
<td>$\lambda_3 = 0.5$</td>
</tr>
<tr>
<td>HMT Parameters</td>
<td>Estimated</td>
<td>Optimized</td>
<td>Estimated</td>
<td>Optimized</td>
<td>Estimated</td>
<td>Optimized</td>
<td>Estimated</td>
</tr>
<tr>
<td>$\beta_\pi$</td>
<td>2.251</td>
<td>4.532</td>
<td>4.030</td>
<td>3.687</td>
<td>3.277</td>
<td>4.352</td>
<td>4.753</td>
</tr>
<tr>
<td>$\Theta_y$</td>
<td>1.303</td>
<td>-0.260</td>
<td>0.125</td>
<td>0.303</td>
<td>0.650</td>
<td>0.106</td>
<td>0.589</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.607</td>
<td>0.467</td>
<td>0.466</td>
<td>0.514</td>
<td>0.510</td>
<td>0.656</td>
<td>0.163</td>
</tr>
</tbody>
</table>
for us to build-up our analysis and form conclusions about BNM’s policy behaviour under different policy preferences. Simulation of economic outcomes when BNM adopts different policy preferences are reported in column 2 to 6 in both tables.

Analysis of simulation results are divided into four parts. It starts with discussion on the comparison between the estimated and optimized HMT Rule. Then, the remaining parts analyze the simulation results when BNM adopts strict inflation targeting and when BNM operates with multiple objectives without exchange rate smoothing. We also look at the outcomes when BNM aims to smooth the exchange rate movement.

7.2.1 Comparison between Estimated and Optimized HMT Interest Rate Rule

A quick glance to Table 7.1 and 7.2 indicates two major features about the estimated and optimized BNM’s reaction function. First, from part (ii) of both tables, the estimated and the optimized values for HMT interest rate rule parameters are fairly different to each other. Second, use of the optimized reaction function produces better economic outcomes than the estimated reaction function. From part (i) of both tables, it is clear that standard deviations of all variables from the model’s simulation (which uses the optimized HMT rule to represent BNM’s reaction function) are lower than what are projected in the model’s estimation (which uses the estimated HMT rule to represent BNM’s reaction function).

Naturally, differences in the parameter values between the estimated (historical) and optimized HMT rules will lead us to the conclusion that BNM’s historical monetary policy action is not consistent with the outcome of the economic optimization problem. While this could be a factor that we cannot totally rule out, we view this thinking as not very convincing due to three reasons. First, based on our empirical results in Chapter 3 and 5, the HMT interest rate rule is able to describe BNM’s reaction function very well. This can be interpreted to indicate there is a systematic component in the way BNM conducts monetary policy to achieve certain policy objectives. In addition, the empirical results also show BNM’s policy behaviour adheres to Taylor’s principle, which by its own right, is in line with the optimizing policy making behaviour. Second, one of the key factors to the success story of the Malaysian economy is the contribution from proficient economic management and good formulation of economic policies
Table 7.2: Simulation Results under Different Policy Preferences: With Exchange Rate Smoothing ($\lambda_2 = 0.2$)

(i) Standard Deviations

<table>
<thead>
<tr>
<th>Variables</th>
<th>Actual Data</th>
<th>Model’s Estimation</th>
<th>Model’s Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int. Rates</td>
<td>0.025</td>
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<td>0.015*</td>
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<td>0.033</td>
<td>0.111</td>
<td>0.105#</td>
</tr>
<tr>
<td>Output</td>
<td>0.029</td>
<td>0.038</td>
<td>0.038#</td>
</tr>
</tbody>
</table>

* Lowest volatility across different scenarios
# Highest volatility across different scenarios

(ii) Parameters of HMT rule

<table>
<thead>
<tr>
<th>BNM’s Preferences Parameters</th>
<th>Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda_1 = 0$</td>
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</tr>
<tr>
<td>$\lambda_3 = 0$</td>
<td>$\lambda_3 = 0$</td>
</tr>
<tr>
<td>$\lambda_2 = 0$</td>
<td>$\lambda_2 = 0.2$</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>HMT Parameters</th>
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<th>Optimized</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>$\Theta_y$</td>
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<td>-0.260</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.607</td>
<td>0.467</td>
</tr>
</tbody>
</table>
(Athukorala and Menon (1999); Corden (2002)). Undoubtedly, one of the key components to this is the sound conduct of monetary policy. So, it is fair to assume that some sort of optimum behaviour has been practiced by BNM in conducting its policy affairs. Lastly, on the theoretical ground, a long-standing principle that is consistently applied in the economics field is any economic behaviour can be understood as a problem of constrained optimization. Hence, when modelling the behaviour of a central bank, this principle should equally apply as it does to modelling the behaviour of other economic agents like consumers and firms. Due to these reasons, while the size of coefficients between the estimated and optimized reaction functions could be different, it should not be viewed as suggesting BNM does not behave optimally. The difference between the optimized and estimated reaction functions that we encountered above happens due to other reasons.

Having said that, we do not try to identify explicitly the reasons that cause the difference between the optimized and estimated reaction function for BNM that we encountered in this chapter. However, looking at the related study by Rudebusch (2001) is useful to give us an idea on the possible source of this outcome. Rudebusch attempts to reconcile the different outcome between the historical estimates and the optimized coefficients of the interest rate rules for the US Federal Reserve. He suggests three aspects of uncertainties that the Fed has to face in the formulation of monetary policy in real life - data, model specifications and parameter uncertainties. These may explain why the Fed’s observed (estimated) reaction functions are different from the optimized. In particular, these uncertainties make the Fed’s estimated reaction function to be less forceful and timid than the policy action prescribed by the optimized reaction function. Hence, it is very likely that the same reasons are equally applicable to the case of BNM which we do not explicitly cover in this chapter. This is an interesting area to be looked at in future research.

Simulation results also suggest the use of the optimized HMT rule produces a strictly improved outcome for the Malaysian economy. Compared to its estimated counterpart, representing BNM’s reaction function using the optimized HMT rule produces a significantly lower volatility in inflation and a much more stable interest rates movement. Optimized HMT rule also produces more stable RER and output movement. The reason for this better economic outcomes can be attributed to the way the optimized HMT rule prescribe how BNM should set interest rates. Comparison between the optimized and estimated reaction function suggests in the optimized policy setting,
BNM should react much stronger to inflation ($\beta_\pi$: 3.2-4.7 in optimized against 2.2 in estimated), less aggressively to the output gap ($\Theta_y$: -0.3-0.6 in optimized compared to 1.3 in estimated) and should practice lower policy inertia ($\rho$: 0-0.5 in optimized compared to 0.6 in estimated). These suggest the use of alternative policy action in accordance to the one suggested by the optimized HMT rule could be more effective than the representation of historical policy action that we believe was taken by BNM during the 1975-2005 period.

Having said that, one admonition to this finding. It should not be viewed as our comprehensive attempt to evaluate BNM’s past policy decisions. Neither does it suggests BNM made policy mistakes by not setting interest rates for the 1975-2005 according to the recommendations prescribed by the optimized rule. To start with, the optimized HMT rule reported in part (ii) of Table 7.1 and 7.2 are produced conditional to the assumptions that we outlined in Section 7.1. Admittedly these assumptions could be too simplistic to mimic the actual policy making taken by BNM during the 1975-2005 period. There could be other factors that constraint BNM’s policy action which we fail to take into account which caused BNM to behave the way it did.

In addition, in the actual policy setting, we do not expect BNM to set interest rates by following mechanically the optimized interest rate rule. Every central bank uses more information than what the simple optimized rule is based on. No central bank, including BNM, would restrict itself to react mechanically in a pre-described way as suggested by the optimized rule. Thus, the role of a simple optimized rule is at best, to provide a baseline and comparison to the policy actually followed. Based on this premise, the above finding should not be looked solely at the quantitative differences in the coefficients between the optimized and estimated HMT rule. Instead, qualitative information from these differences could be more useful. It provides applicable guidance on how BNM should have set its reaction function. From the recommendation prescribed by the optimized rule, to get better economic outcomes, BNM should set interest rates by responding more forcefully to inflation, less aggressively to the output gap and practice lower policy inertia.

Next, we discuss in detail the main objective of this chapter - simulation outcomes with different BNM’s policy preferences.
7.2.2 Policy Simulation I: Strict Inflation Targeting

First, we look at the simulation results if BNM was to adopt the strict inflation targeting preference during the 1975-2005 period. It produces one important results. Having price stability as a single policy objective is able to minimize inflation volatility to the Malaysian economy. Compared to other policy scenarios that we considered in Table 7.1, results in column 1a produces the lowest level of inflation volatility (0.007). However, becoming an inflation nutter does not come without cost. There is a clear trade-off between inflation and output volatility. When BNM is solely concern with achieving price stability, the simulation results indicate output volatility is also at its highest level (0.038). In addition, it also produces the highest volatility in the RER movement (0.105).

The above outcomes are consistent with the assertion made by King (1997) and Svensson (2000) about the limitation of this ambitious policy preference. Adoption of strict inflation targeting will produce excessive variability in the economic variables other than inflation. Since keeping inflation as close to the target as possible is the only concern to these policymakers, they will react excessively to bring inflation back to its target as soon as possible. This requires a very vigorous and activist policy action, which involves drastic interest rate changes. In addition, in the case of the open economy set-up (like the one we use in this chapter), Svensson argues the direct exchange rate channel has the shortest lag among the transmission channels. Due to this reason, the central bank will move the exchange rate aggressively, exploiting the direct impact of the exchange rate on import prices to bring down inflation quickly (Svensson (2000)). As we found in the simulation exercise, this activist policy action may succeed in stabilizing inflation. However, it causes large variability to other variables as well. This is one of the key factors that makes strict inflation targeting less favourable to the policymakers.

Another interesting observation about the simulation results of BNM adopts strict inflation targeting is the behaviour of the optimized reaction function. The sign for the feedback coefficient on the output gap ($\Theta_y$) in the optimized HMT rule is negative (see Table 7.1(ii)). This suggests under a strict inflation targeting framework, BNM should reduce the interest rate when the economy is experiencing a positive output gap. We do not have a good explanation for this counter-intuitive result. It only happens in the case of strict inflation targeting and not in other policy scenarios that we considered in this Chapter. Perhaps, this could be a unique property of the optimized reaction
function when a central bank is assumed to adopt strict inflation targeting. The same outcome was also reported in Svensson (2000), Smets and Wouters (2002) and Flamini (2007) when they conducted a similar exercise using a small open economy model. None of them provide any explanation to this outcome either. We leave finding the possible reasons to this outcome to other research.

For the same reasons outlined in Svensson (1997b), strict inflation targeting may also be not preferable to the policymakers in Malaysia. Thus, simulation result of the remaining scenarios show the economic outcomes when BNM moves away from the strict inflation targeting to the policy preference with multiple objectives. This will be discussed next.

### 7.2.3 Policy Simulation II: Multiple policy objectives without exchange rate smoothing

This sub-section discusses the results of the simulation exercise with the assumption that BNM does not smooth the exchange rate ($\lambda_2 = 0$, refer to Table 7.1). We start the analysis for the policy preference with multiple objectives by looking at another extreme scenario. What happens to Malaysia’s economic outcomes during 1975Q1-2005Q2 period if BNM puts all the policy objectives equal importance? Scenario 2a represents this situation, with all the policy objectives in the loss function is given an equal weight. The outcome of the simulation results suggest there will be little improvement in economic outcomes when BNM moves away from being an inflation nutter to a policymaker which puts an equal importance to all of its policy objectives. The latter produces a lower standard deviation for RER as well as a more stable output. Interestingly, these improved outcomes are achieved with a minimal change to the interest rates and inflation volatility. Hence, moving away from a single policy objective for price stability does not necessarily cause unfavorable inflation outcomes. Even in the case when BNM is indifferent between the three policy objectives that it tries to achieve, it still produces generally better economic outcomes than what is achieved by the strict inflation targeting preference.

The above finding suggests the policy preference with multiple objectives is likely to be BNM’s choice. Particularly, when we already established from the empirical evidence in
Chapter 4 that in formulating monetary policy, BNM was also concerned with fulfilling other policy objectives. But, how should BNM rank the price stability objective in the list of policy objectives that it tries to pursue? The answer to this question will give us an idea about the general relationship between the ranking of price stability in BNM’s preferences and the economic outcomes. For this purpose, we consider two orderings for the price stability objective. Scenario 3a (with $\lambda_1 = \lambda_3 = 0.5$) represents the situation when price stability objective is strictly dominant and is ranked as BNM’s first policy priority. Scenario 4a (with $\lambda_1 = \lambda_3 = 1.5$) is the opposite of scenario 3a. It assumes BNM puts the inflation objective as the least importance and it is ranked as the last policy priority. We analyze the outcome from changing the ordering of the price stability objective in BNM’s policy preference below.

We find the ordering of the price stability objective in BNM’s preference has an important role in influencing the overall economic outcomes in Malaysia. In particular, overall economic conditions generally become more stable when BNM ranks inflation ahead of other policy variables. This is shown by comparing the simulation results between column 3a and 4a. In the case when the price stability objective is strictly preferred, both inflation and interest rates are less volatile. In addition, the benefit of putting other policy objectives ahead of inflation is not very significant. Compared to the outcomes in Scenario 3a, it only reduces RER volatility slightly. Having a large preference bias for output stabilization like in Scenario 4a (with $\lambda_1 = 1.5$) also reduces output volatility very marginally. A preference bias to smooth interest rates (with $\lambda_3 = 1.5$) does not produce the intended results either. In the situation where the price stability objective is least dominant, interest rates volatility is also higher than the scenario when $\lambda_3$ is set at a lower value. Hence, putting the price stability objective at the lowest policy rank in BNM’s list of policy objectives does not produce a significant betterment to the overall economic outcomes. More interestingly, compared to the results of other policy scenarios that we considered in Table 7.1, results in Scenario 4a produces the highest volatility for inflation. This suggests the importance for BNM to always put the price stability ahead of other policy objectives that it wants to achieve.

Interestingly, based on the information that we gather from the estimation results in Chapter 4, putting inflation as the least important policy priority as in Scenario 4a is the closest resemblance to what we found was actually practiced by BNM during the
1975Q1-2005Q2 period.\footnote{Admittedly, estimate of policy preference parameters ($\lambda$) are model dependent. This makes comparison on the value of policy preference parameters inaccurate. Due to this reason, we do not use the quantitative information (i.e. parameter estimates) from Chapter 4 here. However, we view qualitative information about BNM placed output stabilization and interest rate smoothing ahead of price stability that we gathered from Chapter 4 are still valid and applicable.} Hence, the above findings raise one interesting question. Does it suggest there is room for improvement in the overall economic outcomes during the 1975-2005 period if BNM was to put inflation as the first policy priority in its past policy preference? Looking at the results of different policy preference scenarios in Table 7.1(i) able to shed some lights to this question. Simulation results for other scenarios with the weights attached to output and interest rate smoothing objective is smaller than or equal to the inflation objective (i.e. $\lambda_1, \lambda_3 \leq 1$) indicate that they would produce generally better economic outcomes than the set of policy preferences that we believe BNM chose in the past.

Next, we conduct a policy experiment to investigate the impact of changing the individual size of $\lambda_1$ and $\lambda_3$. This experiment will resemble the situation where BNM varies its relative policy preferences. As mentioned in Chapter 4, a possible change in BNM's relative policy preference can happen following the change in the economic circumstances, in line with the evolution of the Malaysian economy. Since possible changes in the relative policy preference is likely to occur from time to time, it is interesting to see its impact to the economic outcomes. For this purpose, we consider two policy scenarios. In Scenario 5a, we set the value of $\lambda_1 = 0.5$ and $\lambda_3 = 1$. In Scenario 6a, we reverse this order to $\lambda_1 = 1$ and $\lambda_3 = 0.5$. Then, to analyze the impact from changing the individual value of $\lambda_1$ and $\lambda_3$ while holding values of other preference parameters constant, we made the comparison of the simulation results of Scenario 5a and 6a to the outcomes in Scenario 3a. In Scenario 3a, $\lambda_1$ and $\lambda_3$ are both set to 0.5. By comparing the outcomes between Scenario 5a to Scenario 3a, it can be used to predict the impact to the economy when BNM increases its policy preference to smooth interest rates ($\uparrow \lambda_3$). Similarly, comparing the results of Scenario 6a to Scenario 3a will predict the impact when BNM becomes more concerned about stabilizing output ($\uparrow \lambda_1$). We analyze the outcomes of these two situations below.\footnote{Note that the same analysis can also be done by comparing results of Scenario 5a and 6a to the outcomes in Scenario 2a (with $\lambda_1$ and $\lambda_3$ are both set to 1). However, it must be done in the reverse order. For example, comparing results between Scenario 5a to Scenario 2a should be interpreted as the impact when BNM decreases its policy preference to stabilize output ($\downarrow \lambda_1$). Similarly, comparing results between Scenario 6a to Scenario 2a should be taken as the outcome when BNM decreases its policy preference to smooth interest rates ($\downarrow \lambda_3$). Hence, the impact to the economic outcomes will}
Comparing the results between column 5a and 3a, an increase in BNM's policy preference to smooth interest rates (↑ \( \lambda_3 \)) gives three effects to Malaysia's economic outcomes during the 1975-2005 period. First, albeit slightly, such action reduces the interest rate volatility (to 0.014 from 0.016). Second, it does not affect output and inflation outcomes very much. Compared to the outcomes in column 3a, standard deviations for inflation and output in column 5a are virtually unchanged. Third, an increase in BNM's relative preference to smooth interest rates leads to a more volatile exchange rate movement (to 0.105 from 0.101). An increase in the policy preference to smooth interest rate also requires different policy action from BNM. From comparing parameters of optimized HMT rule between column 5a and 3a in Table 7.1(ii), such action requires BNM to respond more forcefully to inflation (↑ \( \beta_\pi \)), less aggressively to the output gap (↓ \( \Theta_y \)) and place greater policy inertia (↑ \( \rho \)).

As mentioned in Chapter 2, there are a few reasons why central banks smooth interest rates. As argued by Cukierman (1992), one rationale for this is to reflect the central bank's concerns on the stability of the financial system. Hence, looking from the same angle, the above results can be taken to represent this situation. Our simulation results suggest that when BNM raises its policy preference parameter to smooth interest rates in order to stabilize the Malaysian financial system, such action will not give much detrimental impact to the inflation and output volatility. However, BNM needs to expect that such action will have a negative consequence to the stability of real exchange rates. A possible explanation for this result is as follows. In our DSGE model, movement in the real exchange rate acts as an automatic stabilizer in the economy to ensure equilibrium is achieved. Thus, when BNM is not willing to change interest rates as much and as frequently as it should due to its concern about financial stability, the real exchange rate will automatically change in a larger scale to fill in the gap.

There is one suggestion that we want to bring forward from the above finding. Increases in the RER volatility following BNM's desire to stabilize the financial system should not become a big concern to the policymakers. It is just a natural economic reaction to its choice of policy preference and action. More importantly, BNM should refrain from taking a countermeasure action by smoothing the exchange rate movement through direct intervention in the exchange rate market. Like we explained in Chapter 4, during the 1975Q1-2005Q2 period, BNM conducts direct intervention in the exchange
rate market from time to time to smooth the exchange rate movement. However, we advocate, such countermeasure action will only create more distortion in the system and it will deter smooth adjustment to take place in the economy. Consequently, building up of disequilibrium in the economy requires a much bigger adjustment from the policy-makers and this will lead to much bigger changes in the interest rates level later on. Obviously, if this happens, it works against BNM’s initial intention to minimize interest rate volatility by raising its policy preference to smooth interest rates.

Now, we look at the outcomes when BNM increases its relative preference for output stabilization ($\uparrow \lambda_1$). The results indicate an increase in BNM’s preference for output stabilization will not cause much harm to the overall stability of the Malaysian economy for the 1975Q1-2005Q2 period. From comparing the results between column 6a and 3a, raising BNM’s preference for output stabilization while holding $\lambda_3$ unchanged, produces favourable results in reducing volatility for inflation and RER. It also makes output more stable as intended. In fact, compared to other policy scenarios that we consider in Table 7.1(i), Scenario 6a produces the lowest volatility for inflation, RER and output. However, this action requires a more active use of interest rates to fine tune the economy and this leads to higher interest rates volatility (to 0.019 from 0.016 previously). The more active policy action under this condition is reflected in the size of optimized HMT coefficients for scenario 6a (see Table 7.1(ii)). Compared to the outcomes in column 3a, size for optimized parameter measuring the interest rate smoothing ($\rho$) is lower in column 6a, suggesting under this condition, the interest rate needs to be changed in a bigger magnitude and/or more frequently than before. Similarly, value for the optimized feedback coefficients $\beta_\pi$ and $\Theta_y$ are much larger in column 6a than in column 3a.

7.2.4 Policy Simulation III: Multiple policy objectives with exchange rate smoothing

This sub-section discusses the outcome when BNM puts exchange rate smoothing as one of its policy objectives ($\lambda_2 = 0.2$, refer to Table 7.2). Even though from results in Chapter 4 we cannot find concrete empirical evidence to suggest exchange rate smoothing is one of the policy objectives that BNM pursued during the 1975Q1-2005Q2 period,
here we try to simulate the impact to the economic outcomes if BNM put it into practice. For this purpose, we introduce three additional scenarios - Scenarios 2b, 3b and 4b. They produce three interesting results that we discuss below.

First, introducing exchange rate smoothing as an additional policy objective in BNM’s loss function fulfills its purpose in stabilizing the real exchange rate movement. From comparing the results between column 1b vs. 2b and 6a vs. 4b of Table 7.1(i) and 7.2(i), the standard deviation for RER is much lower for the cases when \( \lambda_2 = 0.2 \) than the outcomes when \( \lambda_2 = 0 \). Consistent with Svensson’s suggestion that strict inflation targeting will cause excessive exchange rate movement, the biggest decline in the RER volatility is shown when BNM moves way from the strict inflation targeting (column 1b vs. 2b). In that case, moving to the dual monetary policy objectives - stabilizing inflation and smoothing the real exchange rate - reduces the standard deviation for RER by almost 15\% (from 0.105 to 0.090). To further support Svensson’s suggestion, we find the magnitude of reduction in the RER volatility declines when the initial BNM’s policy preference is not strict inflation targeting. Comparing the outcome between columns 6a and 4b, introducing RER smoothing as an additional objective when \( \lambda_1, \lambda_3 > 0 \), only reduces RER volatility by about 3\% (from 0.094 to 0.091).

Second, there is a trade-off between the exchange rate and the interest rate stability. While introducing exchange rate smoothing as an additional policy preference is successful to stabilize the exchange rate, it leads to a more volatile interest rate. From comparing results between columns 1b and 2b, interest rate volatility increases by almost 40\% to 0.021 (from 0.015 in 1b) in the latter. This situation is not unique only to the situation when BNM moves away from being a strict inflation targeter in favour for dual policy targets (inflation and exchange rate). Similar effects can also be seen from comparing the results between column 6a vs. 4b, a situation when BNM has multiple objectives as its initial policy preference (i.e. \( \lambda_1, \lambda_3 > 0 \)).

Lastly, what happens when BNM tries to mitigate the trade-off between interest and exchange rate volatility by setting a positive value for parameter \( \lambda_3 \)? The outcome from this policy preference can be seen in the results of column 3b. Compared to the outcome in column 2b, the policy preference like Scenario 3b only solves half of the problem. While interest rates become more stable (to 0.017 from 0.021) when BNM increases its preference to smooth interest rates, the action causes a higher volatility in the RER (to 0.096 from 0.090). This indicates BNM cannot have the best of both
worlds. Putting interest rate smoothing together with exchange rate smoothing as joint policy objectives does not work as well as if only each objective is introduced one at a time.

There are two interrelated explanations to the above findings.

The first explanation is related to the point we mentioned earlier - about the role of RER as an automatic stabilizer in the economy. This can be easily explained by looking at the UIP condition that governed the RER movement in our model (UIP condition: \( \text{rer}_{t+1} - \text{rer}_t = (r_t - E_t\pi_{t+1}) - (r_t^* - E_t\pi_t^* + \psi_Bz_t + A_t^{UIP}) \)). Suppose there is an increase in the expected inflation (\( \uparrow E_t\pi_{t+1} \)). Without a policy objective to smooth the exchange rate (\( \lambda_2 = 0 \)), holding other factors constant, an increase in expected inflation will cause the real exchange rate to appreciate (\( \downarrow \text{rer}_{t+1} \)). This puts downward pressure on inflation and as such, the central bank does not need to raise interest rates as much to bring the economy back into equilibrium. In contrast, with a policy objective to smooth the exchange rate (\( \lambda_2 = 0.2 \)), the real exchange rate is not allowed to appreciate as much and this reduces the contractionary effect from the exchange rate channel to bring down inflation. Thus, to bring out the same adjustment effect to stabilize inflation, the central bank needs to raise interest rates with a bigger magnitude. This leads to increased interest rate volatility.

Second, attempts to smooth the real exchange rate requires BNM to respond to many factors. Note that, besides domestic interest rates and expected inflation, other variables in the UIP condition like foreign interest rates, foreign inflation and net foreign assets can move the real exchange rate too. Since it tries to smooth RER movement, BNM needs to respond to counter these destabilizing effects, by changing interest rates. Thus, interest rates must be used more frequently and aggressively. As a result, it becomes more volatile. The active use of interest rates as the tool to smooth exchange rate movement is reflected in the size of optimized HMT coefficients (see part (ii) of both tables). In all cases when \( \lambda_2 > 0 \), size for parameter \( \rho \) is very small. It indicates that with the policy objective to smooth exchange rate movement, BNM needs to change interest rates more aggressively. Similarly, the same case applies to the feedback coefficients \( \beta_\pi \) and \( \Theta_y \). Trying to smooth RER movement requires BNM to respond more forcefully to inflation and output gap.

Given the above outcomes, should BNM have put exchange rate smoothing as one of its policy objectives during the 1975Q1-2005Q2 period? We view there is not much benefit
to this choice of policy preference. Comparing the results between column 6a and 4b indicates putting $\lambda_2 = 0.2$ in the latter only produces marginal improvement to the RER and output stability. This improvement comes at the expense of higher interest rates and inflation volatility. Most importantly, value of loss function for Scenario 6a is smaller than what is produced in Scenario 4b. Thus, it is fairly obvious which of these two sets of policy preferences should have been favoured by BNM during the 1975Q1-2005Q2 period.

7.3 Conclusion

In this chapter, we “replay” history by conducting simulation exercises to answer this question - what would have happened to Malaysia’s economic outcomes during the 1975Q1-2005Q2 period if BNM was to change its policy preferences in conducting monetary policy? We conduct this policy experiment by varying the parameters of BNM’s loss function. Then, by assuming monetary policy is conducted through the optimized interest rate rule, the estimated DSGE model for the 1975Q1-2005Q2 period is used as a workhorse to provide the likely outcomes of this different policy behaviour. All in all, these simulation results have given us a good idea on how Malaysia’s economic outcomes during the 1975Q1-2005Q2 would have changed if BNM behaved differently during that period.

The simulation exercises produce several interesting outcomes. On the policy action, there are differences between the estimated and optimized reaction function. In all cases, in order to produce better economic outcomes, the optimized HMT rule recommends that BNM respond more strongly to inflation and less strongly to output gap than what has been practiced in the past. The optimized rule also suggests a lower degree of interest rate smoothing. In relation to policy preferences, the results suggest that strict inflation targeting is not a good policy option to be practiced in Malaysia. Except for inflation, strict inflation targeting produces high volatility in other macro-economic variables. Thus, policy preferences with multiple objectives turns out to be a better option to BNM. In doing so, we suggest BNM should always place the inflation objective ahead of other policy objectives that it wants to pursue. It will produce better economic outcomes than the choice of policy preference that we estimated BNM practiced in the past.
We also analyze the possible impact to the economic outcomes if BNM changed its relative policy preferences. When BNM raises its policy preference parameter to smooth interest rates in order to stabilize the Malaysian financial system, such action will not give much detrimental impact to the overall stability of the Malaysian economy. However, the consequence to this policy change is the rise in the volatility of the real exchange rate. On this development, we suggest BNM should not take countermeasure action by intervening directly in the exchange rate market. BNM should allow the change in the real exchange rate to gravitate smooth adjustment to take place in the economy. Similarly, an increase in BNM’s preference for output stabilization produces favourable economic outcomes. However, in order to accommodate this policy preference, BNM must be willing to move interest rates more aggressively.

Lastly, we conducted a simulation exercise to represent the situation if BNM puts exchange rate smoothing as one of its policy objectives. We find, when exchange rate smoothing is introduced as the additional policy objectives, it diminishes BNM’s ability to minimize interest rates volatility.
# 7.4 Appendix

Table 7.3: Summary of Log-linearized System of Equations

<table>
<thead>
<tr>
<th>Demand Side</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate Demand:</td>
<td>( y_{H,t} = \frac{c}{y_H} (1-\gamma) c_t + \frac{\tau}{y_H} (1-\gamma) inv_t + \gamma y_t^* + \eta \gamma \left( \frac{2-\gamma}{1-\gamma} \right) rer_t - \frac{\eta}{1-\gamma} lop_g_t )</td>
</tr>
<tr>
<td>Consumption:</td>
<td>( c_t - \Upsilon c_{t-1} = E_t (c_{t+1} - \Upsilon c_t) - (1-\Upsilon) (r_t - E_t \pi_{t+1}) )</td>
</tr>
</tbody>
</table>
| Investment: | \( r_{K,t} + q_t = \left(1 - \frac{(1-\delta)}{\pi_K} \right) r_{G,t} + \frac{(1-\delta)}{\pi_K} q_t \)  
\( q_t = \psi_t (inv_t - k_t) \)  
\( E_t r_{K,t+1} = r_t - E_t \pi_{t+1} - \chi(n_{t+1} - q_t - k_{t+1}) \) |

<table>
<thead>
<tr>
<th>Supply Side</th>
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<tbody>
<tr>
<td>Labour supply:</td>
<td>( l_{H,t} = \frac{1}{\Psi} \left[w_{H,t} - \frac{1}{1-\Psi} (c_t - \Upsilon c_{t-1})\right] )</td>
</tr>
</tbody>
</table>
| CPI inflation: | \( \pi_t = \frac{1}{\Gamma_{5,6}} \left[ \beta E_t \{\pi_{t+1}\} + \kappa \pi_{t-1} + (1-\gamma) \Lambda^H mc_{H,t} + \gamma \Lambda^F log_t \right] \)  
(\text{with } \Lambda^H = \frac{(1-\beta \eta)(1-\theta K)}{\tau_{mc}} \text{ and } \Lambda^F = \frac{(1-\beta \eta)(1-\theta F)}{\tau_{mc}}) |
| Production function: | \( y_{H,t} = \alpha k_t + (1-\alpha) \Omega l_{H,t} + A_t^Y \) |
| Cost of factor inputs: | \( r_{G,t} = y_{H,t} + mc_{H,t} - k_t - \left(\frac{\gamma}{1-\gamma} (rer_t - lopg_t)\right) \)  
\( w_{H,t} = y_{H,t} + mc_{H,t} - l_{H,t} - \left(\frac{\gamma}{1-\gamma} (rer_t - lopg_t)\right) \)  
\( w_{E,t} = y_{H,t} + mc_{H,t} - \left(\frac{\gamma}{1-\gamma} (rer_t - lopg_t)\right) \) |
| LOPG: | \( lopg_t = \rho_{LOPG} log_{t-1} + \varepsilon_t^{LOPG} \) |

<table>
<thead>
<tr>
<th>Other State Variables</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RER:</td>
<td>( rer_{t+1} - rer_t = (r_t - E_t \pi_{t+1}) - (r^<em>_t - E_t \pi^</em>_t) + \psi_B z_t + A_t^{UIP} )</td>
</tr>
<tr>
<td>Capital accumulation:</td>
<td>( k_{t+1} = \delta inv_t + (1-\delta) k_t )</td>
</tr>
</tbody>
</table>
| Net-worth: | \( n_{t+1} = (\Gamma_5 + 1) \frac{w_{E,t}}{K} + \kappa \frac{r_{K,t}}{\gamma} (r_t - \pi_t) - \chi \Gamma_6 (q_t - k_t) + \chi (\Gamma_5 + 1) n_t \)  
(\text{with } \Gamma_5 = \frac{\kappa}{\gamma} - 1) |
| Net foreign assets: | \( z_t = \frac{1}{\beta} z_{t-1} + y_{H,t} - (c_t + inv_t) - \left(\frac{\gamma}{1-\gamma} (rer_t - lopg_t)\right) \) |

<table>
<thead>
<tr>
<th>Foreign Block</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>( y_t^* = \mu_{y^<em>} y^</em><em>{t-1} + \varepsilon</em>{y^*} )</td>
</tr>
<tr>
<td>Interest rates</td>
<td>( i_t^* = \mu_{i^<em>} i^</em><em>{t-1} + \varepsilon</em>{i^*} )</td>
</tr>
<tr>
<td>Net-worth:</td>
<td>( \pi_t^* = \mu_{\pi^<em>} \pi^</em><em>{t-1} + \varepsilon</em>{\pi^*} )</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Shocks process</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>UIP</td>
<td>( A_{t+1}^{UIP} = \rho_{UIP} A_t^{UIP} + \varepsilon_t^{UIP} )</td>
</tr>
<tr>
<td>Productivity</td>
<td>( A_t^Y = \rho_Y A_{t-1}^Y + \varepsilon_t^Y )</td>
</tr>
</tbody>
</table>
Table 7.4: Parameter Value used in the Simulation Exercise  
Source: Estimation Results for 1975Q1-2005Q2 of Chapter 5  

| Estimated Parameters |  |
|----------------------|---------------------|---------------------|
| $\Upsilon$ Habit Persistence | 0.565 | $\rho_{LOPG}$ AR$(1)$: LOP shocks | 0.843 |
| $\Psi$ Inv. Elast. Lab. Sply. | 0.720 | $\rho_Y$ AR$(1)$: Tech. shocks | 0.885 |
| $\eta$ Elast. Sub. H/F Goods | 0.465 | $\sigma_{MP}$ S.D. MP shocks | 0.012 |
| $\kappa$ Price Indexation | 0.626 | $\sigma_{y^*}$ S.D. Foreign outp. shocks | 0.008 |
| $\theta_D$ Calvo pricing - domestic | 0.716 | $\sigma_{i^*}$ S.D. Foreign i/r shocks | 0.016 |
| $\theta_F$ Calvo pricing - imported | 0.738 | $\sigma_{\pi^*}$ S.D. Foreign infl. shocks | 0.008 |
| $\mu_{y^*}$ AR$(1)$: Foreign output | 0.881 | $\sigma_{UIP}$ S.D. UIP shocks | 0.020 |
| $\mu_{i^*}$ AR$(1)$: Foreign int. rate | 0.728 | $\sigma_{LOPG}$ S.D. LOP shocks | 0.020 |
| $\mu_{\pi^*}$ AR$(1)$: Foreign inflation | 0.904 | $\sigma_Y$ S.D. tech. shocks | 0.013 |
| $\rho_{UIP}$ AR$(1)$: UIP shocks | 0.751 | $\chi$ Fin. Accelerator | 0.032 |

<table>
<thead>
<tr>
<th>Fixed Parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$ Discount parameter</td>
<td>0.985</td>
</tr>
<tr>
<td>$\alpha$ Cap share in prod.</td>
<td>0.35</td>
</tr>
<tr>
<td>$\delta$ Depreciation rate</td>
<td>0.025</td>
</tr>
<tr>
<td>$\psi_I$ Capital adjustment cost</td>
<td>0.5</td>
</tr>
<tr>
<td>$\psi_B$ Elast. risk premium</td>
<td>0.01</td>
</tr>
<tr>
<td>$\zeta$ Prob. entrep. surviving</td>
<td>0.972</td>
</tr>
<tr>
<td>$\Omega$ Prop. entrep. labour</td>
<td>0.99</td>
</tr>
<tr>
<td>$\frac{\bar{K}}{N}$ Cap Net-worth ratio in SS</td>
<td>3</td>
</tr>
</tbody>
</table>
Chapter 8

Conclusion

Despite being one of the most influential and important participants in an overall economic system, central bank behaviour in arriving at monetary policy decisions is not yet fully understood by most non-policymakers. Hence, analysis of a central bank’s behaviour in formulating monetary policy is of considerable interest to both academic researchers and financial market participants. The current literature that analyzes central banks’ behaviour in formulating monetary policy is mainly concentrated on the experience of developed countries. In order to analyze how a central bank in developing countries executes its monetary policy task, this thesis applied the same analytical framework and estimation approaches to the case of Malaysia. Faced with a different economic structure and perhaps different economic objectives, this thesis explored the applicability of these approaches as a tool to analyze policymakers’ behaviour for a small, open and developing economy like Malaysia. In doing so, certain modifications on the current analytical framework have been made. Besides using the open economy set-up to represent the Malaysian economy, the thesis also explored the role of exchange rates in the overall conduct of monetary policy in Malaysia. It also investigated how Bank Negara Malaysia’s (BNM) behaviour changed over time in line with the change in Malaysia’s economic landscape. For this, besides using the full sample period of 1975Q1-2005Q2, estimation exercises using the sub-sample periods were also attempted.
This Conclusion Chapter is divided into two short sections. We start with discussions on information that we have gathered from the empirical exercises conducted in the previous chapters. The second section then suggests the main areas that could be suitable for a further research.

8.1 What Have We Learned?

8.1.1 Understanding BNM's Policy Behaviour

Empirical exercises in this thesis established a few important features which assist us to understand better BNM's behaviour in formulating monetary policy. Among them are:

1. **BNM’s reaction function and systematic components of interest rate movement**

   Results in Chapter 3, 5 and 6 indicate modelling BNM’s reaction function using a simple Henderson-McKibbin-Taylor (HMT) type interest rate rule tracks the interest rate movement in Malaysia generally well. This suggests the two macroeconomic variables that form the HMT interest rate rule - inflation and output gap - are the two main variables that influence the general interest rate movement in Malaysia. In addition, we also find BNM practices interest rate smoothing. Thus, the level of the interest rate for the last period plays a role too in influencing BNM’s interest rate decision. We also fail to find any empirical evidence to relate BNM’s reaction function and the movement of exchange rates. In terms of model specifications, estimated HMT interest rate rule with a backward looking specification performs poorly in tracking Malaysia’s historical interest rate. HMT rule with contemporaneous and forward-looking specification gives a better fit. This provides empirical evidence that BNM has always adopted a “forward-looking” approach in its policy making.

   However, we find one important caveat about analyzing BNM’s policy behaviour based on its estimated reaction function. Results of the estimated BNM’s reaction function are influenced by the way the HMT interest rate rule is
estimated. Results, when the HMT rule is estimated as a single equation (as in Chapter 3), are fairly different to the results when the same rule is estimated in the system of equations (as in Chapter 5 and 6). This difference in the estimation results between the two estimation methods becomes more apparent for the sub-sample periods. In some cases, the results contradict each other. Hence, this outcome should be used as admonition about the use of an estimated reaction function as a tool to analyze a central bank’s monetary policy behaviour. Having said that, we also acknowledged that both estimation methods have their own strengths and weaknesses. Thus, finding the absolute answer on which of the estimation methods produce a better outcome is not easy. As such, instead of trying to argue and select which method is better in generating the estimates of BNM’s reaction function, we take the view that the results of both methods should not be looked at in isolation. Both results should be used to complement each other as a tool to analyze BNM’s behaviour in formulation of monetary policy in Malaysia.

2. Objectives of monetary policy

Results in Chapter 4 indicate, based on its past policy action, BNM formulates monetary policy in order to fulfill three objectives - to achieve price stability, to stabilize output and to smooth the interest rate. This shows BNM does not adopt a strict inflation targeting framework. As results in Chapter 7 suggest, the strict inflation targeting is not a good policy option to be practiced in Malaysia. Except for inflation, strict inflation targeting produces high volatility to other macroeconomic variables. Thus, policy preferences with multiple objectives which has been practiced by BNM turns out to be a better option for the Malaysian economy.

3. BNM’s relative preferences between multiple objectives

Results in Chapter 4 also reveal important information about the way BNM balances the trade-off between price stability and output growth. BNM puts greater weight on attaining output stability ahead of stabilizing inflation. This finding reaffirms the proposition made by Tang (2006) that the objective of monetary policy in Malaysia is the attainment of sustainable economic growth with price stability.
In Chapter 7, we also analyze the possible impact on the economic outcomes if BNM were to change its relative policy preferences. When BNM raises its policy preference parameter to smooth interest rates in order to stabilize the Malaysian financial system, such action will not give much detrimental impact to the overall stability of the Malaysian economy. However, consequence to this policy change is the rise in the volatility of the real exchange rate. On this outcome, we suggest BNM should not take countermeasure action by intervening directly in the exchange rate market. BNM should allow the change in the real exchange rate to facilitate smooth adjustment to take place in the economy. Similarly, increase in the BNM’s preference for output stabilization produces favourable economic outcomes. However, in order to accommodate this policy preference, BNM must be willing to move interest rates more aggressively.

4. Role of the exchange rate in the conduct of monetary policy

Based on its past policy action, BNM is known to give much attention to the stability of exchange rate movement. There is lots of confusion among the non-policymakers about the role of the exchange rate to BNM. Is it a policy objective that BNM wanted to pursue or just another policy variable that BNM responded to? In this regard, in Chapter 4, we do not find concrete empirical evidence to indicate exchange rate stabilization is one of BNM’s policy objectives. So, what is actually the role of exchange rate stabilization to BNM? We propose another role for exchange rate smoothing in the conduct of monetary policy in Malaysia. BNM uses the stable real exchange rate environment as a means to achieve its other policy objectives.

In Chapter 7, we conducted a simulation exercise to represent the situation if BNM puts exchange rate smoothing as one of its policy objectives. We find, when exchange rate smoothing is introduced as the additional policy objective, it diminishes BNM’s ability to minimize interest rate volatility. Results of the simulation exercises also suggest this additional policy objective only produces marginal improvement to RER and output stability. This marginal improvement also comes at the expense of higher interest rates and inflation volatility. Thus, we view there is not much benefit to this choice of policy preference.
5. BNM's policy behaviour evolves over time

As well as using the full sample covering the 1975-2005 period, estimation exercises in this thesis were also conducted with three sub-sample periods - 1975Q1-1986Q4, 1987Q1-1998Q2 and 1998Q3-2005Q2. In most cases, estimation results of BNM's reaction function using sub-sample periods are fairly different to each other. Hence, this is empirical evidence to suggest BNM's decision rules and policy action was evolving over time.

By employing the standard approach used in the literature to model central banks behaviour, Chapter 4 models BNM's policy behaviour as the solution to the optimal control problem. The results indicate that this standard approach represents BNM's policy behaviour reasonably well. However, this representation is limited to the sample that excludes the September 1998-July 2005 period. During the period when the capital control and the fixed exchange rate regime was in place, this standard approach fails to generate any results. This suggests during the implementation of this controversial policy measure, BNM's behaviour in formulating monetary policy was "abnormal" and different to other periods that we considered.

Results using different sample periods other than 1998Q3-2005Q2 suggest parameters of BNM's loss function are also dependent on the choice of sample periods. The change in BNM's relative preferences over the period could be attributed to the change in its policy emphasis, in line with the evolution of the Malaysian economy. The results also show that BNM's relative preference to smooth output increases in the later period, suggesting BNM's desire to contain the economic overheating problem experienced during the first half of 1990s. In addition, the improvement in the overall monetary transmission mechanism as well as with the more resilient banking system during the post-1986 period, explains the marked decline in BNM's relative preference to smooth interest rates. Besides changing its relative preferences over different policy objectives, the results also suggest BNM has a lower implicit inflation target during the later period.

6. Policy evaluation

In general, the sound conduct of monetary policy requires that central banks always be aggressive in fighting inflation. Not only will such action put inflation
at bay, but also it benefits the aggregate stability of the economy in the form of lower output variability. In BNM’s case, we demonstrated the importance of this proposition in three ways:

- The importance of BNM to set interests rate according to the Taylor’s principle was reported in the estimation results of Chapter 3. Estimate for parameter $\beta_\pi$ (the feedback coefficient for inflation), during the period of 1975-1986 is small and is not statistically significant. BNM’s failure to comply with the Taylor’s principle during this period caused inflation to be much higher and volatile than what was experienced during the later period. Inflation during 1975-1986 remained high for an extended period and peaked at 10.5% in Q2 1984 (refer to table and graph in Figure 3.2 of Chapter 3 for details).

- On the policy action, results in Chapter 7 indicate there are differences between the estimated and optimized reaction function. In all cases, in order to produce better economic outcomes, the optimized HMT rule recommends BNM to respond more strongly to inflation and less strongly to output gap than what has been practiced in the past. The optimized rule also suggests a lower degree of interest rate smoothing.

- In term of policy preferences, we also find the ordering of price stability objective in BNM’s preference has an important role in influencing the overall economic outcomes in Malaysia. In particular, overall economic condition generally becomes more stable when BNM ranks inflation ahead of other policy variables.

To sum up, the main objective of this thesis is to increase our general understanding of BNM’s behaviour in formulating and conducting monetary policy in Malaysia. To some extent, as we listed above, we think this objective has been achieved. Hopefully, the better understanding of BNM’s policy behaviour, which we bring out in this thesis, will provide a helpful guide to the non-policymakers to better comprehend, rationalize and predict BNM’s policy action in the future.
8.1.2 Estimated DSGE Model for the Malaysian Economy

A by-product of our main motivations to better understand BNM’s policy behaviour, is the outcome of an estimated DSGE model for the Malaysian economy. In Chapter 5 and 6, using a Bayesian methodology, we estimate a DSGE model for a small open economy with a financial accelerator for the 1975Q1-2005Q2 period and three sub-sample periods. We find estimates of the structural parameters for the Malaysian economy to be plausible and generally comparable to the values reported in the DSGE literature.

To investigate the stability of the structural parameters over time, the DSGE model in Chapter 6 is also estimated using the sub-sample periods. Comparing the estimation results across the three sub-sample periods, there is no evident sign to suggest estimates of structural parameters for the Malaysian economy change over time. While parameter estimates for HMT interest rate rule exhibit some changes and suggest the evolution of BNM’s policy behaviour over time, estimates of structural parameters like household’s preferences and Calvo pricing are found to be largely intact. Having said that, we also offer a caveat to this finding. Compared to the estimation results for the full sample period, estimates of structural parameters using the sub-sample periods are less accurate. Hence, analysis using the estimated DSGE model involving the sub-sample periods should be taken with care.

We also highlight another weakness on the estimation results of the structural parameters. Some of the estimated parameters are detected to suffer from identification problems. While we do not try to offer any solution to the identification problems that we found in our estimated DSGE model, we regard the results of this investigation beneficial in other ways. They reveal which of the estimated structural parameters from our model are less susceptible to the identification problems and hence can be used with greater confidence.

8.2 Limitations and Area for Further Research

Undoubtedly, this thesis contains several limitations and weaknesses. In this last section, we highlight some of them and provide suggestions for possible improvement in the future.
One of the main weaknesses that we think this thesis has is the assumption of linearity that we imposed in the overall model set-up. One area involving non-linearity is on specification of a central bank’s loss function and decision rule. For example, Nobay and Peel (2003) and Ruge-Murcia (2002, 2004), among others, challenge the assumption of a linear-quadratic loss function. Other studies also find empirical support for the presence of non-linearity in central bank interest rate reaction functions. This include Kim, Osborn, and Sensier (2004), Bec, Salem, and Collard (2002) and Dolado, Maria-Dolores, and Ruge-Murcia (2004). This approach could be useful to represent BNM’s monetary policy behaviour during 1998Q3-2005Q2, the period when the capital control and fixed exchange rate regime was imposed. For example, instead of using a dummy variables approach as we did in Chapter 3, the use of a non-linear reaction function approach to represent BNM’s decision rule during this period can be attempted. Similarly, to get a clearer picture about BNM’s policy objectives and relative preferences during the 1998Q3-2005Q2 period, the use of a non-linear loss function as suggested by Nobay and Peel (2003) can be included in the model set-up of Chapter 4.

In a much broader scope, simplicity of linearity to represent development of a developing economy like Malaysia has a few limitations. For example, Lim and McNelis (2008) state that the use of the first-order perturbation methods such as the standard log-linearization approach of the Euler equations in the DSGE model, by construction, approximates the solution around the deterministic steady state and it is only valid within a specific (local) radius of convergence. Hence, this method assumes the shocks must be small. For a developing country like Malaysia, which experienced continuous expansion and major economic transformation over the relatively short period, the use of this method may not be very suitable. The assumption of a developing economy reaching a deterministic “steady state” is too simplistic. Furthermore, many of the shocks or policy changes facing policymakers in the developing economies hardly represent small or “local” departures or movement around a steady state (McNelis (2001)). Thus, McNelis argues the use of a non-linear model may be more applicable to the case of a developing country. Perhaps, this can be attempted in the future.

Another interesting area that can be looked at is the issue regarding stability of structural parameters over time. This could be an important issue for policymakers in developing economies, which experience rapid economic transformation. Thus, it is likely that the deep parameters could also change in line with the change in the economic structure. While our results in Chapter 5 do not find any evidence to
suggest this has happened in the case of Malaysia, we acknowledged the fact that the
method we used to establish this conclusion is quite simple. We estimate the DSGE
model with sub-sample periods which involve shorter sample points. Due to this factor,
Bayesian estimates using the sub-sample periods were generated with less accuracy and
this creates some doubt on our suggestion that the estimates of deep parameters for
the Malaysian economy were constant. Thus, to verify our finding, the approach used
in Fernández-Villaverde and Rubio-Ramírez (2007), which involves the introduction of
a dedicated parameter drifting mechanism, should be attempted.

Despite all of these caveats, this thesis has presented a range of results that could be
helpful to the non-policymakers to get a general understanding about the behaviour of
Bank Negara Malaysia in formulating monetary policy for the past 30 years. Perhaps,
with the extension that we suggested above, the current understanding that we have
about this topic could be further enhanced in future research.
Bibliography


227


230
KAM, T., K. LEES, AND P. LIU (Forthcoming): “Uncovering the Hit List of Small Inflation Targeters: A Bayesian Structural Analysis,” *Journal of Money, Credit and Banking*.


Definition and Source of Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$GDP_t$</td>
<td>Real GDP for the quarter, in RM billion</td>
<td>1975Q1-1986Q4 - Abeyasinghe and Lee (1998) # 1987Q1 onwards - MSB</td>
</tr>
<tr>
<td>$GDP^*_t$</td>
<td>Potential output for the quarter, in RM billion</td>
<td>Estimated by Hodrick-Prescott filter</td>
</tr>
<tr>
<td>$y_t$</td>
<td>Output gap for the quarter in %</td>
<td>Defined as $\left(\frac{GDP_t}{GDP^*_t}\right) - 1 \times 100$</td>
</tr>
<tr>
<td>$P_t$</td>
<td>Consumer Price Index at end of quarter</td>
<td>MSB</td>
</tr>
<tr>
<td>$\pi_t$</td>
<td>Inflation rate for the quarter in %</td>
<td>Defined as $\left(\frac{P_t}{P_{t-1}}\right) - 1 \times 100$</td>
</tr>
<tr>
<td>$r_t$</td>
<td>1975Q1-1978Q4 3-month Treasury Bills in % 1979Q1 onwards 3-month Interbank rate in %</td>
<td>MSB (average for the quarter)</td>
</tr>
<tr>
<td>$Q_t$</td>
<td>Index of Real Exchange Rate for the quarter</td>
<td>International Financial Statistics (IFS)</td>
</tr>
<tr>
<td>$Q^*_t$</td>
<td>Index of Equilibrium Real Exchange Rate</td>
<td>Estimated by Hodrick-Prescott filter</td>
</tr>
<tr>
<td>$RER_t$</td>
<td>Deviation of real exchange rate from its equilibrium level for the quarter, in %</td>
<td>Defined as $\left(\frac{Q_t}{Q^*_t}\right) - 1 \times 100$</td>
</tr>
<tr>
<td>$M3$</td>
<td>Broad Money Supply, in log</td>
<td>MSB (outstanding at end quarter)</td>
</tr>
<tr>
<td>$y^*_t$</td>
<td>US’s output gap for the quarter in %</td>
<td>IFS</td>
</tr>
<tr>
<td>$\pi^*_t$</td>
<td>US’s inflation rate for the quarter in %</td>
<td>IFS</td>
</tr>
<tr>
<td>$r^*_t$</td>
<td>US’s 3-month interbank rate for the quarter in %</td>
<td>IFS</td>
</tr>
<tr>
<td>$com_t$</td>
<td>Index of World Oil Price, in log</td>
<td>IFS</td>
</tr>
</tbody>
</table>

# Data for Malaysia’s quarterly GDP is only available from 1987 onwards. Abeyasinghe and Lee (1998) apply interpolation method to estimate Malaysia’s quarterly data from 1973Q1.

MSB - Monthly Statistical Bulletin, published by Bank Negara Malaysia
IFS - International Financial Statistics, published by International Monetary Fund (IMF)

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