MACROECONOMIC FLUCTUATIONS IN A SMALL OPEN ECONOMY OF MALAYSIA

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FACULTY OF ECONOMICS AND ADMINISTRATION
UNIVERSITI MALAYA
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THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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ABSTRACT

This thesis examines the sources of macroeconomic fluctuations in a small open economy of Malaysia by utilizing a dynamic stochastic general equilibrium model (DSGE) based on the New Keynesian framework. The model incorporates various features such as external habit formation, internal investment adjustment cost, variable capacity utilization, domestically produced goods prices and wages stickiness, incomplete exchange rate pass-through, and financial accelerator. The model is log-linearized, parameters are estimated with Bayesian techniques, calibrated, and simulated and subjected to several exogenous shocks. The dynamic movements of key macroeconomic variables in response to these disturbances are analyzed using the impulse response functions and the sources of macroeconomic fluctuations are examined through the variance decomposition. The results from the variance decomposition show analysis indicate that, both monetary policy shock and technology shock are the main driving forces of macroeconomic fluctuations of the real sector's variables (output, consumption, investment) and nominal variables (inflation, nominal interest rates, real exchange rate). The results also suggest that domestic shocks play a more significant role as sources of macroeconomic fluctuations in the model than do foreign shocks.

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ABSTRAK

Tesis ini mengkaji sumber turun naik ekonomi makro dalam ekonomi terbuka kecil Malaysia dengan menggunakan model keseimbangan umum stokastik dinamik (DSGE) berdasarkan kerangka Keynesian Baru. Model ini merangkumi pelbagai ciri seperti pembentukan tabiat luaran, kos pelarasan pelaburan dalaman, penggunaan kapasiti berubah, harga barang yang dihasilkan dalam negeri dan ketahanan upah, "pass-through" kadar pertukaran yang tidak sempurna, dan pemecut kewangan. Model ini dilaras log, parameter dianggarkan dengan kaedah Bayesian, dikalibrasi, dan disimulasikan dan tertakluk kepada beberapa kejutan eksogenous. Pergerakan dinamik pemboleh ubah makroekonomi utama sebagai tindak balas terhadap gangguan ini dianalisis dengan menggunakan fungsi tindak balas impuls dan sumber turun naik makroekonomi diperiksa melalui penguraian varians. Hasil dari analisis menunjukkan penguraian varians menunjukkan bahawa, kedua-dua kejutan dasar monetari dan kejutan teknologi adalah kekuatan pendorong utama turun naik makroekonomi dari pemboleh ubah sektor benar (output, penggunaan, pelaburan) dan pemboleh ubah nominal (inflasi, kadar faedah nominal, kadar pertukaran benar). Keputusan kajian ini juga menunjukkan bahawa kejutan dalam domestik memainkan peranan yang lebih penting sebagai sumber turun naik ekonomi makro dalam model daripada kejutan asing.

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INTRODUCTION

1.1 Background of the Study

Macroeconomic fluctuations, or business cycles, are common phenomena in both developed and developing economies. Scholars and policy makers have found it important to understand and distinguish between the various sources of disturbances affecting macroeconomic fluctuations. To maintain economic stability of a country, policy makers need to understand and identify the causes or the sources of macroeconomic fluctuations when designing, choosing and implementing effective macro policies. Accordingly, the issues of short-run macroeconomic fluctuations and long-run economic growth have taken centre stage in the discussions among economists and policy makers.

The literature of modelling macroeconomic fluctuations or business cycles is rich. There are various approaches employed by economists in this literature. Among the popular approaches are structural vector autoregression (SVAR) and dynamic stochastic general equilibrium (DSGE) models. In this study, I use the latter approach. During the last thirty years, the modeling of macroeconomic fluctuations has evolved dramatically. In their seminal paper, Kydland and Prescott (1982) developed a new type of model in which private agents exhibit optimizing behavior, embrace rational expectations and act within a Dynamic Stochastic General Equilibrium (DSGE) structure. Their method, known as Real Business Cycle (RBC) theory became one of the major toolboxes of macroeconomic research for the whole of 1980s. Even though the RBC models include rational expectations to successfully avoid "Lucas Critique", they were criticized for their

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unrealistic modeling settings and arbitrary calibration method. In the 1990s, the New Keynesian DSGE model was come into existence to rectify these inadequacies, by introducing a wider and more realistic set of assumptions.

The incorporation of a strong theoretical structure, with a good empirical fit, has changed New Keynesian DSGE models into one of the most widely used tools for modern macroeconomic modelling and the workhorses of modern macroeconomics. The DSGE methodology has proven to be useful in explaining economic growth, for analyzing macroeconomic fluctuations or business cycles, and for quantitative analysis of monetary and fiscal policies. Moreover, these types of models are particularly suitable for policy simulation exercises as they are, in principle, robust against the Lucas critique. The attractiveness of the DSGE models has captured the interest not only of those in the academia but also a number of policy-making institutions which use them as an input for their activities. Some examples are the International Monetary Fund (IMF), the European Commission, central banks from developed countries such as the Bank of Sweden, the Bank of Finland, the Bank of England, the European Central Bank (ECB), and the Federal Reserve Board (FED).

Among the examples of the DSGE literature which cover the experiences of developing economies in macroeconomic fluctuations or business cycle fluctuations are studies by Medina and Soto (2006, 2007) for Chile; Castilla et al. (2006) for Peru; Kose, and Riezman (2001) for African countries and Hirata et al. (2007) for MENA countries. In the case of Malaysia, there are only a few studies conducted including the research done by Ramayandi (2008), Shaari (2008) and Alp et al. (2012). Ramayandi (2008) used the DSGE model to examine the monetary policy transmission mechanism for each of the five ASEAN countries (including Malaysia), based on the maximum likelihood

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estimation (MLE) approach. Whereas, Shaari (2008) developed an open economy DSGE model which specifically studied the behavioral patterns of central bank monetary reaction-function in formulating monetary policy. The model was estimated using Bayesian techniques. In the case of Alp et al. (2012), their study focused more on the counter-cyclical role played by the Bank Negara Malaysia in conducting its monetary policy during the global financial crisis of 2008–09. In other study for Malaysia, Mansor H. Ibrahim (2013) employed a vector autoregressive (VAR) model to analyze the international influences on macroeconomic fluctuations. Overall, there is not much work been done on the study on macroeconomic fluctuations especially using DSGE modelling framework for Malaysia until recent time. Be it at the university level or research institutions in Malaysia.

1.2 Scope of the Study

This research work analyzes the sources of macroeconomic or business cycle fluctuations in Malaysia as a small open-developing economy. The empirical study of the macroeconomic fluctuations, in the contemporary macroeconomic literature - some which are mentioned above, usually follows several approaches. The most common approaches adopted by academicians and economists are Structural Vector Auto-Regression (SVAR) and Dynamic Stochastic General Equilibrium (DSGE). In the case of Malaysia, Mansor H. Ibrahim (2013) used Vector Auto-Regression (VAR) method. In contrast, the research work of this study is based on the DSGE approach. For its analysis, I’ve constructed a small open economy DSGE model which the literature has referred to as a New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model.

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1.3 Statement of the Problem

It is well documented that most of the research and study of sources of macroeconomic and business cycle fluctuations concentrate on advanced countries. However, research using the methods of DSGE modeling or modern business cycle theory in emerging economies is relatively limited. As there is no attempt by the previous studies to analyze the sources of business cycle fluctuations in Malaysia, this research is an attempt to fill this gap by analyzing in detail the main determinants of macroeconomic fluctuations in the Malaysian economy. In this study, the fluctuations of the Malaysian economy are examined using a small open economy model based on the New Keynesian DSGE approach.

1.4 Justification of the Study

In this study, a Dynamic Stochastic General Equilibrium (DSGE) model based on the New Keynesian framework is used to study macroeconomic fluctuations in Malaysia. Most of the research and study of sources of macroeconomic and business cycle fluctuations concentrate on advanced countries. There is a scarcity of studies using the DGSE framework to analyze the sources of business cycle fluctuations in Malaysia. This research is an attempt to fill this gap by analyzing in detail the main determinants of macroeconomic fluctuations for the Malaysia economy, using a Dynamic Stochastic General Equilibrium (DSGE) model based on the New Keynesian framework.

The distinctive characteristic of these models is that they are explicitly derived from micro-economic foundations and from first concepts or principles. They depict the general equilibrium allocations and prices of the economy in which the representative agents of households and firms behave in such a way that optimizes their objective functions, such as utility and profits, subject to their respective budget or resource

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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. According to Tovar (2009, p. 1), "DSGE models are 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 counterfactual experiments."

1.5 Research Goal and Objectives

The goal of the study is to empirically analyze macroeconomic fluctuations in Malaysia using an open economy DSGE model based on the New Keynesian framework.

The key research questions in this study are as follows:-

- What are the main structural shocks or driving forces that cause the short-term or long-term movements in key macroeconomic variables in Malaysia?
- How do business cycle fluctuations affect the Malaysian economy? In other words, what is the macroeconomic adjustment of Malaysian economy to various exogenous shocks?

The objectives are as follows:-

- To analyze what are the main structural shocks that cause the movements or fluctuations of Malaysia's key macroeconomic variables. In this study, the structural shocks include: technology shock in the domestically produced goods sector, monetary policy shock, and risk premium shock (UIP), as well as external shocks such as foreign interest rates shocks, foreign inflation shocks and foreign output shocks. The macroeconomic

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variables in our analysis are: output (GDP), consumption, investment, inflation, domestic nominal interest rate and real exchange rate.

- To analyze how key macroeconomic variables adjust or response to various exogenous shocks in order to establish how these key variables adjust to shocks to the economy.

1.6 Significance of the Study

The main contribution of this thesis to the literature is the application of a New Keynesian DSGE model to study macroeconomic fluctuations in Malaysia. Also, this study attempts to demonstrate to what extent the empirical evidences found in developed countries is consistent with small open developing countries such as Malaysia. The model and methods used will enable us to examine how well the dynamic properties of the model fit the New Keynesian framework developed for the Malaysian macroeconomic model. This study aims to provide new evidences and shed light on the use of macroeconomic policies to stabilize small open economies.

1.7 Theoretical and Conceptual Framework

The framework or the structure of the model used in this study is adapted based on the model developed by Shaari (2008), Gali and Monacelli (2005) and is modified to include the financial accelerator mechanism from Bernanke et al. (1999). The model assumes that there is a large number of real and nominal frictions common to the New Keynesian DSGE literature as it is required to capture the empirical persistence presented by the macroeconomic model and ensure smooth and realistic responses to shocks. These frictions are sticky prices, sticky wages, variable capital utilization, capital adjustment costs and habit persistence. Furthermore, financial frictions or financial market imperfections are also been taken into account to study their effects on real

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macroeconomic equilibrium and the transmission mechanisms through which exogenous shocks are channeled to the real economy.

The DSGE model assumes the existence of four major economic agents, operating within the home economy. These are households, entrepreneurs, retailers and the monetary authority. Households consume and supply labour to producing firms in return to wages. Producing firms use the capital services rented out by entrepreneurs and the labour supplied by households and entrepreneurs to produce domestic goods consumed locally and exported on world market. Capital producing firms produce and sell capital goods to entrepreneurs on competitive markets. Retailers consist of home and foreign good retailers. Home good retailers reallocate goods produced by the home good producers whereas, the foreign goods retailers purchase the products from foreign producers at the wholesale price reallocate to domestic economy. Monetary authority sets interest rate following the Taylor rule.

1.8 The Methodology

The constructed DSGE models consist of systems of equations that are non-linear in nature that do not have closed-form solutions. A solution to the dynamic DSGE models can be found using empirical methods. Since the models do not have exact solutions in closed-form, a practicable approximation is employed through a log-linear transformation. This transformation is achieved using a first-order Taylor approximation of the model around its steady state-value. Then the log-linearized DSGE model is solved and Bayesian estimation method is used to estimate and calibrate the parameters of the model.

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This process is done by using the DYNARE program. The DYNARE (pre-processor) is a set of MATLAB codes that are used to solve, simulate and estimate DSGE models. Once the system is solved, a simulation analysis is performed. The variance decomposition analysis is used to analyze the relative contributions of the shocks to the system i.e. to identify the main causal driving forces in the macroeconomic variables movement. Lastly, the impulse response analysis to analyze how key macroeconomic variables adjust or response to various exogenous shocks.

1.9 Data Source

For the estimation of the models' parameters, quarterly data from Malaysia and the USA (as a proxy for the foreign economy) are used. The Malaysian data used are real output (GDP), CPI index, nominal interest rate (Money Market Rate) and index of the Real Exchange Rate and the data are obtained from the IMF IFS's online database. The USA data used are real output, CPI index, and nominal interest rate (Federal Fund rate) and the data are retrieved from FRED, Federal Reserve Bank of St. Louis. The sample period for the estimation of the DSGE model is 1992Q1 to 2020Q4.

1.10 Organization of the Study

This thesis consists of five chapters. The current chapter sets the background and motivation for the thesis. Chapter 2 reviews the literature on the theory and empirical evidence on macroeconomic fluctuations in developed and developing economies. Chapter 3 develops the theoretical dynamic stochastic general equilibrium model that tailors the unified framework of this thesis. Chapter 4 presents the Bayesian estimation methodology, impulse response and variance decomposition analyses of the DSGE. Lastly, Chapter 5 summarizes the findings of the thesis and draws several conclusions, together with some recommendations for future study.

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Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature on the theoretical foundations of the sources of macroeconomic or business cycle fluctuations and also some related empirical studies. There are several methods for studying business cycle fluctuations and most have some common properties. Among these properties is that there is always a primary driving force behind the economic fluctuations. Other factors, such as various kinds of shocks, frictions, or disturbances also play an important role in contributing to the cycle. Moreover, it is commonly known that the cycle is usually based on a propagation mechanism that amplifies and converts short-lived shocks into large and persistent economic fluctuations.

This study provides a short review of the literature on business cycle fluctuations based on certain basic propositions by different schools of thought. Among these are the Classical School (CS), Keynesian School (KS), New Classical School (NCS), Real Business Cycle (RBC) and New Keynesian School (NKS).

2.1.1 The Classical School of Thought

The classical model does not explain observed business cycles since according to this model output is entirely determined by the supply side of the economy. In other words, in a static model, capital is fixed and output is determined by the equilibrium quantity of labor (as determined in the labor market) and the production function. In this

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way, the aggregate supply function (AS) is perfectly inelastic (vertical in the output-price space); the aggregate demand function (AD) is downward sloping. Thus, a right/left shift in the AD curve would only produce price increases/reductions respectively but not changes in output. If there is an increase in money supply, for example, nothing happens to output and the excess aggregate demand will produce higher prices. Therefore, the fact that money is neutral is known as the classical dichotomy because money cannot affect any variable in the real sector of the economy. Obviously, the classical model does not provide an explanation for observed macro-fluctuations.

2.1.2 The Keynesian School of Thought

The failure of classical theory to provide convincing explanations for the Great Depression inspired Keynes to challenge the classical view. Keynes suggested several explanations for the Great Depression, which included aggregate supply and aggregate demand factors. Keynes argued that the classical theory's predictions about macroeconomic dynamics are relatively valid only in the long run but not in the short run. In the Keynesian view, markets are not efficient, and agents have imperfect information. Additionally, the adjustment from equilibrium to equilibrium takes time, unlike the classical theory's assumption of instant adjustment. Keynes opined that the short-term policy response is the most important, since “in the long run we are all dead.”

Two important assumptions, according to Keynesian theory, explain market inefficiency: (1) monetary impotence prevents demand from adjusting. This assumption basically asserts that real output fails to adjust to changes in the real money supply, and (2) labor supply fails to adjust because of rigid wages. The rigidity assumption is based

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on the assumption of nominal wages being downwardly “sticky”. This means that real wages do not immediately fall to restore equilibrium in the labor markets, but rather may immediately increase. As a result of this, supply and demand will determine the equilibrium of the economy. Keynesians recommend government intervention in order to stabilize aggregate demand in response to business cycle fluctuations. And this will minimize the negative effects of welfare loss caused by business cycle fluctuations. However, Keynesian views have been criticized widely for their inadequate microeconomic foundations, which in turn are related to the school’s theoretical assumptions. Thus, new lines of Keynesian thought, offering microeconomic foundations for Keynesian theory, began to emerge.

2.1.3 The Monetarist School of Thought

Basically the Monetarist school of thought is an extension to classical theory as explained by Friedman (1968) and followed by Lucas (1973). It is a part of the New-Classical School of thought. The theory responds to the criticisms aimed at the classical views that there is evidence of aggregate demand influence on the economy, and monetary variations precede output variations. Its primary argument was initiated to counter Keynesian arguments concerning the macroeconomic dynamics of the 1970s. The Keynesian view could not explain the recessions of 1970s. Unlike classical theory, monetarists distinguish between short-run and long-run implications of monetary policy. According to monetarists, monetary policy may have a significant effect on output and prices in the short-run. In fact, monetary variations are the main cause of aggregate demand variations in the short run. Two important assumptions are implied by early monetarists. The first is that the economy is efficient and thus the markets clear. The second is that economic agents have imperfect information or inaccurately perceive the economy situation. Furthermore, it takes these agents a long time to adjust

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or correct their misperceptions. Thus, this model is called “fooling model” or “adaptive expectations.” Friedman (1968) argued that a stable and permanent trade-off between inflation and unemployment (output) is not sustainable, but there is a short-run relationship between the speed of inflation acceleration and a temporary decline in the unemployment rate (output). However, in the long-run, there is only one unemployment rate - the natural rate of employment. Money is therefore neutral in the long run, and it only affects nominal variables: prices, total spending and interest rates. Monetarists, such as Friedman (1968), believe that short-run output fluctuations are predominantly caused by changes in money supply caused by monetary policy. They claimed that unstable money supply growth rates are the main cause of macroeconomic fluctuations in the short run.

2.1.4 New Classical Economics and Rational Expectations

The new classical economists believe that unanticipated changes in money supply cause output fluctuation only in the very short run. Rather than having adaptive expectations, they assume that agents have rational expectations, which means that agents cannot be systematically wrong. Lucas (1972, 1973) says that money has real effects because agents have imperfect information and, in the short run, they may confuse variations in the price level with variations in the relative prices. For example when an unanticipated increase in the money stock pushes the price level up, agents may react by increasing their output because they think that the demand for their products has risen. In the long run, however, agents get more information and modify their expectations. Therefore, the effect of unanticipated changes in money supply on output in the long-run are zero. Unanticipated money shocks have no effects on output. Hence, money is actually super-neutral in rational expectations models.

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2.1.5 The Real Business Cycle

The Real Business Cycle (RBC) theory is the latest articulation of the New Classical theory approach to economic fluctuations. It owes its origins to the pioneering work of Kydland and Prescott (1982), and Long and Plosser (1983). Kydland and Prescott would ultimately win the Nobel Memorial Prize in Economics in 2004 for their contribution to business cycles. The RBC model is a dynamic stochastic general equilibrium model, subject to persistent supply shocks in which economic fluctuations stem from inter-temporal substitution activities undertaken by representative, utility maximizing economic agents operating in competitive environments in response to aggregate supply shocks. The assumptions in RBC models are that all agents in the economy are homogeneous, rational optimizers that supply labour in frictionless, perfectly competitive economies with competitive markets. Exogenous stochastic real shocks, for example technological shocks, are the main driving force of business cycles. On the other hand, demand side shocks, such as those caused by monetary policy, have no real effect on output and employment. Therefore, business cycles are an equilibrium phenomenon and are optimal. RBC models also claim that monetary policy is neutral in that money supply has minimal (if any) effect on the real sector in the economy. It only affects inflation and therefore, in order to achieve and maintain price stability in the economy, the monetary authority needs to control the growth of money supply.

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2.1.6 The New Keynesians

New Keynesian (NK) theory provides microeconomic foundations for traditional Keynesian propositions of market failure *vis-a-vis* incomplete nominal price adjustment mechanisms. NK basically attempts to integrate Keynesian arguments with rational expectations, optimizing agents and microeconomic foundations. Their assumptions are that there exists imperfect competition (monopolistic competition) and nominal rigidities and that there are implied real effects of monetary policy. They claim that nominal shocks, such as changes in aggregate demand, are the main contributors to business cycles. Gali (2008) gives the details of the key NK micro-foundations:

- Monopolistic competition by Romer (1993): In the NK models, they assume that the firms use their market power to set and maintain their prices above marginal cost so that to maximize their objectives. Therefore, the existence of price stickiness is due to monopolistic competition.
- Nominal rigidities: Based on the micro-foundations, firms are subject to some constraints in which they can adjust the prices of goods and services they sell. According to menu costs by Mankiw (1985), there exist price sluggishness that caused the firms unable to adjust their prices immediately as they encounter menu costs that prevent them to do so. For the workers, they also facing the similar type of friction in the existing of sticky wages that explains why there exists persistent or involuntary unemployment (e.g. efficiency wage model)..
- In the NK models, price stickiness is the cause of non-neutrality of money. The NK economists argue that a variation in the nominal money supply or the nominal interest rate would not change the price level proportionately in the short run. In the short run money is not neutral due to the presence of nominal rigidities. Based on this argument, in the short run monetary policy has real impacts on output and employment through variations of real interest rates, consumption and investment.

In general, NK describes the distinctive features of the dynamic behavior of output, inflation and nominal interest rates. They have a similar view of the earlier generations of RBC in which technology shocks is perceived as a significant factor in

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forming the dynamic behavior of key macroeconomic variables (Ireland, 2004). The proponents of this school believe that there are other shocks could be important, especially the existence of nominal price rigidities. This is so since this element of price rigidities help dictate how different types of shock effect and transmitted through the economy. Their well-known model is called dynamic stochastic general equilibrium model (DSGE) and it is popular among scholars including Mankiw (1989), Clarida, Gali and Gertler (1999) and Negro and Schorfheide (2004).

2.2 Review of Empirical Literature

From empirical point of view, there are quite a number of study have been done on the sources and dynamics of macroeconomic fluctuations in both the developed and developing economies. These studies have been done using several methods and approaches, whether within the context of the DSGE framework, or the classical vector auto-regression framework, or others, such as the stylized facts framework. In relation to the research on the business cycle phenomenon, my research work will review some selective important empirical studies that use either the vector auto-regression (VAR) system or DSGE approach in order to identify the sources of shocks causing economic fluctuations in both developed and developing countries.

2.2.1 Business Cycles in Developed Countries

It is well documented that a lot of analysis in the business cycle literature has been done on the economies of developed countries, particularly on the U.S economy. This tendency is perhaps not unrelated to the event of the Great Depression, and subsequently to the Second World War from 1939 to 1945. Subsequently, Kydland and Prescott (1982) developed a real business cycle model that was based on the neoclassical growth model. Their model is very simplified and certain assumptions in

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the model were made in order to generate a real business cycle (RBC). This model is based on several assumptions, namely a perfectly competitive market system; labour and capital produce a single good; technology exhibits a constant returns to scale; consumers live infinitely and are identical in the economy; there exist exogenous stochastic shocks to the system in production technology. Their main research question focused on the specific parameters that describe the technology and preferences. Their findings claimed that the specific parameters in question tend to affect the movements induced in output, consumption and employment.

In the following study, Shapiro and Watson (1988) applied Kydland and Prescott (1982) framework to analyze what are the factors that contribute to business cycle frequency and long-run movements of output and prices. They asserted he contribution factor to variation in output in the long run were supply shocks such as shocks to technology, oil prices and labour. They also posited that variation in output the in short run could be due to real and monetary aggregate demand shocks. They subsequently used Structural Vector Autoregressive (SVAR) method to analyze the neo-classical model of long-term growth of the US economy and analyzed the time series properties of the data. They used seasonally adjusted quarterly time series data of the US economy spanning from 1951Q2 to 1987Q2. The variables in their model are hours worked, labour force, inflation, the nominal interest rate, output and real oil prices. Their findings claimed that supply shocks caused permanent effects on output and demand shocks caused nominal effect. Overall, Shapiro and Watson's study indicates the following stylized facts of their model: aggregate demand shocks are responsible for about twenty to thirty percent of output fluctuation in business cycles; technology shocks are responsible for about one-quarter of cyclical fluctuations and about one-third of output variance at low frequencies; about 20 to 30 percent of output fluctuation in business cycles are caused by aggregate demand shocks; about one-quarter of cyclical fluctuations and about one-third of output variance at low frequencies are caused by technology shocks; the variation in output during the 1970s and 1980s are due to shocks to oil prices; and lastly the balance of fluctuations in output, namely about half of its variance at all frequencies are caused by shocks that permanently affect labour input.

In a well-known paper, Blanchard and Quah (1989) used a structural Vector Auto-Regression (VAR) to study the primary sources of the U.S. business cycle fluctuations from 1954Q1–2001Q4. They identified aggregate supply and aggregate demand structural disturbances by assuming that demand shocks do not have a permanent (long-run) effect on real output and supply shocks have long-run effects on output. In essence, they applied a long run restriction that attributes permanent effects to supply factors such as technology shocks and temporary effects to demand factors. This long run exclusion restriction is broadly used in the macroeconomic fluctuation literature. They found that the main source of fluctuations in output was due to aggregate supply shocks over time, while demand shocks are stronger in the short run.

Mendoza (1991) studied a small open economy of Canada where the author analyzed the capability of a theoretical RBC model to replicate the stylized facts of the data. In this model the individual preferences of the discount factor is endogenized so that the preferences parameter depends on the past consumption. Mendoza asserted that making the beta discount factor parameter constant will cause either a non-stationary equilibrium "if the interest rate and the rate of time preferences are not preset to be equal, or if the two are equal, the economy is always at steady state equilibrium that is consistent with any initial level of foreign asset holdings." To allow some variability for the investment variable, the author added capital adjustment costs due to imperfect

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financial markets. The author employed the calibration method for all the parameters in the model and some of the parameter values used in the study were obtained from other studies. In the analysis, all the parameters in the model are calibrated and also some other parameters value were derived from other studies. The parameter value for the world real interest rate and productivity were obtained from Kydland and Prescott (1982). The author used annual data of the Canadian economy from 1946 to 1985. His findings did not support the importance of world real interest rate shocks in contributing for real business cycle fluctuations in the Canadian economy.

Mellander et al. (1992) analyzed the sources of macroeconomic fluctuations in Sweden based on the annual data from the years 1875 to 1986. They demonstrated how co-integration restrictions can be utilized in a restricted vector autoregressive system that included stochastic trends to identify the sources of economic fluctuation in the small open economy of Sweden. They showed how macroeconomic variables in their model responded in the short run to permanent disturbances, that is, to shocks to trends including transitory shocks in the case of Sweden. Their restricted VAR model comprised of four variables, namely, real GDP, real consumption, real investment, and terms of trade. In brief, while the study by Mellander et al. suggested that permanent real supply shocks have explained the majority of fluctuations in real GDP, transitory shocks have only explained most of the short-run movements in investment and terms of trade for the Swedish economy.

Karras (1993) investigated the macroeconomic fluctuations of the US economy from 1973 to 1989 based on the structural vector autoregressive method to analyze the significance of different types of shocks to the economy. There were six kinds of structural innovations or shocks in the model, namely oil, aggregate supply, fiscal,

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monetary, aggregate, and exchange rate disturbances. The findings demonstrated that output fluctuations both in the short-run and long-run were mainly caused by the supply-side shocks and these shocks have an impact on output permanently as predicted from the theory. In contrast, the demand-side of monetary policy shocks affect output temporary. The findings too showed that in the short-run inflation was affected by all the innovations, but changes in money supply has permanent effects on inflation. Fiscal and monetary policies were the main cause of the changes in US dollar exchange rate. The depreciation in the exchange rate was caused by the combination of faster money growth and higher budget deficits. Hence, their last findings were in contradict to the belief that dollar's appreciation was primarily caused by high budget deficits.

Ahmed and Murthy (1994) studied the key propositions of Real Business Cycles (RBC), particularly on the views of various sources of economic fluctuations for Canada in a small open economy framework. Their analysis was based on structural vector autoregressive (VAR) method and the model is estimated for the Canadian economy and the identification was achieved by imposing long-run restrictions, including the long-run neutrality of money. The long-run neutrality of money is consistent with both real business cycle models and monetary business cycle models in which the classical dichotomy holds in the long-run. The sample observation is from 1973Q1 to 1992Q4. Their findings suggested domestic supply shocks were the main factor that cause output fluctuations in the short run. The real interest rate and terms of trade changes are not. Their findings also revealed that in the short run, the primary cause of money-output correlation was the output shocks affecting inside money. Therefore, based on their analysis on the Canadian data, they rejected the view that there exist a correlation between the high-powered money or demand deposits and output.

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Ahmad and Park (1994) investigated the sources of macroeconomic fluctuations on a selected group of OECD small open economies. Based on an open economy framework, the analysis was carried out on Australia, Austria, Canada, Finland, France, Italy and the United Kingdom. They analyzed the relative contributions of domestic and external shocks in explaining fluctuations of macroeconomic variables in small open economies. The authors imposed long-run identifying restrictions in a structural VAR setting to recover structural external disturbances, as well as domestic disturbances consisting of demand, supply, and price shocks. However, they did not impose small open economy restrictions in the short run. Ahmad and Park concluded that output fluctuations were predominantly the result of supply shocks, and domestic demand shocks were a primary source of variation in the trade balance.

From the study of Clarida and Gali (1994), the authors extended this basic analysis of structural Vector Autoregressive to include short-term nominal shocks. They identified sources of real exchange rate fluctuations for post-Bretton Woods period for US, Japan, Germany, and Canada. In a three-variable structural VAR, they analyzed the impact of three aggregate shocks, namely, supply, demand, and nominal shocks. They classified the temporary nominal shocks by a price variable that is directly affected by nominal shocks in both the short and the long run. Their assumption was mainly derived from the long-run neutrality of nominal shocks which is a widespread practice in business cycle studies. However, they distinguished nominal shocks from demand shocks by showing that only demand shocks have a permanent effect on the real exchange rate. Consequently, nominal shocks can have a long-run effects only on the price level. They concluded that real shocks accounted for about ninety percent of output innovations and sixty percent of real exchange rate innovations respectively.

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Giannini et.al (1995) studied the business cycle fluctuations of the Italy economy, using quarterly data for the period between 1970Q1 to1990Q4. In their study, they developed a structural Vector Autoregressive model for five macroeconomic variables. The model was identified based on Keynesian setting. The structural shocks that been identified in the model able to produce dynamic simulation results that consistent with Keynesian view associated with behavior of data series in the model. The five structural shocks identified in the model are demand, supply, prices, wages and money. The findings revealed that in the short run demand shocks have significant effect on output fluctuations and lead to a temporary growth in prices and a drop in the unemployment rate. In the short and medium run, real supply shocks were the main contributing factor in explaining unemployment fluctuations, but they were not relevant in explaining the variation in other variables. The analysis of the Italian data suggested that wages behaved as a typical exogenous variable where fluctuations were almost entirely explained by their own shocks. Their study concluded that for the last two decades wages and prices were the important cause of business cycle fluctuations in the model, and that was consistent with the theoretical interpretation of the Italian economic facts.

Karras and Song (1996) studied the business cycle of twenty-four OECD countries. Their aims are to analyze as to what extent the output volatility is associated to a set of variables that consistent with a prevalent view of business-cycle theories. Based on annual data from the years 1960 to 1990, they conducted a regression analysis of twenty-four OECD countries. From their findings they concluded that output volatility is positively related to the variability of multifactor productivity as measured by the Solow residual, and this supports the Real Business Cycle (RBC) theory. The variation of the money supply is positively related to output volatility, and this consistent with monetarist views of the business cycle. The size of the government sector is negatively

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related to output volatility and this associated with the Keynesian notion that the government plays a stabilizing role in the macro-economy. The size of the economy's openness and exchange-rate flexibility is positively related output volatility. And lastly, output volatility are not correlated with price flexibility, the economy's industrial structure, and measures of labor market imperfections (as proxied by nominal and real wage stickiness).

Keating and Nye (1999) studied the relative importance of the effects of aggregate demand and supply disturbances on the sources of macroeconomic fluctuations in the G7 countries. In their study they used output and the unemployment rate data from the G7 countries that based on post-World War II and pre-World War 1 period. They employed a bivariate VAR method to estimate the model as suggested by Blanchard and Quah (1989). To identify the shocks in the model they assumed that there exist permanent movements in output obtained from aggregate supply shocks, and aggregate demand shocks. Their findings revealed that in the post-World War 2 period output was more prone to be sensitive to aggregate demand shocks as compare to that in the pre-World War 1 period. The findings was compatible with the perception that price adjustment was slower in the latter half of the twentieth century. Their second findings revealed that the increase in unemployment rate and decrease for other countries were caused by supply shocks. This result implied that at the minimum there exists two different types of supply shocks were at work. They concluded by discussing the implications of their results for macro-econometric research.

Prasad (1999) analyzed the dynamics of international trade in response to different types of macroeconomic shocks in the G-7 countries from 1974Q1 to 1996Q4. In this empirical model framework, he augmented Clarida and Gali's (1994) stochastic version of Obstfeld's (1985) open economy macroeconomic model by explicitly incorporating a trade balance equation. This is a Mundell-Fleming model version that has stochastic features and composed of sluggish price adjustment. The estimation of the model was based on the restrictive structural VAR methodology and a set of long-run restrictions were used for model identification. The main findings was the fluctuations in trade variables of G-7 countries were mainly caused by the nominal shocks in the post-Bretton Woods period. These shocks incline to produce positive correlations between output and the trade balance.

Bjornland (2000) investigated the dynamic effects of different shocks in Germany (1969-1994), Norway (1967-1994), the UK (1966-1994), and the US (1960-1994). The goals of her study were to analyze how oil price shocks differ from demand and supply shocks, and to investigate the symmetry of economic responses. The model was based on that of Blanchard and Quah (1989). She identified three shocks: demand shocks, supply shocks, and oil-price shocks through the combination of short run and long run restrictions with three variables - real GDP, oil prices, and the unemployment rate. The results showed that adverse oil price shocks have a negative impact on output in the short run for all countries, namely Germany, the UK, and US, and have a positive impact on that of Norway (which is major oil-producing country). In the long run, the effects from oil price shocks were eliminated for Germany and the UK, but persisted for Norway and the US. Demand shocks explained most the variation of output in Norway, the UK, and the US, in the short-term. In the long run, the supply disturbances are the dominant cause of economic fluctuations. And for Germany, the source of economic fluctuations in the short-run and long-run were from the supply shocks.

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Smets and Wouters (2003) built a dynamic stochastic general equilibrium (DSGE) model that incorporated sticky prices and wages for the Euro area. The model comprised of various characteristics such as habit formation, costs of adjustment in capital accumulation, and variable capacity utilization. Bayesian methodology was used to estimate the model based on the sample data from e 980Q2–1999Q4. The seven key variables used in the analysis are GDP, consumption, investment, prices, real wages, employment, and the nominal interest rate. The model was subjected to ten structural shocks which comprised of productivity, labor supply, investment, preference, cost-push, and monetary policy shocks. The findings demonstrated that the output variations in the Euro-area were mostly caused by labor supply and the monetary policy shocks. The findings also revealed that the major contributory factors to inflation growth in the Euro area were price markup shock and monetary policy shock.

Schmidt and Zimmermann (2005) analyzed the effect of the importance of oil price shocks that affect the business cycles in Germany. The authors developed a DSGE model for the German economy that comprised oil price shocks and nearly all the parameters in the model are calibrated. The model also has been constructed in such a way to allow for the Germany's economy to adjust from closed to open by changing the degree of economic openness in different time frames. In their analysis, the whole sample time series 1970-2002 were divided into two subsample periods, namely the first from 1970 to 1986 and the second from 1987 to 2002. Also in their analysis, for a closed economy structure, the interest rate was set as endogenous variable while for an open economy setup, it was set as exogenous variable. Their findings showed that the closed economy model was capable of replicating some of the stylized facts of the business cycle in the first subsample period, and that the open economy model performed much better in the second subsample period. The results did not suggest that oil price shocks had a significant role in explaining business cycles in Germany during the two subsample periods.

In the study by Adolfson et al. (2007), the authors extended the DSGE model of Christiano et al. (2005). The authors' objectives were to explore the relative importance of external and domestic shocks and also the importance of external and domestic shocks to the macroeconomics fluctuations for the Euro area. The DSGE model was designed to incorporate the open economy aspects for Euro area and integrated some elements of the closed-economy structure with some of the elements setup that commonly appeared in the new open economy macroeconomics literature. The new features that were added are nominal and real frictions such as sticky prices, sticky wages, variable capital utilization, capital adjustment costs and habit persistence. The quarterly data sample period used for analysis is from 1970:Q1–2002:Q4 and estimation was done using Bayesian techniques. There are fifteen variables used in the model and was subjected to "open economy" shocks and "domestic" shocks. The findings strongly support the incorporation of nominal and real frictions, sticky prices in the domestic, import and export sectors, sticky wages, investment adjustment costs and habit persistence in consumption in the model. The findings also revealed that open economy shocks was the major contributory factor in explaining the variation in the real exchange rate and had little impact on output fluctuations. For the closed economy shocks, the technology shocks were the major contributory factor in explaining the variation in output but were less significant in explaining the decline in domestic inflation. As for preference shocks, shocks to labor supply also play a significant role in output fluctuations, and policy shocks account for some variations in output growth, but are not as important as technology and labor supply shocks.

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Buckle, R.A. et al. (2007) developed a restricted structural vector autoregression (SVAR) to analyze relative importance of international and domestic shocks developed a restricted structural vector autoregression (SVAR) to analyze relative importance of international and domestic shocks to the business cycle for the small open economy of New Zealand. The authors developed a 13 variable SVAR model and incorporated the features of non-recursive structures, with restricted specification and block exogeneity in the analysis. In the model, the equations are organized into four blocks, namely an international economy block, an international trading prices block, a domestic economy block, and a domestic climate block. Sample data used was from 1983Q1 to 2004Q2. Their findings revealed that the most important contributory factors to the business cycle of New Zealand were the fluctuations in export and import prices. Another important contributory factor was the climatic variable which has important influence, particularly during the recessions in 1997/98 and 2001, and in causing slower growth in 2003.

In another related study, Smets and Wouters (2007) further extended the studies by Christiano, Eichenbaum, and Evans (2005), and Smets and Wouters (2003), in a DSGE model of the US economy. Their model comprised of several common features from their past model, such as sticky prices and wages, habit formation, costs of adjustment in capital accumulation, and the variable of capacity utilization. Using quarterly data of US economy for the period 1966Q1-2004Q4, seven key macroeconomic time series data were estimated using Bayesian method. The key macroeconomic variables here are real GDP, consumption, investment, completed work hours, real wages, prices and the short-term nominal interest rate. To analyze the dynamic behavior of the model, the model was subjected to seven structural shocks. The findings showed that the model fit the main US macro data very well. The findings also demonstrated that "demand"

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shocks such as the risk premium, exogenous spending and investment-specific technology shock accounted to a significant fraction of output variation in the short run. In the medium to long run, output variation was mostly attributable to wage mark-up (or labour supply) and productivity shocks. Productivity shocks had a significant negative impact on hours worked in short run, whereas price mark-up shocks had been an important driving force for inflation in short run and wage mark-up shocks in the long run.

Seneca (2008) developed DSGE model for a small open economy of Iceland based on New Keynesian. The goal of this study was to investigate the main causes contributing to business cycle fluctuations and develop a tool for economic and policy analysis in support of inflation targeting at the Central Bank of Iceland. The model has the typical New Keynesian features such as goods and labour markets featuring imperfect competition and nominal rigidities. Based on the 14 quarterly data series of the sample period 1991Q1-2005Q4, the model was estimated using the Bayesian techniques. The model was subjected to several shocks, namely a monetary policy shock; a mark-up shock; technology shocks; a risk-premium shock and a government spending shock. The findings suggested that nominal rigidities have been an important contributory factor for propagation mechanism of the Icelandic economy. The findings also revealed that compare to other Nordic countries, the pass-through of exchange rate movements to domestic prices is high for the Icelandic economy. This implied that monetary policy through its exchange rate channel is important in Iceland. The overall findings showed that the dominant contributory factors of the Icelandic business cycle were technology shocks, markup shocks and risk-premium shocks.

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Breuss and Rabitsch (2009) built a dynamic stochastic general equilibrium (DSGE) model for the small open economy of Austria and it is similar type of the New Open Economy Macroeconomics. The model setup and the objective was to investigate what kind of factors that contribute to the business cycle fluctuations and also to evaluate the relative importance of various shocks and frictions that cause the dynamic behavior of the model. The authors also examined the impact of the monetary regime switch during the final stage of the EMU and to what extent this event has altered the macroeconomic transmission. Bayesian methodology was used to estimate the quarterly data from 1976Q2–2005Q1. The model was then subjected to several structural shocks, such as shocks to technologies, shocks to preferences, cost-push type shocks and policy shocks. The findings demonstrated that Austria’s economy reacted strongly to demand shocks, whereas other countries of the Euro Area reacted more strongly to supply shocks. Consumption preference shocks have a larger impact on consumption, and variations in investment were caused largely by temporary variations in investment efficiency. Labor supply shocks were a significant cause of variations in employment and real wages, and variations in inflation rates were mostly caused by cost-push type shocks. The findings demonstrated that Austria’s economy reacted strongly to demand shocks, whereas other countries of the Euro Area reacted more strongly to supply shocks. Consumption preference shocks have a larger impact on consumption, and variations in investment were caused largely by temporary variations in investment efficiency. Labor supply shocks were a significant cause of variations in employment and real wages, and variations in inflation rates were mostly caused by cost-push type shocks.

Jaaskela and Nimark (2011) developed a new Keynesian open economy DSGE model of Australia to analyze business cycle fluctuations. In their model a number of shocks, frictions and rigidities were incorporated in order to match the large number of

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observable time series data. The estimation of the parameters in the model was based on Bayesian techniques and the sample quarterly data from 1993Q2 to 2007Q3 for Australia was used for this study. The model was subjected to five structural shocks, namely technology shocks, supply shocks, domestic demand shocks, external shocks and monetary policy shocks. In their findings both foreign and domestic shocks were the main significant driving force of Australia business cycle fluctuations. The findings also revealed that an initial increase in the demand for Australian commodities has a negative effect on inflation. Even though there exist a persistent positive effect on inflation that had been dominant for prolonged periods, it was perceived that the enhancement in the real exchange rate that caused the inflation lower.

Cover and Mallick (2012) studied what are the main factors that caused the fluctuations in macroeconomic and exchange rate for the UK economy. In this study they developed a five-variable structural vector-autoregressive model based a common new-Keynesian framework. Time series quarterly data from 1993Q2 to 2007Q3 for UK were used for this analysis. In their findings the authors claimed the main factors contributing to variation in the unemployment rate and output in the UK were technology and IS (or AD) curve shocks. Both of these shocks together explained at least 85 percent of the forecast-error variance of the unemployment rate and output. Both of these two shocks together also explained about 43 percent of the forecast-error variance of the nominal effective exchange rate (NEER) of the British pound, and 29 percent of the variance of the Bank of England's base interest rate. The findings also showed that with respect to monetary policy shocks, there exists a long-run neutrality of money, and that monetary policy was not the main contributing factor to output and employment fluctuations during the sample period.

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2.2.2 Empirical Evidences for Developing Countries

Just as in the developed countries, literature on business cycle analysis and empirical evidences for developing countries are now increasingly available. Hoffimaister and Roldos (1997) studied macroeconomic fluctuations in Asia and Latin America, using the Structural Vector Autoregression (SVAR) approach that incorporated the equilibrium and disequilibrium views of the business cycle. Their study was based on two balanced panels of annual observations, from the years 1970 through 1993, with these panels consisting of 15 Asian and 17 Latin American economies. The main findings regarding Asia and Latin America were as follows:

a) Domestic shocks were the primary source of output fluctuations, while external shocks explained only a small fraction of these fluctuations. Among the domestic shocks, in the short run, supply shocks are the primary source of output growth fluctuations.
b) The real exchange rate was driven mainly by domestic shocks, with external shocks explaining only a small share of its fluctuations. Among the domestic shocks, in the short run, the primary source of fluctuations were fiscal shocks and in the long run was somewhat less.
c) The important factors contributing to trade balance fluctuations were terms of trade shocks and world interest rate shocks. The fluctuations in output or real exchange rate were not influenced by these factors. For Asia, their output affected more by external factors and for Latin America domestic demand shocks were dominant.

Kydland and Zarazaga (1997) analyzed the empirical regularities of business cycle fluctuations in Argentina based on two sets of data with different base years. For

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the first set of data, the sample quarterly time series was from 1970Q1 to 1990Q4 based on constant 1970 prices. The second set was from 1980Q1 to 1995Q4 with constant 1987 prices. In contrast to other empirical studies of modern business cycle fluctuations analysis where the popular dynamic stochastic general equilibrium model was employed, the authors' analysis was merely based on atheoretical methodology to analyze the regularities of business cycle fluctuations. Their findings for Argentina showed that there was a high absolute volatility of output. In terms of cyclical component correlation, real total consumption was strongly correlated with real GDP and was consistent within the range observed in other countries. Lastly, the statistics obtained for investment, labour inputs, and productivity were similar to that obtained in the United States or in the European countries.

In another study, Hoffimaister, Roldos, and Wickham (1998) examined macroeconomic fluctuations in Sub-Saharan Africa, using a structural vector autoregression (SVAR) approach that incorporated equilibrium and disequilibrium views of the business cycle. The data consisted of two balanced panels on annual observations from the years 1971 through 1993 with these panels containing 8 member countries of the CFA franc zone and 15 non-member countries. The Sub-Saharan Arica study divided the region into CFA franc countries –which have pegged their franc to the French franc- and non-CFA franc countries. The SVAR model used was similar to the one used for the study on Asia and Latin America. The findings demonstrated that domestic shocks were the primary contributory factor to macroeconomic fluctuations for both groups of countries (CFA and non-CFA). Whereas, for external shocks, the main contributory factor in explaining fluctuations in output and in the real exchange rate in CFA franc countries were particularly the terms of trade shocks. Their findings

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also showed that macroeconomic fluctuations in non-CFA franc countries were the same as those in other developing countries, especially in Latin America.

Agenor et al. (1999) studied the stylized facts of macroeconomic fluctuations and business cycle regularities for a group of twelve developing countries (four Latin American countries: Colombia, Chile, Mexico, and Uruguay; four Asian countries: India, Korea, the Philippines, and Malaysia; three Middle Eastern/North African countries: Turkey, Morocco, and Tunisia; and one Sub-Saharan African country: Nigeria). The authors examined the movements of the detrended quarterly data of the period between 1978Q1 to 1995Q4 (detrended here means using a modified HP filter, the Baxter-King band-pass filter, and a nonparametric technique). And they arrived at the following conclusion: The volatility of output varied considerably across the developing countries. And on average, it was much higher than the level typically obtained in industrial countries. At the same time, there was a substantial persistence in output fluctuations in the developing countries. There was a strong negative relationship between government expenditure and the domestic business cycle (as measured by fluctuations in industrial output). Based on this evidence, this implied that government expenditure was used as a countercyclical measure in these countries.

Carmicheal et al. (1999) developed a New Keynesian DSGE model. Their goals were to calibrate and replicate the business cycle fluctuation compatible with the real data of the sample countries in their analysis. In the study, the authors made use of cross-country sample data of nineteen less developed countries of Africa, Asia, the Middle East and Latin America. Annual time series were used varying between 21 years and 34 years depending on the available data of the country. The authors showed that it was not easy to replicate some important stylized facts of the countries under study

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based on open economy extensions of real business cycle (RBC) models. Their findings implied that there was too much consumption smoothing and consumption correlation across the countries. They also reported having difficulties to replicating the variability of the trade balance and its correlation with the terms of trade. Overall, the authors' main conclusion was that, about half of the output irregularity was attributed to the terms of trade shocks. They also claimed that their approach of study was acceptable in the sense that it was capable of documenting business cycle statistics and calibrating the model.

Kose and Riezman (2001) examined how and to what extent the external shocks as a contributory factor to macroeconomic fluctuations in African countries. For its analysis, they developed a dynamic stochastic general equilibrium multi-sector which was based on small open economy model framework. The annual time series data of 22 non-oil exporting African countries between 1970 and 1990 were used for this analysis. The model was subjected to five shocks in which four were external shocks and one domestic shock. They claimed that, the use of export and import price shocks in the model was a better technique than using shocks to the terms of trade. They claimed similarly to the study by Mendoza (1995) that the terms of trade were not important factor influence the business cycles fluctuations in the African countries. For calibration of the parameters in the model, the authors utilized the Solow residual method as a proxy for productivity, and the world real interest rate as a proxy for London Interbank Offer Rate. The findings showed that the benchmark model was able to replicate some of the business cycle features in the African economies. Also, about half of the variation in output was able to be explained by trade shocks. However, the findings showed that the world real interest rate did not have a significant effect on output since it only explained less than one percent of output variability.

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Kim et al. (2003) examined the business cycle properties and characteristics of Asian countries and compared them with those of the G-7 countries, especially in the pre-crisis period. Their analysis was merely based on documentation of similarities and differences in business cycle properties based on cross-country annual data of Asian countries from 1960-1996. The sample countries chosen were consisting of seven Asian countries (Indonesia, Korea, Malaysia, the Philippines, Singapore, Taiwan and Thailand). For G7 countries, the data was divided into two periods, namely, 1960-1984 and 1985-1996 in order to test the structural stability of the Asian economies. Their study showed some several interesting results. There exist important similarities pattern of business cycle fluctuations for the main macroeconomic aggregate across the Asian countries. There were also significant differences in the behavior of fiscal and monetary policy variables in those countries. The findings also showed that there was a high degree of co-movement between individual country business cycles and their measure of the Asian business cycle. This implied that the existence of a regional business cycle specific to the Asian countries. The authors attempt did not use theoretical stipulations or requirements of macroeconomic data in analyzing and making conclusions. The authors only highlight a simple feature of business cycle fluctuations and also recognized that the more suitable method in this study were to designed a DSGE model framework that could able to represent the features of Asian countries.

Medina and Soto (2006) developed a DSGE model for the Chilean economy to conduct simulations and policy analysis. Sample quarterly data from 1990Q1 and 2005Q4 was used for the study. The model incorporated some important features, such as wages and prices are sticky with adjustment costs in investment; habit persistence in consumption behavior; and exchange rate pass-through to import prices is imperfect. The supply side consisted of domestic sector firms produce tradable goods and a

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commodity for the export sector. The parameters in this DSGE model were estimated based on Bayesian techniques. Their findings demonstrated that habit persistence in consumption and adjustment costs in investment were appropriate characteristics of the model. The Impulse-response analysis demonstrated that the commodity price shock produced a moderate growth in consumption, investment and output. It also demonstrated that the appreciation of real exchange rate caused the fall in inflation and decreases employment. Lastly, the authors claimed that there was a positive responses of GDP, consumption and investment, and a drop in inflation rate to a monetary policy shock.

Hirata, et.al. (2007) developed a dynamic stochastic general equilibrium (DSGE) model based on small open-economy structure. Their goals were to investigate the cause of macroeconomic fluctuations in the emerging countries for the Middle East and North Africa (MENA). In their study the authors investigated the primary causes of macroeconomic fluctuations in these countries and how these different kinds of shocks affect the economies of these countries. Their sample analysis was based on annual time series data from 1960 to 2000. Their main findings demonstrated that more than 60 percent of the variation in aggregate output and cyclical fluctuations in the MENA countries were primarily caused by the terms of trade shocks. They also found that about 40 percent of business cycle variation in aggregate output was caused by domestic productivity shocks. Government spending shocks and world interest rate shocks were also considered important driving forces of cyclical fluctuations only in certain macroeconomic variables, and their overall effect of contribution to the dynamics of aggregate output was considered to be relatively small.

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In another study by Medina and Soto (2007), the authors developed a DSGE model and incorporated some features of nominal and real rigidities into the model. Their aims were to investigate the sources of business cycle fluctuations in Chile from a structural perspective. The estimation of the parameters in the model was done using Bayesian techniques based on sample data for the period 1987Q1 to 2005Q4 and the model was subjected to fourteen shocks. They concluded that a substantial share of output fluctuations over the last 20 years had been contributed by foreign shocks and domestic supply shocks. A tight domestic monetary policy condition was a contributory factor to containing inflationary pressures caused by other shocks, such as a slowdown in productivity in the mid 1990s. Volatility in the real exchange rate was largely caused by foreign factors, although a monetary contraction also contributed to it as this factor played a role in the delayed adjustment of the exchange rate in response to the effects of the Asian crisis.

Mehrara, and Oskoui (2007) investigated the sources of macroeconomic fluctuations in four oil-exporting countries, namely Iran, Indonesia, Kuwait, and Saudi Arabia. The authors developed a small open-economy version of a structural long-run restricted vector autoregression (SVAR) model and for the empirical analysis, they used annual data from the years of 1970 to 2002. The model was subjected to four structural shocks, namely nominal demand, real demand, aggregate supply, and oil price shocks. Their main findings showed that the external shocks were the dominant factor in explaining the fluctuations in output in Iran and Saudi Arabia, but not in Kuwait and Indonesia. Furthermore, the findings implied that on the one hand, the oil price shocks were the primary cause of output fluctuation in Iran and Saudi Arabia and on the other hand aggregate supply shocks were the primary cause of output fluctuations in Kuwait and Indonesian. They concluded that the external factors played an insignificant role in

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Kuwait and Indonesia in causing macroeconomic instability during the period under consideration.

Shaari (2008) developed an open economy DSGE model for Malaysia. The design of the DSGE model was built extensively on the model developed by Gali and Monacelli (2005), and the model was modified to include the financial accelerator mechanism. Bayesian techniques were employed to carry out the estimation on key structural parameters of the model. The objectives of this study were to analyze the role of the financial accelerator in affecting the empirical properties of the model and to analyze the behavior of Bank Negara Malaysia (BNM) in formulating monetary policy. The model was estimated using data for the 1975Q1-2005Q2 period. The model was subjected to six shocks, namely the law of one price shocks; uncovered interest parity shocks; technology shocks; foreign inflation shocks; foreign output shocks; and foreign interest rates shocks. Analysis using the impulse-response functions and variance decomposition between the two model specifications demonstrated how the operation of a financial accelerator mechanism had amplified and propagated the effects of transitory shocks to economic activities. Positive monetary policy shocks, for example, had caused the impulse response functions of variables in the financial accelerator model to react with a bigger magnitude than that in the non-financial accelerator model. This was due to the presence of a financial accelerator mechanism which amplified the effect of monetary policy shocks. The amplification contributed to higher volatility in the variables such as investment and output. Furthermore, the financial accelerator served as an additional friction in the model and acted to reduce the ability of some variables (such as investment and net-worth) to adjust more instantaneously.

Just as in other developing countries, Ramayandi (2008) developed a simple small open economy DSGE model for the ASEAN-5 countries that consisted of Indonesia, Malaysia, the Philippines, Singapore and Thailand. The model was adapted from the work of Gali and Monacelli (2005) version which featured imperfect competition and nominal price rigidities, and this is a typical type of new Keynesian small open economy model. The objective was to investigate the monetary policy transmission mechanism for ASEAN-5 countries as a case study. The author employed the maximum likelihood estimation (MLE) method to estimate the structural parameters of the DSGE model based on the sample quarterly time series data from 1989Q1 to 2004Q4. Data for Malaysia started from the year 1991 and the data for Thailand started from the year 1993 due to unavailability of data from earlier year. The model was subjected to seven structural shocks. The findings showed that the model was capable to generate the estimated parameters that mainly captured the economic properties and dynamics of each of the countries under consideration. Overall, the main empirical finding was that the variation in interest rates were compatible with the underlying objective of the monetary policy within each of the sample countries which targeted inflation and the output gap.

Teo (2009) developed a new Keynesian open economy DSGE model to investigate the characteristics of the monetary policy and sources of business cycle in Taiwan. The author employed Bayesian methods to estimate the parameters in the model based on sample quarterly data from 1992Q1 to 2004Q4. The model was subjected to several structural shocks. There were several main findings yielded from this analysis. Among them were: the money supply growth rate rule was the best indicator for monetary policy in Taiwan; the important sources of output growth fluctuations were the export price mark-up and investment-specific technology shocks that contributed an average 43

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percent and 30 percent of the unconditional variance in output growth respectively; money supply shocks were not the main cause of the fluctuations of the real variables, but were considered significant movement causing fluctuations in consumer price inflation and nominal depreciation; and lastly, domestic price mark-up shocks and exogenous risk premium shocks were the dominant factors causing fluctuations in consumer price inflation and nominal depreciation.

Alp et al. (2012) investigated the role of countercyclical policies such as interest rate cuts and exchange rate flexibility to alleviate the aftereffect from the global 2008-09 financial crisis in the Malaysian economy. The authors developed a small open economy DSGE model in their study. The authors incorporated some important features of nominal and real frictions, and also incorporated a financial accelerator mechanism à la Bernanke et al. (1999) in the model setup. The model was estimated by using Bayesian methods and it used twelve standard time series quarterly data covering the years 2000 to 2010. From their findings, the authors asserted that, Bank Negara Malaysia (BNM) had successfully helped alleviate the impact of the global financial crisis with the implementation of discretionary monetary policy and the availability of exchange rate flexibility in place. The findings also implied that the Malaysian economy would have been hit by a much more severe economic downturn due to the global financial crisis if such policies had not been implemented by BNM.

Despite their wide use and its popularity in recent times, DSGE models have also certain drawbacks. The most problematic issues which are currently much discussed in the literature are mainly concerned with: (i) unrealistic assumptions (e.g. Ricardian equivalence, rational expectations hypothesis, infinitely-lived households etc), (ii) unconvincing method of estimation (which is a combination of calibration and Bayesian

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estimation), (iii) questionable assumption about the structural parameters that are assumed to be invariant to policy changes, (iv) issue related with the use of revised or real-time data when estimating the model, and (v) poor performance during the recent crisis. For more detailed discussion of these issues, see Romer (2016), Blanchard (2016) and the other contributions (see Blanchard (2017) for an extensive list of references). Despite these shortcomings, I decided to use a DSGE framework as I believe that it is flexible enough to be used for my purposes, while other models are more limited in terms of their ability to fully address the research questions under study.

Overall, the above empirical reviews show that the study of macroeconomic and business cycle fluctuations have not only been dominated by the developed countries but have also been gradually spreading to developing countries. Researchers and economists have utilized different approaches and models in their studies. But the DSGE remains the most dominant and most popularly used model.

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Chapter 3

A DSGE MODEL FOR A SMALL OPEN ECONOMY

3.1 Introduction

The literature on dynamic stochastic general equilibrium (DSGE) modeling is immense and has been growing in recent years. The popularity of DSGE modeling framework is due to its usefulness and practicality in analyzing macroeconomic fluctuations, for quantitative macroeconomic analysis and also for forecasting in macroeconomic models. It has become a standard framework and represents the core of contemporary macroeconomic models used not only in academia but also by institutions, especially central banks in developed and developing countries. In practice, the DSGE model are widely used by central banks for monetary policy analysis and forecasting. Examples of the DSGE model that have been developed and used in central banks include those by Adolfson et al. (2005), Jakab and Világi (2008), Dmitry and Gelain (2009), Grabek et al. (2011), Argo et al. (2012) and Brave et al. (2012). These models not only provide a theoretical framework for a central bank's economic discussions and analysis, but also help economists to evaluate the current state of the economy and produce forecasts.

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It is appropriate to say that a great deal of the present literature on DSGE modeling focuses on the experiences of advanced countries. However, we can also observe that there are a few examples in this literature concerned with the experiences of developing countries, specifically of Latin American countries. Among the most cited in the literature are studies by Medina and Soto (2006, 2007) for Chile, Castillo et al. (2006) for Peru and Marcos et al. (2011) for Brazil. Ramayandi (2008) developed a DSGE model for four ASEAN economies (including Malaysia).

The distinctive characteristic of these models is that they are explicitly derived from micro-economic foundations and from first concepts or principles. They depict the general equilibrium allocations and prices of the economy in which the representative agents of households and firms behave in such a way that optimizes their objective functions, such as utility and profits, subject to their respective budget or resource constraints. In essence, the calibrated or estimated parameters of the structural equations of DSGE models represent deep parameters, such as, for example, the discount factor, the elasticity of substitution among goods, the elasticity of inter-temporal substitution, the elasticity of labor supply, etc. They are assumed to be invariant to the policy regime changes, i.e. they are immune to the Lucas (1976) critique. This is because economic decisions of the agents are made in a rational, forward looking manner in anticipation of any policy changes. For this reason, it is appropriate to state that DSGE models are considered robust tools that form a systematic and cogent framework for policy discourse and analysis. These models are often regarded as useful tools for forecasting and predicting the effect of policy changes, for helping to identify the sources of fluctuations and structural changes, and for carrying out counterfactual scenario analysis. They also can act as a linkage between structural characteristics of the economy and its reduced form parameters, which previously was not possible, especially in large-scale traditional systems-of-equation form macroeconomic models.

The objective of this chapter is to develop a DSGE modeling framework for the small open economy of Malaysia. The DSGE model environment in this research work is based on the model developed by Gali and Monacelli (2005), as well as by Shaari

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(2008), and it also incorporates the financial accelerator mechanism features of Bernanke et al. (1999). With this alteration and adjustment the main features of model are quite similar to the open economy DSGE model in Devereux et al. (2006). In this small open economy model it is assumed that the country produces tradable goods for domestic consumption and exports to the world markets at an exogenous price where the small open economy is a price taker. As in Christiano, Eichenbaum and Evans (2005), and Smets, Frank, and Raf Wouters (2003), this model incorporates a number of nominal and real frictions such as sticky prices, sticky wages, capital adjustment costs and habit persistence. The DSGE model is assumed to consist of four major economic agents operating within the home economy. These are households, entrepreneurs, retailers and the monetary authority.

In this section the model setup begins with definitions of consumption composites, price indices, terms of trade and the real exchange rate. These definitions behave as the building block for the model set-up. Before proceeding, we must first make a statement concerning the notation. Throughout this chapter, a variable in an upper case letter indicates the variable in its original form. Those in a lower case letter indicate the corresponding variable written in log form and as a percentage deviation from a corresponding non-stochastic steady state.

3.1.1 Consumption Demand and Price Indices

The consumption index C_t is an elasticity of substitution (CES) aggregate of the representative household's consumption of domestic and imported goods defined as

$$C_t = \left[(1-\gamma)^{\frac{1}{\eta}}\left(C_{H,t}\right)^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}}\left(C_{F,t}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \qquad (3.1)$$

$C_{H,t}$ and $C_{F,t}$ indicate the aggregate consumption index of domestic and imported goods respectively; $\eta > 0$, is the elasticity of substitution between domestic and foreign goods. Parameter $\gamma \in [0,1]$ indicates the share of imported goods in the consumption basket. It measures the degree of openness of domestic economy.

The home goods consumption index is defined as

$$C_{H,t} = \left(\int_0^1 C_{H,t}(h)^{\frac{\epsilon-1}{\epsilon}} dh\right)^{\frac{\epsilon}{\epsilon-1}} \qquad (3.2)$$

with elasticity of substitution between different varieties of goods ϵ. There is a continuum of home goods varieties. The demand function for a particular variety of home goods[1] can be written as

$$C_{H,t}(j) = C_{H,t}\left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\epsilon} \qquad (3.3)$$

The home goods price index is defined as

$$P_{H,t} = \left(\int_0^1 P_{H,t}(i)^{1-\epsilon} di\right)^{\frac{1}{1-\epsilon}} \qquad (3.4)$$

The foreign goods consumption index definition is similar to the definition of the home goods index (3.2). Therefore, the demand function for a particular variety of foreign goods and the foreign goods price index are similar to (3.3) and (3.4). The consumer price index (CPI) P_t is defined as

$$P_t = \left[(1-\gamma)P_{H,t}^{1-\eta} + \gamma P_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}} \qquad (3.5)$$

[1] The derivation of this result can be found on pp.111-112, Appendix A, Section A.1.1

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The demand of households for home and foreign goods[2] is given by the following functions:

$$C_{H,t} = C_t(1-\gamma)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} \tag{3.6}$$

$$C_{F,t} = C_t\gamma\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} \tag{3.7}$$

3.1.2 Inflation, Terms of Trade and Real Exchange Rate

A standard definition of CPI inflation is assumed such that

$$\pi_t = log\left(\frac{P_t}{P_{t-1}}\right) = P_t - P_{t-1} \tag{3.8}$$

Analogously we define the inflation of home goods prices $\pi_{H,t}$, inflation of foreign goods prices $\pi_{F,t}$ and foreign[3] CPI inflation. Note that all the price indices are assumed to be equal to one in steady state. Log-linearization of price index definition (3.5) gives this result

$$p_t = (1-\gamma)p_{H,t} + \gamma p_{F,t} \tag{3.9}$$

which implies

$$\pi_t = (1-\gamma)\pi_{H,t} + \gamma\pi_{F,t} \tag{3.10}$$

The terms of trade is defined as $TOT_t \equiv \frac{P_{F,t}}{P_{H,t}}$. This variable measures the relative price of foreign and home goods and it is expressed in domestic currency. Since $tot_t = P_{F,t} - P_{H,t}$, it can be shown that $P_t = P_{H,t} - \gamma tot_t$ and $\pi_t = \pi_{H,t} + \gamma\Delta tot_t$.

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[2] The derivation of this result can be found in the appendix A, section A.1.2

[3] Foreign variables are denoted by an asterisk.

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The nominal exchange rate S_t is defined as the price of foreign currency in terms of the domestic currency. Thus, growth of S_t indicates a depreciation of domestic currency and vice versa. The real exchange rate, RER_t is then defined as

$$RER_t = S_t \frac{P_t^*}{P_t}$$

where P_t^* is the foreign CPI index. It is supposed that law of one price holds for domestic exports, $C_{H,t}^*$, i.e.

$$P_{H,t}^* \equiv \frac{P_{H,t}}{S_t}$$

However, this is not the case for domestic imports, or foreign goods. We assume that there is a wedge between the price of foreign goods in the domestic economy and the price level of foreign country, this means that the law of one price does not hold for imported goods. We define a law of one price gap

$$LOPG \equiv \frac{S_t P_t^*}{P_{F,t}}$$

In log-linear terms $lopg_t = s_t + p_t^* - p_{F,t}$. It can be shown that the following relation holds for the real exchange rate, terms of trade and the law of one price gap

$$rer_t = (1-\gamma)tot_t + lopg_t \tag{3.11}$$

The development of the law of one price gap is exogenous in this model and its deviation from steady state is assumed to follow an AR(1) process in the following form

$$lopg_t = \rho_{LOPG} lopg_{t-1} + \varepsilon_t^{LOPG} \tag{3.12}$$

where $\rho_{LOPG} \in [0,1]$ is the AR(1) coefficient and the innovation term $\varepsilon_t^{LOPG} \sim iid(0, \sigma_{LOPG}^2)$.

3.2 The Economic Agents

3.2.1 Households

The economy is populated by a continuum of infinitely lived households in the unit interval. Households maximize expected discounted sum of utilities by choosing optimal consumption and labor paths and solve the following optimization problem

$$\max_{\{C_t, L_t\}_{t=0}^{\infty}} E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U\left(C_t, C_{t-1}, L_{H,t}\right) \right\}$$

subject to a budget constraint. E_t is the expectation operator conditional on the information available at period t, and $0 < \beta < 1$ is the subjective discount factor parameter of the representative household. The following form of the utility function of the representative household is assumed

$$U(C_t, C_{t-1}, L_t) = \log[(C_t, -\Upsilon C_{t-1})] - \frac{L_{H,t}^{1+\Psi}}{1+\Psi}$$

where C_t is the composite consumption index and $L_{H,t}$ is the labour supply chosen by household. Υ is the parameter of the external habit formation in consumption level taken as exogenous by the household. Parameter $\Upsilon \in [0,1]$ is a constant term, and it captures the degree of habit persistence consumption (see, e.g. Abel (1990), Fuhrer (2000a, b); McCallum and Nelson 1999) in the economy. The incorporation of habit formation in the model helps in generating persistence in the consumption dynamics following the

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monetary policy shocks. The inverse elasticity of labour supply is represented parameter $\Psi > 0$.

The budget constraint of representative household has following form

$$\widetilde{W}_{H,t} L_{H,t} + R_{t-1} D_{t-1} + R^{*}_{t-1} \Psi^{B} (Z_{t-1}, A^{AUIP}_{t-1}) S_t B_{t-1} + \Pi_t + T_t \leq P_t C_t + D_t + S_t B_t$$

This implies that the household gets remuneration for supplying labour, $L_{H,t}$ at a nominal wage rate $\widetilde{W}_{H,t}$. The household obtain transfers T_t from the remainder of the equity from entrepreneurs that go bankrupt and abandon the economy. Households also receive profits (Π_t) made by the retail firms which operate in the monopolistically competitive market. The representative household spends its income on consumption but they can also buy two kinds of financial assets: domestic bonds D_t (denominated in domestic currency) from a domestic intermediary and foreign bonds B_t (denominated in foreign currency). Domestic bonds yield nominal interest rate R_t in one period. Foreign bonds yield risk-adjusted[4] return $R^{*}_{t-1} \Psi^{B} (Z_t, A^{UIP}_t)$. The risk-premium is specified according to Adolfson et al. (2007) as

$$\Psi^{B} (Z_t, A^{UIP}_t) = \exp[-\psi^{B} (Z_t + A^{UIP}_t)]$$

where R^{*}_t is foreign nominal interest rate, $Z_t = \frac{S_t B_t}{Y P_t}$ is the real outstanding net foreign assets position of the domestic economy. Parameter $\psi^{B} > 0$ is the elasticity of the risk premium. The debt-elastic risk premium shock is represented by A^{UIP}_t. Deviation of this shock from a steady state is assumed to follow AR(1) process of standard form,

[4] Schmitt-Grohé and Uribe (2003) show that the borrowing cost allows the achievement of stationarity in the net foreign asset position.

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$$A_t^{UIP} = \rho_{UIP} A_{t-1}^{UIP} + \varepsilon_t^{UIP} \qquad (3.13)$$

where $\rho_{UIP} \in [0,1]$ is the AR(1) coefficient and the random shock or the innovation term $\varepsilon_t^{UIP} \sim iid(0, \sigma_{UIP}^2)$. The solution of households' optimization problem[5] can be summarized by following optimality conditions:

- Optimal choice between consumption and free time:

$$\frac{\widetilde{W}_{H,t}}{P_t} \equiv W_{H,t} = L_t^{\psi}(C_t - \Upsilon C_{t-1}) \qquad (3.14)$$

- Optimal choice between consumption and domestic bonds is given by:

$$R_t = \frac{1}{\beta} \frac{C_{t+1} - \Upsilon C_t}{C_t - \Upsilon C_{t-1}} \frac{P_{t+1}}{P_t} \qquad (3.15)$$

- Optimal choice between consumption and foreign bonds:

$$R_t^* \Psi^B(Z_t, A_t^{UIP}) = \frac{1}{\beta} \frac{S_t}{S_{t+1}} \frac{(C_{t+1} - \Upsilon C_t)}{(C_t - \Upsilon C_{t-1})} \frac{P_{t+1}}{P_t} \qquad (3.16)$$

- Optimal choice between foreign and domestic bonds:

$$R_t^* \Psi^B(Z_t, A_t^{UIP}) = \frac{S_t}{S_{t+1}} R_t$$

$$R_t^* exp[-\Psi^B(Z_t + A_t^{UIP})] = R_t \frac{RER_t P_t}{P_t^*} \frac{P_{t+1}^*}{P_{t+1} RER_{t+1}} \qquad (3.17)$$

[5] The derivation of these results can be found in the appendix A, section A.2.

which is a risk-adjusted uncovered interest parity (UIP) condition. In log-linear terms we can write:

$$l_{H,t} = \frac{w_{H,t}}{\Psi} - \frac{c_t - \Upsilon c_{t-1}}{\Psi(1-\Upsilon)} \tag{3.18}$$

$$(1-\Upsilon)(r_t - E_t\pi_{t+1}) = (c_{t+1} - \Upsilon c_t) - (c_t - \Upsilon c_{t-1}) \tag{3.19}$$

$$rer_{t+1} - rer_t = (r_t - E_t\pi_{t+1}) - (r_t^* - E_t\pi_{t+1}^*) + \Psi^B z_t + \Psi^B A_t^{UIP} \tag{3.20}$$

3.2.2 Entrepreneurs

Following Bernanke et al. (1999), we next introduce a production factor of capital into the model and describe the entrepreneur as a representative economic agent. Entrepreneurs play two important roles in the model. Firstly, they own and manage firms that produce intermediate (wholesale) goods and, secondly, they own and produce the capital goods. In owning and production of capital goods the entrepreneurs also encounter a funding constraint. This means that the entrepreneurs are not fully self-funding, and therefore, they have to borrow resources from commercial banks. The banks always impose a higher interest rate than the policy interest rate. The spread between commercial interest rate and policy interest rate is determined by the ratio of the value of capital stock and entrepreneurs' net worth (leverage ratio). What we have just explained is the financial accelerator mechanism and it is the source of financial frictions in this model. It is assume that the entrepreneurs are unable to amass enough net worth and unable become fully self-financing, and therefore, the entrepreneurs have to have a finite horizon. For that reason it is assumed that a fraction $\varsigma \in [0,1]$ of entrepreneurs bankrupt and exit business in each period. The remaining share $(1-\varsigma)$ of entrepreneurs survives to the next period.

3.2.3 Intermediate Goods Production

Firms are assumed to produce intermediate goods and operate at perfectly competitive market. This means that these firms have no market power and will attain no profits. Intermediate goods $Y_{H,t}$ is produced by combining the production factors of capital K_t and labour L_t. The output is sold at wholesale price $P_{H,t}^{W}$ to retailers. The standard Cobb-Douglas production technology is assumed,

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

where parameter $\alpha \in [0,1]$ determines the income share of capital. Variable A_t^{Y} is a productivity factor shocks and are common to all firms in the economy. It is assumed that its deviation from steady state evolve according to following AR(1) process

$$A_t^{\mathrm{Y}} = \rho_Y A_{t-1}^{\mathrm{Y}} + \varepsilon_t^{Y} \qquad (3.21)$$

where $\rho_Y \in [0,1]$ is the AR(1) coefficient and $\varepsilon_t^{Y} \sim iid(0, \sigma_Y^2)$ is the random shock. The total labour input is defined as a composite of the labour provided by households $L_{H,t}$ and by entrepreneurs $L_{E,t}$,

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

Following Bernanke et al. (1999), it is assumed that the supply of entrepreneur labour is constant and is normalized to 1. Hence, the production function can be then rewritten as

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

or in log-linear terms

$$y_{H,t} = \alpha k_t + (1-\alpha)\Omega l_{H,t} + A_t^{Y} \tag{3.22}$$

The solution of entrepreneurs' optimization problem[6] can be summarized by following set of optimality conditions:

$$\frac{\tilde{R}_{G,t}}{P_t} \equiv R_{G,t} = \alpha \frac{Y_{H,t}}{K_t} MC_{H,t} \frac{P_{H,t}}{P_t}$$

$$\frac{\widetilde{W}_{H,t}}{P_t} \equiv W_{H,t}(1-\alpha)\Omega \frac{Y_{H,t}}{L_{H,t}} MC_{H,t} \frac{P_{H,t}}{P_t}$$

$$\frac{\widetilde{W}_{E,t}}{P_t} \equiv W_{E,t}(1-\alpha)(1-\Omega) Y_{H,t} MC_{H,t} \frac{P_{H,t}}{P_t}$$

where $R_{G,t}$, is the gross nominal rental rate for capital, $W_{H,t}$, is the nominal wage paid to households, $W_{E,t}$ is the nominal wage paid to entrepreneurs themselves and $MC_{H,t}$ are the real marginal costs of home goods production. After log-linearization we obtain

$$r_{G,t} = y_{H,t} + mc_{H,t} - k_t - \left(\frac{\gamma}{(1-\gamma)}(rer_t - lopg_t)\right) \tag{3.23}$$

$$w_{H,t} = y_{H,t} + mc_{H,t} - l_{H,t} - \left(\frac{\gamma}{(1-\gamma)}(rer_t - lopg_t)\right) \tag{3.24}$$

$$w_{E,t} = y_{H,t} + mc_{H,t} - \left(\frac{\gamma}{(1-\gamma)}(rer_t - lopg_t)\right) \tag{3.25}$$

[6] The derivation of these results can be found in the appendix A, section A.3.1.

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Substituting for k_t and $l_{H,t}$ from (3.23) and (3.24) into the production function (3.22) we obtain the expression for real marginal costs,

$$mc_{H,t} = \frac{(1-\alpha)(1-\Omega)y_{H,t} + \alpha r_{G,t} + (1-\alpha)\Omega w_{H,t} - A_t^Y}{\alpha + (1-\alpha)\Omega} + \frac{\gamma}{(1-\gamma)}(rer_t - lopg_t) \tag{3.26}$$

Equation (3.26), therefore, implies that depreciation of the real exchange rate increases real marginal costs while an increase of the law of one price gap decreases them.

3.2.4 Capital Goods Production

Entrepreneurs produce capital goods and sell it at competitive market at nominal price $\tilde{Q}_t$. Capital is produced by combining already existing capital with investment INV_t. Investment INV_t is a bundle of home and foreign consumption goods. We assume, that the entrepreneurs choose the optimal mix of goods varieties in the same way as the households. Therefore, the investment is defined similarly to the consumption index C_t in equation (3.1),

$$INV_t = \left[(1-\gamma)^{\frac{1}{\eta}}\left(C_{H,t}\right)^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}}\left(C_{F,t}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{3.27}$$

Thus, the demand of entrepreneurs for home and foreign goods as well as the respective price indices are the same as in the case of households. Stock of capital goods is assumed to evolve according to

$$K_{t+1} = \Phi\left(\frac{INV_t}{K_t}\right)K_t + (1-\delta)K_t \tag{3.28}$$

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The capital depreciation rate is represented by parameter $\delta \in [0,1]$. Parameter $\Phi(.)$ is a concave and increasing production function. The following functional form is assumed for $\Phi(.)$

$$\Phi\left(\frac{INV_t}{K_t}\right) \frac{INV_t}{K_t} - \frac{\psi^I}{2}\left(\frac{INV_t}{K_t} - \delta\right)^2$$

where $\psi^I > 0$ is the capital adjustment costs parameter. Following Bernanke et al. (1999), the capital adjustment costs are introduced into the model to allow movement in the price of capital, which increases the volatility in entrepreneurs' net worth and contributes to the financial accelerator effect. In the steady state, the production function has following properties: $\Phi\left(\frac{\overline{INV}}{\overline{K}}\right) = \delta$, $\Phi'\left(\frac{\overline{INV}}{\overline{K}}\right) = 1$. These properties ensure the deterministic level of capital stock in the steady state (investment only replaces depreciated capital, $\overline{INV} = \delta\overline{K}$) and also that the price of capital will be equal to one in the steady state ($\bar{Q}$=1). Therefore, log-linearizing the law of motion of capital (3.28) gives[7]

$$k_{t+1} = \delta inv_t + (1-\delta)k_t \tag{3.29}$$

The entrepreneur decides how much new capital to produce. The optimality condition is[8]

$$Q_t = \frac{1}{1 - \psi^I\left(\frac{INV_t}{K_t} - \delta\right)}$$

which in log-linear terms means

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[7] The derivation of this result can be found on p.117, Appendix A, Section A.3.2.

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$$q_t = \psi^I \delta + (i_t - k_t) \qquad (3.30)$$

Now we define entrepreneur's gross real return on capital investment $R_{K,t}$,

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

In log-linear terms we obtain

$$r_{K,t} = \left(1 - \frac{(1-\delta)}{\bar{R}_K}\right) r_{G,t} + \frac{(1-\delta)}{\bar{R}_K} q_t - q_{t-1} \qquad (3.31)$$

Utilization of capital in production of intermediate goods yields the gross real rental rate $R_{G,t}$. Since the entrepreneurs own the capital, any change in the price of capital also influences the return on investment and consequently it affects the entrepreneur's net worth.

3.2.5 Financial Friction

For the entrepreneurs, besides involved in production activities, they also own capital. To finance their activities, they combine their net worth represented by (N_{t+1}) and borrow funds from the financial intermediary represented by (F_{t+1}). Thus, the entrepreneur's resource constraint can be written down as

$$Q_t K_{t+1} = N_{t+1} + F_{t+1}$$

Under the financial accelerator mechanism environment, entrepreneurs not only must pay the gross real interest rate $R_t \frac{P_t}{P_{t+1}}$, but also the external finance premium, F_{t+1} if

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they borrow funds from a financial intermediary. This also depends on the borrower's leverage ratio. In conformity with method used by Bernanke et al. (1999), it is perceived that the external finance method is more expensive than the internal funds for entrepreneurs to borrow funds from financial intermediary. This is because of the existence of agent-principal problem in the credit market. The external finance premium is determined by the entrepreneur's financial position which can be written in the following form:

$$F_{t+1} = \left(\frac{N_{t+1}}{Q_t K_{t+1}}\right)^{-\chi}$$

Parameter $\chi > 0$ measures the elasticity of the external finance premium with respect to the leverage ratio $\frac{N_{t+1}}{Q_t K_{t+1}}$. See Bernanke *et al*. (1999) for details explanation and derivation on the optimal contract that inspires the positive relationship between the external finance premium and the borrower's leverage ratio. According to this ratio $\left[\frac{N_{t+1}}{Q_t K_{t+1}}\right]$, the higher is the leverage ratio of the borrowers, the lower is to this ratio $\left[\frac{N_{t+1}}{Q_t K_{t+1}}\right]$. If the lenders perceived the leverage ratio is high, so they demand a higher premium from borrowers. This is to remunerate for the higher risk of default which my incurred by the borrowers with increased incentive to misreport the project outcome.

The risk-neutral entrepreneurs maximize profits by choosing the level of capital K_{t+1}. This level of capital K_{t+1} is corresponded with amount of borrowed funds F_{t+1}. At the optimal level, the entrepreneurs will choose the expected marginal return from capital investment equal the expected marginal financing cost. As such, the entrepreneur's optimality condition is given as,

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

or in log-linear terms

$$E_t r_{K,t+1} = r_t - E_t \pi_{t+1} - \chi(n_{t+1} - q_t - k_{t+1}) \quad (3.32)$$

The evolution of the entrepreneur's net worth can be derived in the following way. The entrepreneurs net-worth is N_{t+1}. The N_{t+1} comprises of the entrepreneurial equity, V_t, held by the fraction (ς) of entrepreneurs that are active in business during current period. The entrepreneur's wage income is $W_{E,t}$ from supplying labour for the production of household goods. Thus, the implied net-worth can be expressed as:

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

The existing entrepreneurs who leave the economy transfer their equity to households as transfers $T_t = (1 - \varsigma)V_t$. According to Bernanke *et al*. (1999), this mechanism is to ensure that net worth is pinned down in steady state. We also assume that labour income of entrepreneurs is small $(1 - \Omega = 0.01)$. The wage income of entrepreneurs will ensure that they always have positive net worth to do business with. Entrepreneurs' equity is defined as

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

where the amount borrowed by entrepreneurs is $F_t = Q_{t-1}K_{t+1} - N_{t+1}$. Thus, the entrepreneurs' equity is the realized return on capital investment minus the repayment of loans. There are two fundamental sources for the movement of the entrepreneur's

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equity position. Firstly, 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 is the change in the loan repayment burden. If there is an increase in the interest rate, this will lower the entrepreneur's net worth via higher debt burden. This will raise the external finance premium that eventually increases the amount of outstanding loan. The entrepreneur's net worth is further reduced with higher liability due to higher external finance premium. These are the factors that influence the entrepreneur's capability to borrow and eventually will influence the demand and supply of capital in the economy.

To obtain a log-linear approximation of entrepreneurial net worth dynamics in the neighbourhood of steady state, we log-linearize the entrepreneurial equity definition and re-arrange to obtain

$$n_{t+1} = \varsigma \bar{R}_K\left[(\Gamma_5 + 1)r_{K,t} - \Gamma_5(r_{t-1} - \pi_t) - \chi\Gamma_5(q_{t-1} + k_t) + (\Gamma_5 + 1)n_t\right] + (\Gamma_5 + 1)\frac{\bar{W}_E}{\bar{K}}W_{E,t} \tag{3.33}$$

where $\Gamma_5 = \frac{\bar{K}}{\bar{N}} - 1$ and $\frac{\bar{K}}{\bar{N}}$ is the capital net-worth ratio in the steady-state. $\frac{\bar{W}_E}{\bar{K}}$ is the entrepreneur's wages-capital ratio in the steady-state.

3.2.6 Retailers

In the model, it is assumed that there are two categories of retailers. Home goods retailers buy intermediate goods from entrepreneurs and sell it as home goods to households or export it abroad. Foreign goods retailers buy final goods abroad and sell it to the households as foreign goods. Both types of retailers operate at monopolistically competitive markets. Thus, the retailers have certain market power and earn non-zero profits. These profits are distributed back to households. The retailers are assumed to

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practice Calvo-type price setting with inflation indexation, which means that there are nominal price rigidities in the model.

3.2.7 Home Good Retailers

Home goods retailers buy the intermediate good from entrepreneurs at the wholesale price $P_{H,t}^{W}$ and at no additional costs they distribute the home goods to the households. Let $P_{H,t}(z)$ be the price set by home goods 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, only a fraction $(1-\theta_H)$ of home goods retailers re-optimize their prices by setting $P_{H,t}(z) = P_{H,t}^{NEW}$. The remaining fraction of the retailers θ_H do not re-optimize their price. 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"), $\pi_{t-1} \equiv log\left(\frac{P_{t-1}}{P_{t-2}}\right)$ is the CPI inflation.[9] Accordingly, the expected duration for a price to adjust to its optimum level is given by,

[9] The inflation indexation is introduced in order to generate the Phillips Curve that contains both the forward-looking and backward-looking elements. See Gali and Gertler (1999) for a detailed discussion.

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

Thus, for example, if θ_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

$$P_{H,t}=\left[(1-\theta_H)\left(P_{H,t}^{NEW}\right)^{1-\epsilon}+\theta_H\left(P_{H,t}(\pi_{t-1})^{\kappa}\right)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{3.34}$$

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,

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

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

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

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. Parameter β is the exogenous discount factor.[10] The FOC of the above optimization problem is,

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

Then, using the above FOC expression, the optimal price is,

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

where $\mu = \frac{\epsilon}{\epsilon - 1}$ 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.

[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, β.

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

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

where $mc_{H,t+s} = p_{H,t+s}^{NEW} - p_{H,t+s}$. Also, log-linearized the domestic price equation from equation (3.34) to get,

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

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

$$\pi_{H,t} = \frac{1}{(1+\beta_\kappa)}\left[\beta E_t\{\pi_{H,t+1}\} + \kappa\pi_{t-1} + \Lambda^H mc_{H,t}\right] \qquad (3.35)$$

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 Λ^H is decreasing in θ_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.

3.2.8 Foreign Goods Retailers

Foreign goods retailers buy the final goods abroad and sell it to the households at price $P_{F,t}$. Law of one price is assumed to hold at the wholesale level. Therefore, the foreign goods retailers buy the goods at a price $P_{F,t}^W = S_t P_t^*$ (expressed in the local

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currency). Since the law of one price does not hold at retail level ($P_{F,t} \neq S_t P_t^*$), the effect of the incomplete exchange rate pass-through is introduced into the model. Similarly to the home goods retailers, the foreign goods retailers set their prices in a staggered fashion or à la Calvo with parameter θ_F and inflation indexation with parameter κ. The imported good retailer z set price price at $P_{F,t}(z)$ in period t. The import retailers re-optimize their price by choosing $P_{F,t}(z) = P_{F,t}^{NEW}$ based on a fixed probability $(1-\theta_F)$. Those remaining import retailers who do not re-optimize (with probability θ_F) just update their price based on the last period CPI inflation as determined by this equation;

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

According to the assumption of price-setting structure, the aggregate price level for the foreign good is given by

$$P_{F,t} = \left[(1-\theta_F)\left(P_{F,t}^{NEW}\right)^{1-\epsilon} + \theta_F\left(P_{F,t}(\pi_{t-1})^{\kappa}\right)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \qquad (3.36)$$

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

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

subject to the demand constraint, $P_{F,t+s}(z) \leq \left(\frac{P_{F,t}^{NEW}}{P_{F,t+s}}(\pi_{t+s-1})^{\kappa}\right)^{-\epsilon} Y_{F,t+s}$, with total aggregate demand for the foreign goods of

$$Y_{F,t} = \left(\int_0^1 Y_{F,t}(z)^{\frac{\epsilon-1}{\epsilon}} dz \right)^{\frac{\epsilon}{\epsilon-1}}$$

Similar at before, note that $\frac{P_{F,t}^W}{P_{F,t+s}} = MC_{F,t+s}$ is the real marginal cost for the import retailers. Import retailer's optimal price is,

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

To obtain the equation 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 expressed as,

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

Log-linearizing equation (3.36),

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

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

$$\pi_{F,t} = \frac{1}{(1+\beta_\kappa)} [\beta E_t\{\pi_{F,t+1}\} + \kappa\pi_{t-1} + \Lambda^F lopg_t] \quad (3.37)$$

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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. Λ^F is decreasing in θ_F. Similarly to its domestic counterpart, foreign good inflation is also determined by three factors - expectation on 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).

3.2.9 CPI Inflation

Finally, we will derive the log-linear approximation of CPI inflation dynamics for this small open economy. Substituting the results of (3.37) and (3.35) into the definition of CPI inflation (3.10) we obtain

$$\pi_t = \frac{1}{(1+\beta_\kappa)}\left[\beta E_t\{\pi_{t+1}\} + \kappa\pi_{t-1} + (1-\gamma)\Lambda^H mc_{H,t} + \gamma\Lambda^F lopg_t\right] \qquad (3.38)$$

The equation (3.38) implies the combination of domestic and foreign factors are the primary cause of the CPI inflation in this economy. From the domestic side point of view, the real marginal cost is determined by the cost of the factor inputs for producing intermediate goods. In a similar manner, the impact of the foreign factor is channeled through the measure for the law of one price gap (LOPG), $lopg_t$. The relative importance between the domestic and foreign factors in influencing the overall dynamics of the CPI inflation is determined by the parameter γ, the degree of economic openness.

3.2.10 The Monetary Authority

In our model, the monetary authority is modelled using standard forward-looking Taylor rule (1993). This interest rate rule specifies how the central bank reacts

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to expected deviations of CPI inflation and aggregate output from steady state when it decides the policy interest rate. In log-linear terms the Taylor rule can be written down as

$$r_t = (1 - \rho)\left[\beta_\pi \pi_{t+1} + \Theta_y y_{t+1}\right] + \rho r_{t-1} + \varepsilon_t^{MP} \qquad (3.39)$$

where $\rho \in [0;1]$ is smoothing parameter, $\beta_\pi > 1$ represents the elasticity of policy interest rate with respect to the expected CPI inflation, $\Theta_y \geq 1$ stands for the elasticity of policy interest rate with respect to the expected output gap and $\varepsilon_t^{MP} \sim iid(0, \sigma_{mp}^2)$ is the monetary policy shock.

3.2.11 Market Clearing and Equilibrium

3.2.11.1 Foreign Sector

The consumption demand of the foreign country has the same structure as the one described in section 3.1.1. Similar to equation 3.7, the optimal demand for the home good abroad (imported goods for the recipient country) is,

$$C_{H,t}^* = \gamma \left(\frac{P_{H,t}^*}{P_t^*}\right)^{-\eta} Y_t^*$$

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 $P_{H,t}^* = \frac{P_{H,t}}{S_t}$. This allows the demand for the home good abroad to be written as,

$$C_{H,t}^* = \gamma \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} \left(\frac{P_t}{S_t P_t^*}\right)^{-\eta} Y_t^*$$

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

$$C_{H,t}^* = \gamma \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} \left(\frac{1}{RER_t}\right)^{-\eta} Y_t^* \tag{3.40}$$

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

$$\begin{aligned} y_t^* &= \mu_{y_t^*} y_{t-1}^* + \varepsilon_t^{y^*} \\ i_t^* &= \mu_{i_t^*} i_{t-1}^* + \varepsilon_t^{i^*} \\ \pi_t^* &= \mu_{\pi_t^*} \pi_{t-1}^* + \varepsilon_t^{\pi^*} \end{aligned} \tag{3.41}$$

where $\mu_i \in [0;1]$, $i = y_t^*, i_t^*, \pi_t^*$, is the respective AR(1) coefficient and $\varepsilon_t^i \sim iid(0, \sigma_i^2)$ is the respective random shocks.

3.2.11.2 Aggregate Budget Constraint

The production of domestic firms, i.e. 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 $(INV_{H,t})$. Finally, demand for home final goods comes from the foreign country $(C_{H,t}^*)$. In aggregate term, total demand for the home good is $Y_{H,t} = C_{H,t} + INV_{H,t} + C_{H,t}^*$. Using the domestic demand for home goods (3.6) and its analogue for investment demand and also the foreign demand for home goods (3.40) we obtain the aggregate resource constraint,

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

which in log-linear terms means,

$$y_{H,t} = \frac{\bar{C}}{\bar{Y}_H}(1-\gamma)c_t + \frac{\overline{INV}}{\bar{Y}_H}(1-\gamma)inv_t + \gamma y_t^* + \eta\gamma\left(\frac{2-\gamma}{1-\gamma}\right)rer_t - \frac{\eta\gamma}{1-\gamma}lopg_t$$

(3.42)

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.

3.2.11.3 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,

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

The net foreign assets position, $Z_t = \frac{S_t B_t}{YP_t}$ is defined as a ratio of foreign bonds value and nominal GDP. This 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. The evolution of net foreign assets position can be, therefore, approximated by following log-linear equation

$$z_t = \frac{1}{\beta} z_{t-1} + y_{H,t} - (c_t + inv_t) - \frac{\gamma}{(1-\gamma)}(rer_t - \gamma lopg_t) \qquad (3.43)$$

3.2.12 Log-Linearized Equations

For the purpose of simulation analysis, 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 log-linearized equations from previous section can be summarized as below:

Demand Side

- Aggregate Demand or Output

$$y_{H,t} = \frac{\bar{C}}{\bar{Y}_H}(1-\gamma)c_t + \frac{\overline{INV}}{\bar{Y}_H}(1-\gamma)inv_t + \gamma y^*_t + \eta\gamma\left(\frac{2-\gamma}{1-\gamma}\right)rer_t - \frac{\eta\gamma}{1-\gamma}lopg_t$$

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- Consumption

$$c_t - \Upsilon c_{t-1} = E_t(c_{t+1} - \Upsilon c_t) - (1 - \Upsilon)(r_t - E_t\pi_{t+1})$$

- Investment

$$q_t = \psi_I(inv_t - k_t)$$

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

$$E_t r_{K,t+1} = r_t - E_t\pi_{t+1} - \chi(n_{t+1} - q_t - k_{t+1})$$

Supply Side

- Labour supply

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

- Domestic CPI inflation

$$\pi_t = \frac{1}{(1+\beta_\kappa)}\left[\beta E_t\{\pi_{t+1}\} + \kappa\pi_{t-1} + (1-\gamma)\Lambda^H mc_{H,t} + \gamma\Lambda^F lopg_t\right]$$

- 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

$$lopg_t = \rho_{LOPG} lopg_{t-1} + \varepsilon_t^{LOPG}$$

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Other State Variables

- RER

$$rer_{t+1} - rer_t = (r_t - E_t\pi_{t+1}) - (r_t^* - E_t\pi_{t+1}^*) + \psi_B z_t + A_t^{UIP}$$

- Capital accumulation

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

- Net-worth

$$n_{t+1} = \varsigma\bar{R}_K\big[(\Gamma_5+1)r_{K,t} - \Gamma_5(r_{t-1} - \pi_t) - \chi\Gamma_5(q_{t-1} + k_t) + (\Gamma_5+1)n_t\big] + (\Gamma_5+1)\frac{\bar{W}_E}{\bar{K}}W_{E,t}$$

where $\Gamma_5 = \frac{\bar{K}}{\bar{N}} - 1$

- Net foreign asset position

$$z_t = \frac{1}{\beta}z_{t-1} + y_{H,t} - (c_t + inv_t) - \frac{\gamma}{(1-\gamma)}(rer_t - \gamma lopg_t)$$

- Domestic monetary policy rule

$$r_t = (1-\rho)\left[\beta_\pi\pi_{t+1} + \Theta_y y_{t+1}\right] + \rho r_{t-1} + \varepsilon_t^{MP}$$

Foreign Block

- Output

$$y_t^* = \mu_{y_t^*}y_{t-1}^* + \varepsilon_t^{y^*}$$

- Interest rates

$$i_t^* = \mu_{i_t^*}i_{t-1}^* + \varepsilon_t^{i^*}$$

- CPI inflation

$$\pi_t^* = \mu_{\pi_t^*}\pi_{t-1}^* + \varepsilon_t^{\pi^*}$$

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Shocks Process

- UIP

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

- Productivity

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

3.2.13 Steady State Conditions

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

- All prices equal unity, i.e. $\bar{P} = \bar{P}_H = \bar{P}_F = \bar{P}^* = 0$ 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), $\overline{lopg} = 0$. Thus, $\bar{P}_F = \overline{SP}^*$. Then, the nominal exchange rate in the steady-state is $\bar{S} = \frac{\bar{P}_F}{\bar{P}^*} = 1$.

  Also, $\overline{RER} = 1$.

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

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

- 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, $\bar{Z} \equiv \frac{\bar{S}}{\bar{Y}} \frac{\bar{B}}{\bar{P}} = 0$.

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

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

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

- 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 $\bar{R}_K = \left(\frac{\bar{N}}{\bar{K}}\right)^{-\chi} = \frac{1}{\beta}$ and $\bar{Q} = 1$, the rental on capital in the steady-state is $\bar{R}_G = \left(\frac{\bar{N}}{\bar{K}}\right)^{-\chi} = \frac{1}{\beta} - (1-\delta)$.

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

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

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

- Consumption to output ratio, is $\frac{\bar{C}}{\bar{Y}_H} = 1 - \frac{\overline{INV}}{\bar{Y}_H}$.

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Chapter 4

MODEL ANALYSIS AND SIMULATION

4.1 Solving the Model

The model presented in the previous chapter in section 3.2.12 is a log-linearized dynamic stochastic general equilibrium model that describes the deviations of the endogenous variables as linear equations. The system consists of 22 equations and 22 variables $\{y_{H,t}$, c_t, inv_t, π_t, rer_t, $lopg_t$, r_t, $r_{G,t}$, $r_{K,t}$, q_t, k_t, n_t, $l_{H,t}$, mc_t, $w_{H,t}$, $w_{E,t}$, z_t, y_t^*, i_t^*, π_t^*, A_t^{UIP}, $A_t^{Y}\}$ that satisfy the 22 equilibrium conditions, given seven exogenous shocks $\{\varepsilon_t^Y$, ε_t^{UIP}, ε_t^{MP}, ε_t^{LOPG}, $\varepsilon_t^{y^*}$, $\varepsilon_t^{i^*}$, $\varepsilon_t^{\pi^*}\}$. All the seven exogenous shocks are assumed to be i.i.d process.

Technically speaking, the DSGE model belongs to a first order non-linear rational expectations (RE) system class, whose solution consists of a set of first order difference equilibrium equations relating the current variables to the past state of the system and current shocks, which is referred to as the policy function. As shown in Uhlig (1999), the analysis for the non-linear system may be conducted by the following procedure:
(i) identifying the equilibrium conditions to construct a non-linear rational expectations (RE) system; (ii) transforming the non-linear rational expectations (RE) system into the linear one by using a first order Taylor expansion approximation around the steady state; (iii) choosing the parameter values by calibration; (iv) solving the first order linear rational expectations (RE) system by applying numerical methods as in Blanchard and Kahn (1980), Klein (2000) and others; and then (v) investigating the properties of the equilibrium path by analyzing the impulse responses of the model economy to a certain shock.

Having transformed the non-linear model into the linear rational expectations (RE) system by applying the log-linearization technique presented in section 3.2.6, we may write the model in the following linear first order difference equation system:

$$AE_t\{X_{t+1}\} = BX_t + CZ_{t+1}$$

where X_t is a 22 x 1 vector of (log-deviated) endogenous variables, Z_t is a 7 dimensional vector of (log-deviated) exogenous stochastic shocks, *A* and *B* are 22 x 22 coefficient matrices, and *C* is a 22 x 7 coefficient matrix.

The log-linearized DSGE model is solved and estimated using DYNARE v4.6.4,[11] given that the Blanchard and Kahn (1980) conditions are satisfied. 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.

4.2 Estimation Method

In the literature there are several ways on how to take DSGE models to the data and how to work with these models empirically. At the beginning of this macroeconometric research field classical estimation techniques prevailed. There has been a trend toward advanced econometric methods for the last several years due to better computational skills. Bayesian estimation is now the most common technique when working with DSGE models. The classical approach (non-Bayesian) has been elaborated extensively. Surveys of these methods can be found in papers of Kim and Pagan (1995) or Canova (2007) which also provides introduction to Bayesian estimation.

[11] DYNARE is a set of MATLAB© codes to solve, simulate and estimate DSGE models. All versions of DYNARE toolbox and manuals are available on the website http://www.dynare.org/

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An overview Bayesian of method is provided by An and Schorfheide (2007). Ruge-Murcia (2007) introduces and compares following methods: GMM (Generalized Method of Moments), ML (Maximum Likelihood) with Bayesian priors, SMM (Simulated Method of Moments) and Indirect Inference. A very extensive and detailed discussion and overview of Bayesian estimation is provided by Fernandez-Villaverde (2009). The main difference among all methods is in amount of information each method is able to handle. Methodological discussion of various estimation and model evaluation techniques can be found in Sims (1996) or Kydland and Prescott (1996).

In one of the example of Bayesian technique, 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. For example Liu, P (2006) which estimate the model for New Zealand and Adolfson, Laseen, and Lindé (2008) for Sweden. Examples of published work involving developing countries are Medina and Soto (2005, 2007) and Castillo, Montoro, and Tuesta (2006) and Majuca (2011) apply the Bayesian approach to estimate a DSGE model for Chile, Peru and the Philippines respectively.

According to An and Schorfheide(2007) the use of Bayesian approach in the context of estimating the DSGE model has following advantages: First, Bayesian estimation takes advantage of the general equilibrium approach and its system fits the DSGE model to a vector of aggregate time series which are based on the likelihood function generated by the model. As in contrast to GMM estimation which is based on particular (partial) equilibrium relationships such as Euler equation in consumption. Second, the estimation of the Bayesian approach is based on the likelihood function

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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. Last, prior distributions can be used to incorporate additional information into the parameter estimation. Bayesian estimation outperforms the techniques of GMM and ML in small samples. Moreover, according to Rabanal and Rubio-Ramirez (2005), in case of misspecified models, Bayesian estimation and model comparison are consistent.

4.2.1 Bayesian Estimation

This section provides a brief description 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. The key building blocks of Bayesian estimation are the priors, the likelihood density function and Bayes' theorem. To briefly explain the procedures of the Bayesian estimation, let θ_M indicates 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:

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

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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:

$$p(\theta_M|Y_T, M) = \frac{p(Y_T|\theta_M, M) \times p(\theta_M|M)}{p(Y_T|M)}$$

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

$$p(Y_T|M) = \int_{\theta_M} p(Y_T|\theta_M, M) \times p(\theta_M|M) d\theta_M$$

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 key part of doing this is to utilize the parameter's posterior kernel equation,

$$K(\theta_M|Y_T, M) \equiv p(\theta_M|Y_T, M) \propto p(Y_T|\theta_M, M) \times p(\theta_M|M)$$

The construction of the parameter's posterior distribution involves two major 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 θ_M, its explicit form is unknown. Thus, 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.

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The Bayesian estimation in this chapter was performed using DYNARE v4.64. 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:

- 2 parallel Markov chains

- 150,000 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%.

4.2.2 Priors Information and Fixed Parameters

This section deals with setting and selection of priors of the parameters before Bayesian estimation. Priors' distributions (means and standard deviations) are gleaned from personal belief about parameter values and economic theory, Schorfheide (2000). In practice, priors are chosen on the basis of theoretical restrictions on the parameter values (non-negativity or confidence interval) given in the existing literature. 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 reasonable prior distribution, the next phase is to find a reasonable value for the prior mean and standard deviation of each parameters. Consequently, results from other empirical studies are used.

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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 served as a reference. In this regard, the main references I used are Shaari (2008); Alp, Harun et al (2011) and Ramayandi (2008). The information from these estimates is useful in guiding us to set the priors for most of the parameters in this exercise. By making use of information from Shaari (2008) estimation results on the deep parameters for the Malaysian economy, fairly tight priors are set on the deep parameters Υ, Ψ, η, κ, θ_D, θ_F. Table 4.1 reports the prior distribution of the parameters are mainly taken from Shaari (2008).

Table 4.1: Prior Distributions of Parameters

	Description	Density	Mean	Std Dev.
Υ	Habit Persistence	Beta	0.50	0.05
Ψ	Inverse elasticity of labour supply	Gamma	2.00	0.50
η	Home and foreign goods elasticity of substitution	Gamma	0.50	0.10
κ	Price indexation	Beta	0.50	0.10
θ_D	Calvo pricing - domestic goods	Beta	0.80	0.10
θ_F	Calvo pricing - imported goods	Beta	0.80	0.10
χ	Financial Accelerator	Beta	0.07	0.02
ρ	Taylor rule - interest rate smoothing	Beta	0.50	0.25
β_π	Taylor rule - inflation weight	Normal	1.20	0.25
Θ_y	Taylor rule - output gap weight	Normal	1.00	0.25
$\mu_{y_t^*}$	AR(1) : foreign output	Beta	0.50	0.25
$\mu_{i_t^*}$	AR(1) : foreign int. rate	Beta	0.50	0.25
$\mu_{\pi_t^*}$	AR(1) : foreign inflation	Beta	0.50	0.25
ρ_{UIP}	AR(1) : UIP shocks	Beta	0.50	0.25
ρ_{LOPG}	AR(1) : LOP shocks	Beta	0.50	0.25
ρ_Y	AR(1) : technology shocks	Beta	0.50	0.25
σ_{MP}	Std. dev. monetary policy shocks	Inverse Gamma	0.05	Infinity
σ_{y^*}	Std. dev. foreign output shocks	Inverse Gamma	0.05	Infinity
σ_{i^*}	Std. dev. foreign int. rates shocks	Inverse Gamma	0.05	Infinity
σ_{π^*}	Std. dev. foreign inflation shocks	Inverse Gamma	0.05	Infinity
σ_{UIP}	Std. dev. UIP shock	Inverse Gamma	0.05	Infinity
σ_{LOPG}	Std. dev. LOP shocks	Inverse Gamma	0.05	Infinity
σ_Y	Std. dev. technology shocks	Inverse Gamma	0.05	Infinity

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As commonly done in the DSGE literature, a number of fixed parameters were calibrated from the outset, not being included in the estimation process. This procedure helps to deal with the problem of identification from which DSGE models commonly suffer, arising from the fact that the variables used in the estimation may contain little information about some of the parameters of interest. For the household discount parameter β, the value is 0.985. The share of capital in the production function, α, is set at 0.35. Values around one third are usually used in the literature, see, for example, Adolfson, Laséen and Villani (2007). The depreciation rate, δ, is 0.025, which implies an annual depreciation rate of 10% which is standard and is widely used in the literature. The degree of retailer's monopoly power, ϵ, is set at 6, which implies a gross steady-state price markup (μ) of 1.20. The parameter measuring capital adjustment cost ψ_I, is set at 0.5. Following Schmitt-Grohe and Uribe (2003), the parameter for the elasticity of the risk premium ψ^B is set to 0.01. Most of the parameters for the financial accelerator mechanism are the same as in Bernanke, Gertler, and Gilchrist (1999). The probability that an entrepreneur will survive for the next period, ς, 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, Ω, is fixed at 0.99.

4.2.3 Data

For the estimation of the models' parameters, quarterly data from Malaysia and the USA (as a proxy for the foreign economy) are used. The Malaysian data used are real output (GDP), CPI index, nominal interest rate (money market rate) and index of the real exchange rate and the data are obtained from the IMF IFS's online database. The US data used are real output, CPI index, and nominal interest rate (Federal Fund rate) and the data are retrieved from FRED, Federal Reserve Bank of St. Louis. As the Malaysian data are not seasonally adjusted, they (except interest rate) are adjusted using the US Census

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Bureau's X12 seasonal adjustment program in Eviews. All data enter into the estimation are log-transformed (except the nominal interest rate), and are detrended using a one-sided Hodrick-Prescott filter.[12] The sample period for the estimation of the DSGE model is 1992Q1 to 2020Q4. Figure B1 showing the original data can be found in Appendix B.

4.3 Estimation Results

The estimation results are reported in Table 4.2 showing the distribution used, the prior mean, the posterior mean, standard deviation, and the 95% confidence interval for the estimated parameters obtained through the Metropolis-Hastings sampling algorithm. Based on the 95% confidence interval of the estimated parameters, the results indicate that all estimated parameters are significantly different from zero and lie within the commonly accepted range of reasonable values in the literature. This result indicates that the simple open economy DSGE model is able to fit the data reasonably well. Besides this statistical information, graphs of prior and posterior distributions of the estimated parameters are depicted in the Appendix C in figure C1.

Estimates of parameters describing household's preferences are mixed. The estimated posterior mean for the degree of habit persistence (Υ) of 0.5 is identical to the prior of 0.50 and is very close to Shaari (2008) who reports the value of 0.56. This value is relatively low compared to the estimates of around 0.7-0.9 reported in Adolfson, Laséen, and Villani (2007) for the Euro area; Liu (2006) for New Zealand; Ramayandi (2008) for Indonesia, Thailand and Philippines and Alp, Elekdag, and Lall (2011) for South Korea. Despite the difference, our estimate still indicates a significant degree of habit formation in Malaysia consumption data and the important role of the reference level in households' utility function.

[12] Pfeifer (2015) provides a comprehensive introduction to the specification of observation equations and data transformation.

Table 4.2: Prior and Posterior Estimates of Parameters

	Density	Prior Mean	Posterior Mean	Posterior Std Dev.	Confidence Interval at 95%	
Υ	Beta	0.50	0.500	0.050	0.399	0.612
Ψ	Gamma	2.00	1.696	0.500	0.811	2.622
η	Gamma	0.50	0.600	0.100	0.483	0.793
κ	Beta	0.50	0.351	0.100	0.187	0.518
θ_D	Beta	0.80	0.844	0.100	0.805	0.883
θ_F	Beta	0.80	0.880	0.100	0.848	0.912
χ	Beta	0.07	0.027	0.020	0.003	0.073
ρ	Beta	0.50	0.915	0.250	0.882	0.946
β_π	Normal	1.20	1.321	0.250	0.759	1.839
Θ_y	Normal	1.00	1.280	0.250	0.763	1.834
$\mu_{y_t^*}$	Beta	0.50	0.619	0.250	0.499	0.743
$\mu_{i_t^*}$	Beta	0.50	0.886	0.250	0.831	0.944
$\mu_{\pi_t^*}$	Beta	0.50	0.162	0.250	0.017	0.304
ρ_{UIP}	Beta	0.50	0.702	0.250	0.617	0.787
ρ_{LOPG}	Beta	0.50	0.915	0.250	0.859	0.987
ρ_Y	Beta	0.50	0.058	0.250	0.000	0.150
σ_{MP}	Inverse Gamma	0.05	0.004	Inf	0.004	0.005
σ_{y^*}	Inverse Gamma	0.05	0.011	Inf	0.010	0.012
σ_{i^*}	Inverse Gamma	0.05	0.004	Inf	0.004	0.005
σ_{π^*}	Inverse Gamma	0.05	0.007	Inf	0.006	0.008
σ_{UIP}	Inverse Gamma	0.05	0.008	Inf	0.006	0.010
σ_{LOPG}	Inverse Gamma	0.05	0.105	Inf	0.070	0.133
σ_Y	Inverse Gamma	0.05	0.072	Inf	0.048	0.100

The estimated inverse elasticity of substitution for labour,(Ψ) is 1.69 and this value is higher than Shaari (2008) who reports the value of around 0.7-1.0. The estimate is in accordance with the values of 1.5 to 2 found in Kam, Lees, and Liu (2009) 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 (Ψ) is greater than 1 indicates that the labour supply in our empirical model is non-elastic. This implies a one percent increase in real wage will result in only a small change in labour supply.

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The elasticity of substitution between domestic and foreign goods (η) is estimated at 0.60. This is close to the study by Shaari (2008) who reports the value of around 0.5-0.6. This estimate is also close to the values found in many of the open-economy DSGE literature, among others by Lubik and Schorfheide (2005), Adolfson, Laséen, and Villani (2007) and Alp and Elekdag (2012). The less than unitary estimate for η indicates substitution between domestic and foreign goods is inelastic. This suggests consumption preferences in Malaysia are biased towards domestic produced goods.

The estimates of the price indexation parameter (κ) of 0.35 are in line with Alp et al. (2012), who found the estimate of 0.38. This estimated value is lower than Shaari (2008) who finds the value of around 0.6, suggesting a fairly moderate degree of inflation persistence in the Malaysian economy. The posterior mean of Calvo pricing parameters - θ_D and θ_F - are estimated at the value of 0.84 and 0.88 respectively. The obtained results are in accordance with Ramayandi (2008) who found values near 0.84 and 0.88 for Philippines and Singapore respectively. However, Shaari (2008) reports rather lower price rigidity with Calvo parameters of home and foreign goods of 0.71 and 0.74 respectively. The estimated values for parameter θ_D and θ_F (the probability of not changing prices from Calvo-style price setting behaviour of domestic producers and importers) suggest that, the average duration of the price contracts is therefore [1(1-θ_D)] approximately 6 quarters for the domestic producers and approximately 8 quarters for importers. This is very much in line with the estimated duration in the Philippines and Singapore reported by Ramayandi (2008).

Financial accelerator parameter (χ) is assigned prior mean of 0.07 and standard deviation of 0.02. Posterior mean of the estimate is near 0.027, which is not far from result reported by Shaari (2008) of 0.032 but quite similar to the result of Tonner and Vašíček

(2011) of 0.0269 for the Czech economy. Turning to the estimates of the monetary policy rule, the estimate for (ρ) which measures the degree of interest rate smoothing is about 0.91. This estimated value is higher than reported by Shaari (2008) of 0.6 but much closer to 0.86 estimated by Alp, Elekdag, and Lall, (2012). Our estimate may suggest that there is a persistence of interest rate smoothing in the monetary policy framework during the estimation period. The estimated posterior mean of the reaction coefficient on the inflation rate, (β_π) is 1.32 which is much lower than to Shaari (2008) who finds the value of around 2.1-2.20. This may also suggest that one of the goals of the central bank is to stabilize the inflation rate albeit in much moderate manner. Similarly, the estimated posterior mean of the reaction coefficient on output gap (Θ_y) is 1.28 and is quite close to about 1.3-1.5 as reported by Shaari (2008). Taken together, these results suggest that the central bank reaction function shows strong responses to both inflation and output gap during the estimation period. As to the estimates of the autoregressive parameters AR(1) of the shocks, (ρ_{LOPG}) is estimated to be very persistent (posterior mean is 0.91), and this follows by ($\mu_{i_t^*}$) and (ρ_{UIP}). On the other hand, the least persistent is the shocks to (ρ_Y) estimated at 0.06. Estimated standard deviations of innovations of these processes display high volatility of the shock is (ρ_{LOPG}) estimated at 1.05. The posterior estimates for both monetary policy shock (σ_{MP}) and foreign interest rate ($\mu_{i_t^*}$) at 0.04 respectively are the least volatile.

4.4 The Impulse Response Analysis

In this section we can observe the dynamic properties of the model by studying its impulse response functions. In this regard we want to analyze how key macroeconomic variables adjust or response to various exogenous shocks in order to establish how these key variables adjust to shocks to the economy. Impulse response functions describe reactions of endogenous model variables to exogenous shock innovations i.e. one

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standard deviation shock. In our study there are only six exogenous shocks that we focus on, such as technology, monetary policy, foreign output, foreign interest rate, risk premium (UIP), and foreign inflation shocks respectively. The structure of the exogenous shocks offer us the most natural way of orthogonalized decomposition of the subspace of exogenous variables - all shocks are modelled to be independently distributed and they have a well-defined economic foundation, based on the behavior of the individual agents in the economy described in chapter 3.

4.4.1 Impulse Responses to a Technology Shock

Figure 4.1 shows that the responses of the output, consumption, investment, inflation, domestic interest rate and RER (real exchange rate) to a positive technology shock are in line with the real business cycle model (RBC) predictions. The qualitative effects of this shock on output, inflation, and interest rate are also very similar to the empirical evidence from developed economies, such as the Euro area or the United States (see Smets and Wouters, 2003, 2007)). A positive technology shock initially expands output, while consumption also increases. As output and consumption return to the steady state, their growth rates decline, only moderately for output because of the highly persistent total factor technology process. The investment also increase follows a hump-shaped pattern, which distinguishes that impulse response from that of the real output and consumption. Due to the rise in productivity, the intermediate good firm's marginal cost falls, and this causes inflation to initially drop below the steady state. The demand for labor also falls as is normally the case in models with nominal rigidities (Gali, 1999), but it recovers over time. Because domestic inflation is decreasing, the central bank tries to stabilize inflation and lowers the nominal interest rate. The fall in domestic prices and the lower interest rate causes the real exchange rate to depreciate for several periods and subsequently appreciates.

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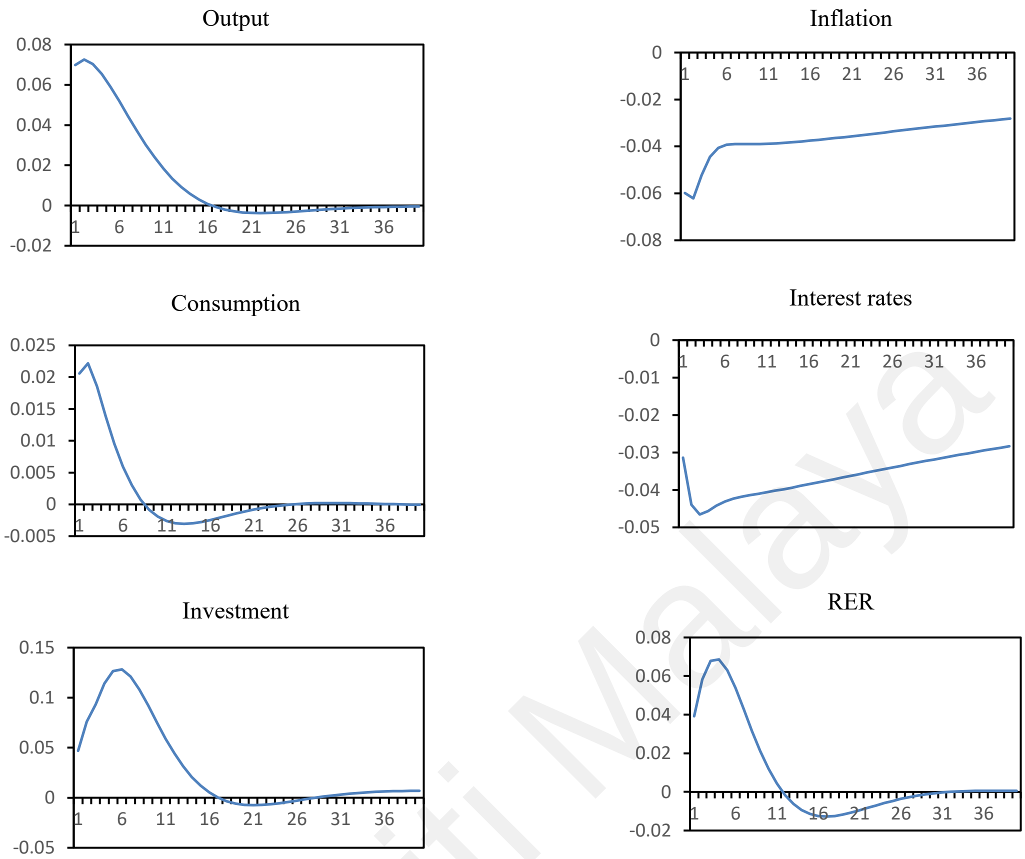
Figure 4.1: Impulse Responses to a Technology Shock



4.4.2 Impulse Responses to a Monetary Policy Shock

Figure 4.2 shows the effect of a temporary positive nominal interest rate shock. It represents a restrictive monetary policy change involving a 1% increase in the interest rate. The positive shock in the nominal interest rate policy triggers an immediate rise in the interest rate. Due to the nominal frictions in the model (such as price and wage stickiness), the real interest rate rises as well, leading to a reduction in output, consumption, investment as well as inflation. The consumption response is hump-shaped because, under habit formation, agents smooth both the level and the change of consumption. The peak of the consumption response takes place after three periods. High nominal interest rate also induces real exchange rate appreciation, which supports the domestic demand for foreign imports and decreases the foreign demand for domestic

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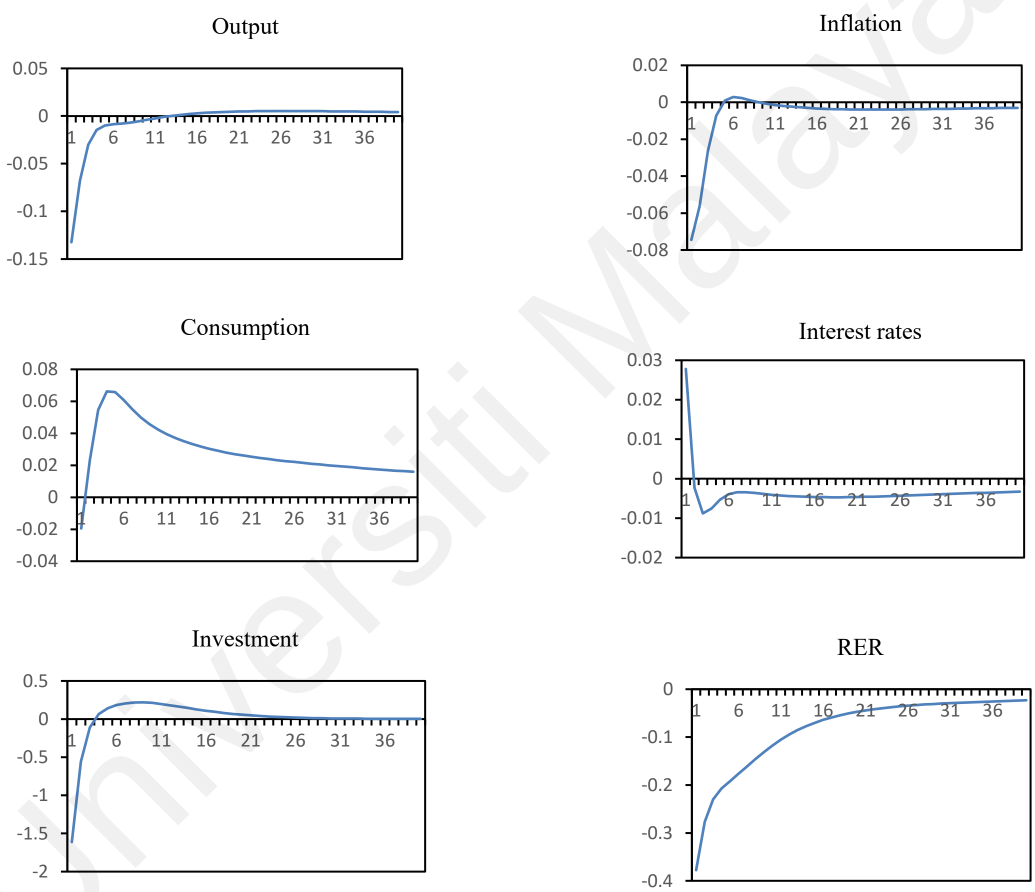
exports. The adjustment of the domestic consumption is rather sluggish and so the drop in the investment demand outweighs the effect of the real exchange rate appreciation. Overall we can observe the main variables of output, consumption, investment and inflation adjust at different speed after the impact of the monetary policy shock and move toward their steady state or equilibrium rates.

Figure 4.2: Impulse Responses to a Monetary Policy Shock



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4.4.3 Impulse Responses to a Foreign Output Shock

The influence of a temporary positive foreign output shock is shown in Figure 4.3. In the small open economy, the growth in foreign output means a growth of demand for exports of the domestic economy. Aggregate output and investment are each stimulated by the increase in foreign demand, but not for a long period. As for consumption, it only slowly increases two periods after the impact of the foreign output shock. The higher foreign output shock leads to an increase in domestic production and this stimulates demand for labor. The shock causes higher marginal costs, and hence increases the price of domestic goods and inflation. The rise in inflation and the domestic interest rate causes a widening of the difference between foreign and domestic interest rates. This creates pressure for a depreciation in the domestic currency. The real exchange rate depreciates initially and it eventually appreciates after period five. The total influence on the economy is important, and we can observe the main variables of output, consumption, investment and inflation adjust at different rates after the impact of the foreign output shock and move toward their steady state or equilibrium rates.

4.4.4 Impulse Responses to a Foreign Interest Rate Shock

Figure 4.4 shows the impulse responses to a one percent positive shock to the foreign interest rate, and this shock can be interpreted as a monetary policy tightening abroad. According to the uncovered interest rate parity condition, the increase in the foreign interest rate induces a depreciation of the domestic currency. The real exchange rate initially depreciates and subsequently returns to its steady state in approximately 23 periods when the effect of the shock gradually disappears. The depreciation of the domestic currency influences other variables as well. It stimulates the demand for domestic exports and aggregate output increases and subsequently decreases after period two. The increase in aggregate product implies higher marginal costs and a higher

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inflation rate. As a result, the domestic monetary authority raises the nominal interest rate to which domestic output responds with a slight decline. Households' consumption decreases because of the high real interest rate and investment also decreases because of higher cost of borrowing. Overall the model dynamics seem to match the standard new open economy predictions.

Figure 4.3: Impulse Responses to a Foreign Output Shock

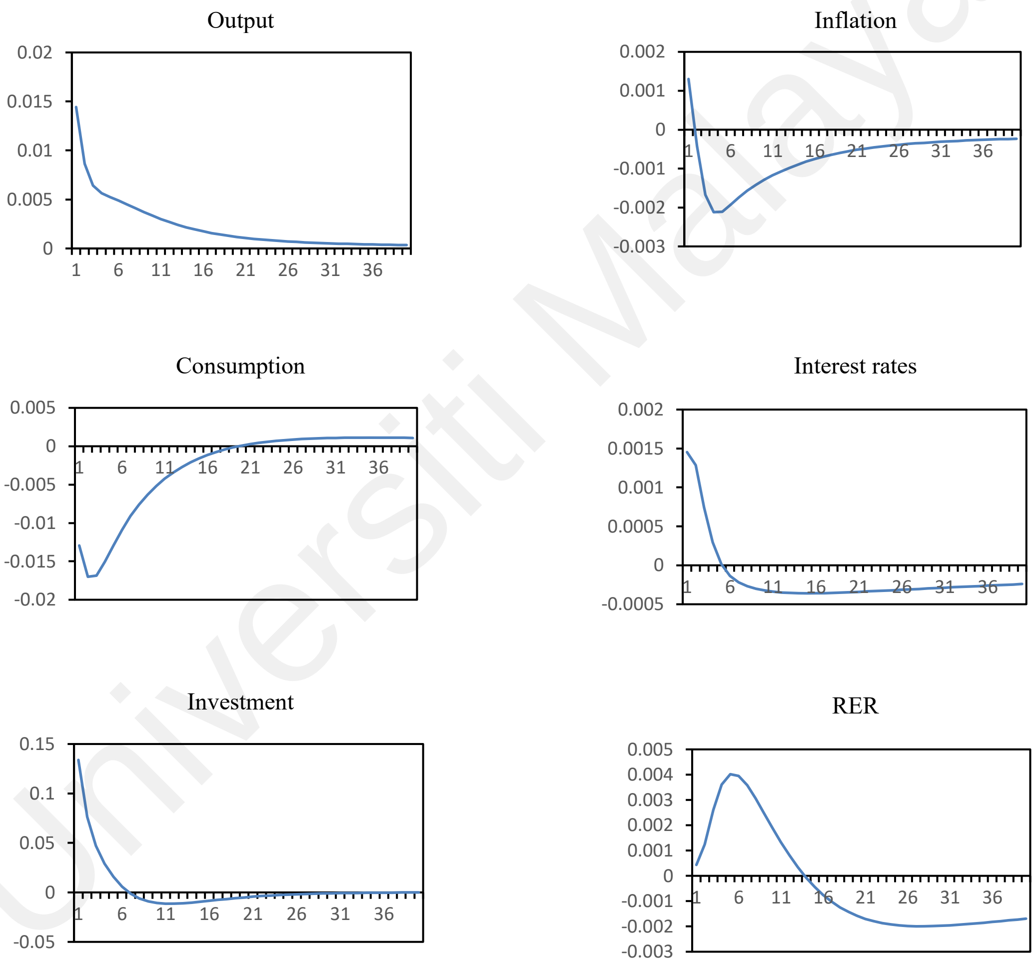

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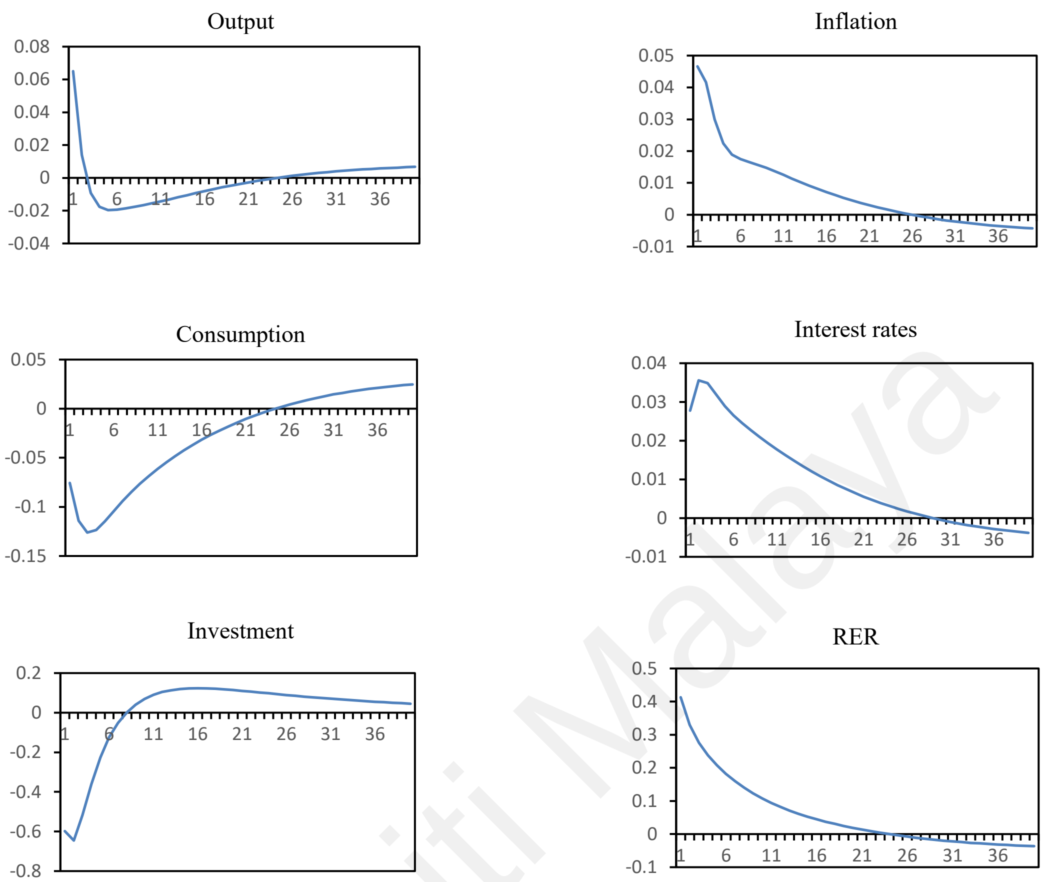
Figure 4.4: Impulse Responses to a Foreign Interest Rate Shock



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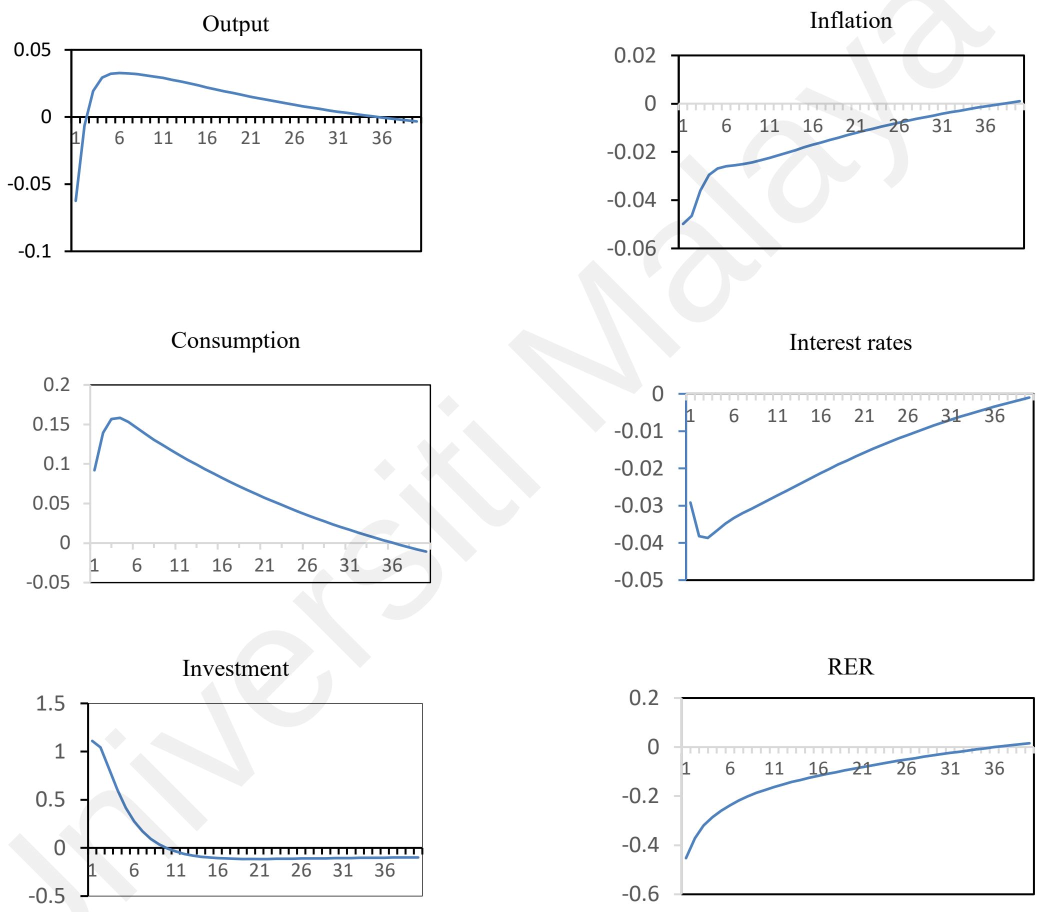
4.4.5 Impulse Responses to a Risk Premium Shock (UIP)

Figure 4.5 illustrates the impulse responses to an innovation in the debt-elastic risk premium shock. A Positive innovation in the UIP shock causes a decline in the risk premium and an appreciation of the real exchange rate. This induces higher demand for imported goods and causes a growth of consumption and investment. Foreign demand for domestic exports, however, declines and so does net exports, and aggregate output as well for a few periods and recovers progressively. As a results of this development, the net foreign asset position also deteriorates. The declining price of foreign goods brings about a deflation of consumer prices, the inflation rate falls and rises gradually to its steady state level. The appreciation of the real exchange rate also causes a decrease in domestic marginal costs, wages and the capital rental rate. The premium shock forces an initial decline in the domestic interest rate, partially to respond to the initial deflation, and moderately restores the equilibrium condition imposed by the uncovered interest rate parity condition in the financial markets.

Figure 4.5: Impulse Responses to a UIP shock



4.4.6 Impulse Responses to a Foreign Inflation Shock

Figure 4.6 shows the effects of a positive foreign inflation shock. The rise in foreign inflation leads to a decrease of the real exchange rate (appreciation) because of the uncovered interest parity condition. After the shock, the export position of domestic producers deteriorates and the net asset position falls. Output falls moderately and

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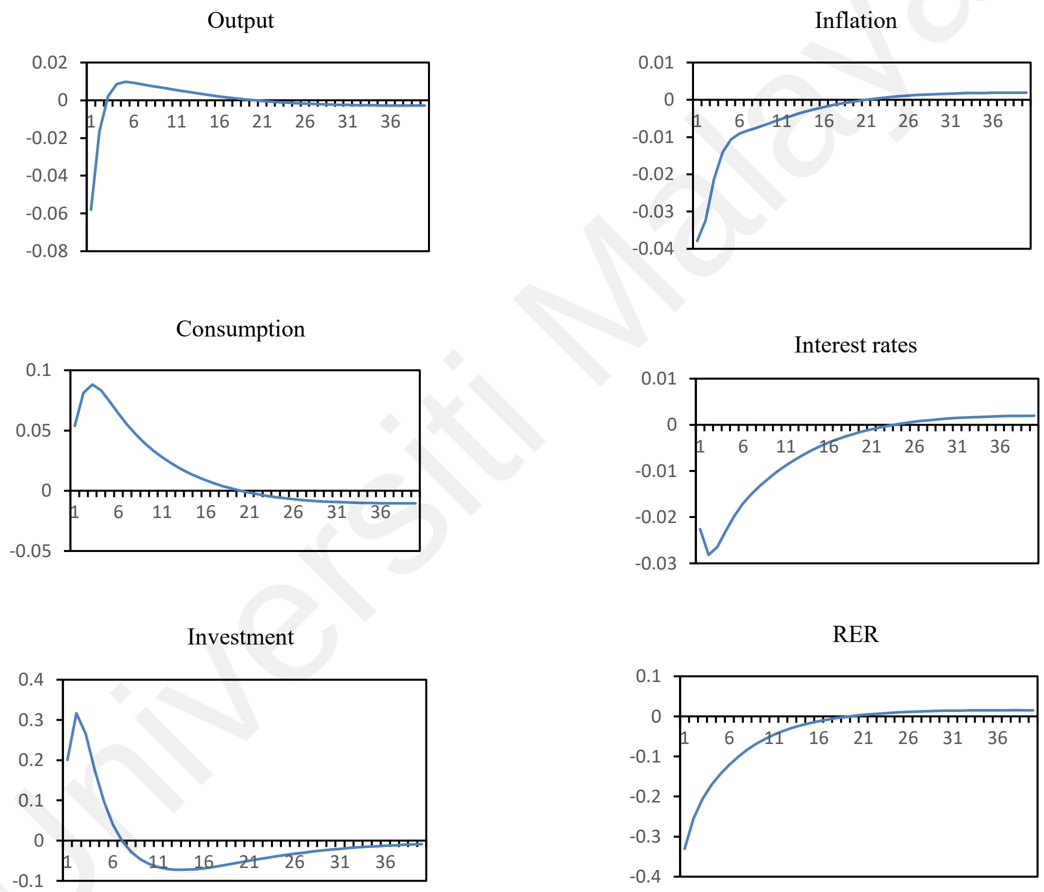
recovers back to steady state two periods later. The shock creates a downward pressure on inflation. As output declines, marginal costs and labour demand also fall. The central bank sets the nominal interest rate lower to stabilize the real exchange rate, output, and inflation. Subsequently household consumption and investment expand moderately. Higher consumption causes an upward pressure on output, and for domestic inflation to reach its steady state value over time.

Figure 4.6: Impulse Responses to a Foreign Inflation Shock



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4.5 Forecast Error Variance Decomposition (FEVD) Analysis

In this section, the sources or the main driving force of fluctuations in the economy's main aggregate variables are analyzed by applying the forecast error variance decomposition to the dynamic model. In particular, we analyze the contribution of each of the shocks in the model to the variations in output, consumption, investment, inflation, nominal interest rate, and real exchange rate at various horizons that could characterize the short-run, the medium-run, and the long-run. We define 1-4 quarters as the short-run, 8-16 quarters as the medium-run, and 64 quarters as the long-run. The variance decomposition is reported in Table 4.3.

In the short term, the key drivers of output is found to be monetary policy, UIP, and foreign interest rate shocks. At that horizon, monetary policy shock was the main driver of output, contributing to about 54% variation in output, followed by UIP shock (13%), and foreign interest rate shock (7.7%). After the initial four quarters, monetary policy shock remains to be the main driver of output in both medium and long terms. Specifically, it contributes to about 60% in the variability of output followed by UIP shock (9.8%), and foreign interest rate shock (6.4%) in the long run. One interesting fact is that technology shock is never too important relative to other shocks, accounting for 1.5% of variation in output in the short run but only 4.6% in the long run.

Regarding the drivers of consumption, it can be seen that, technology shock, foreign interest rate shock, and UIP shock are the most important. In terms of their contributions to the fluctuation in consumption, technology shock contributes largely (about 42%) in the short run, followed by foreign interest rate shock (6%), and UIP shock (4%). As for the medium and long run, technology shock remains the most important, and it can be noticeable that, monetary policy shock and foreign interest rate shock appeared to be more important than UIP shock. In terms of their contributions to the fluctuation in

Table 4.3: Forecast Error Variance Decomposition (in percent)

Shocks	Output	Consumption	Investment	Inflation	Nominal interest rate	Real exchange rate
			1st Quarter			
Technology shock	1.54	42.15	8.15	74.36	0.01	12.25
Monetary policy shock	54.12	0.82	89.54	21.08	88.83	42.10
UIP shock	12.90	4.15	1.55	1.57	2.61	17.63
Foreign output shock	0.76	0.24	0.07	0.00	0.05	0.10
Foreign interest rate shock	7.69	5.99	0.67	1.42	2.42	12.73
Foreign inflation shock	0.06	0.00	0.00	0.00	0.00	0.07
			4th Quarter			
Technology shock	1.34	41.65	8.29	65.71	8.46	18.70
Monetary policy shock	61.21	3.18	82.07	29.40	58.53	37.85
UIP shock	10.11	3.66	1.84	1.61	4.72	11.11
Foreign output shock	0.56	0.14	0.06	0.19	0.04	0.09
Foreign interest rate shock	6.63	6.03	1.38	1.57	7.12	10.97
Foreign inflation shock	0.04	0.00	0.00	0.00	0.00	0.03
			8th Quarter			
Technology shock	1.62	39.47	10.16	69.19	20.55	27.22
Monetary policy shock	61.46	7.98	79.15	25.41	40.77	33.60
UIP shock	9.98	2.67	1.76	2.17	3.43	7.90
Foreign output shock	0.55	0.08	0.07	0.28	0.12	0.07
Foreign interest rate shock	6.50	5.21	1.46	1.59	6.77	8.89
Foreign inflation shock	0.04	0.00	0.00	0.00	0.00	0.02
			16th Quarter			
Technology shock	2.81	39.70	10.22	70.68	24.83	35.09
Monetary policy shock	60.78	10.89	78.93	23.30	31.29	31.11
UIP shock	9.84	1.92	1.87	2.32	3.01	6.12
Foreign output shock	0.55	0.05	0.07	0.32	0.27	0.05
Foreign interest rate shock	6.41	3.97	1.62	1.87	5.33	7.09
Foreign inflation shock	0.04	0.00	0.00	0.00	0.00	0.02
			64th Quarter			
Technology shock	3.39	40.07	10.80	68.36	20.58	39.39
Monetary policy shock	60.40	12.81	78.31	22.29	27.60	30.65
UIP shock	9.78	1.57	1.86	2.36	2.59	5.34
Foreign output shock	0.55	0.05	0.07	0.35	0.36	0.05
Foreign interest rate shock	6.38	3.34	1.70	2.82	6.35	6.23
Foreign inflation shock	0.04	0.00	0.00	0.00	0.00	0.01

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consumption, technology shock contributes about 40% in the long run, followed by monetary policy shock (13%), foreign interest rate shock (3.3%), and UIP shock (1.6%).

With regard to the investment variable, monetary policy shock is found to be the most dominant force at all the horizons and contributing to about 90% of variation in investment in the short run, 79% in the medium run and about 78% in the long run respectively. This followed by technology shock, accounting for about 8%, 10%, and 10.1% in the short, medium, and long terms respectively. UIP shock and foreign interest rate shock appeared to be less important, accounting for 1.9% and 1.6% in explaining the variability of investment in the long run.

Turning to inflation, technology shock appeared to be the main driving force and this followed by monetary policy shock and the least influence are UIP shock and foreign interest rate shock. In terms of their contributions to the fluctuation in inflation, technology shock contributing to about 74% variation in inflation, followed by monetary policy shock (21%), UIP shock (1.6%), and foreign interest rate shock (1.4%). As for the medium and long runs, technology shock remain the most important force accounting for about 71% variation in inflation, and this followed by monetary policy shock contributing about 23% and 22%.

As expected, in the short term, monetary policy shock is the key drivers of nominal interest rate variation, followed by UIP shock, and foreign interest rate shock. At that horizon, monetary policy shock can account for about 89% of nominal interest rate fluctuations, UIP shock (2.6%), and foreign interest rate shock (2.4%). After the initial four quarters, monetary policy shock remains the main driver of nominal interest

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rate fluctuations in both medium and long terms. Also at that horizon, technology shock becomes more important than UIP shock and foreign interest rate shock. In terms of their quantitative importance, monetary policy shock accounting for 28% in the long-run, followed by technology shock (21%), foreign interest rate shock (6%), and UIP shock (2.6%).

Finally, for real exchange rate variable, monetary policy shock is found to be the main driving force in the short term, contributing to about 42% of variation in real exchange rate. This is followed by UIP shock accounting for about 18%, foreign interest rate shock 13%, and technology shock 12%. However, after the initial four quarters, technology shock overtook monetary policy shock to be the main driver of real exchange rate in both medium and long terms. Accordingly, technology shock accounting for about 40% variation in real exchange rate, followed by monetary policy shock (31%), foreign interest rate shock (6.2%), and UIP shock (5.3%) in the long-run.

In summary, the results of the variance decomposition analysis indicate that, the monetary policy shock and technology shock are the main driving forces of macroeconomics fluctuations of the real sector's variables (output, consumption, investment) and nominal variables (inflation, nominal interest rates, real exchange rate). The relative importance of each shock varies with the horizon. Monetary policy shock is also predominantly explains movements in the output, investment, nominal interest rates and real exchange rate both in the short-run and long-run. The technology shock predominantly explains movements in consumption, inflation, real exchange rate in the short-run and long-run. The remaining shocks such as UIP shock and foreign interest rate shock play only marginal role in the long run. Foreign output shock and foreign inflation shock have minor and insignificant effect on macroeconomic variables.

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The aim of this chapter is focusing on answering the first and second research questions and reported the main results from the applications of the theoretical DSGE model in the analysis. What are the main structural shocks or driving forces that cause the short-term or long-term movements in key macroeconomic variables in Malaysia? In this regard, forecast error variance decomposition (FEVD) is employed and the findings reported in section 4.5 of this chapter. How do business cycle fluctuations affect the Malaysian economy? In other words, what is the macroeconomic adjustment of Malaysian economy to various exogenous shocks? We conducted the impulse response analysis, described the macroeconomic adjustment to exogenous shocks, and analysed the dynamic properties of the model as reported in section 4.4 this chapter. The analysis showed that the model implications on the macroeconomic adjustment are essentially in line with the conventional wisdom of the literature. For example, a technology shock leads to an increase in the output and a fall into the inflation as predicted by the New-Keynesian model.

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Chapter 5

SUMMARY AND CONCLUSION

5.1 Summary and Conclusion

This thesis studies the sources of business cycle fluctuations in a developing country economy by utilizing a dynamic stochastic general equilibrium model (DSGE) based on the New Keynesian framework. The design of the DSGE model builds on a model developed by Gali and Monacelli (2005), and is modified to include the financial accelerator mechanism as described in Bernanke et al. (1999). The model consists of representative households, representative firms, a central bank, and an exogenous foreign sector. All agents optimize their behavior with respect to their constraints. The model is subjected to six structural shocks or fundamental disturbances: a technology shock in the domestically produced goods sector, a monetary policy shock, a risk premium shock (UIP), and external shocks which consist of foreign interest rate shock, foreign inflation shock and foreign output shock. These shocks move the economic system away from the steady state or the balanced growth path and trigger business cycle fluctuations in the macroeconomic variables. Thus, exogenous shocks cause business cycle fluctuations in developing economies, and the dynamic effects of these shocks drive macroeconomic variables from their steady state values to paths marked by peaks and troughs. Real, nominal, and financial frictions slowdown the macroeconomic adjustment, magnify the economic volatility, and generate persistence in the macroeconomic variables. The dynamic movements of key macroeconomic variables in response to these disturbances are analyzed using the impulse response functions.

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Moreover, the sources of macroeconomic fluctuations are examined through the variance decomposition technique.

Chapter 2 documents the literature on the theory and empirical evidence on business cycle fluctuations in developed and developing economies. Chapter 3 develops the theoretical dynamic stochastic general equilibrium model that tailors the unified framework of this thesis. Chapter 4 presents the Bayesian estimation methodology, calibration, impulse response and variance decomposition analyses of the DSGE model. And Chapter 5 summarizes the study and draws several conclusions and implications.

The impulse response analysis helped to examine the dynamic properties of the model, to check its stability, and to identify the variables that display complex and interesting dynamics. Thus, as the main results showed, productivity shocks have a positive impact on output, followed by an immediate fall in inflation, as it reduces the marginal costs of firms' production caused by an increase of labour productivity which allows firms to keep their production levels with less employment. A positive interest rate shock, considered a contractionary monetary policy change, has negative impact on output, consumption, investment, inflation and marginal cost and causes the real exchange rate to appreciate and improves the net asset position. Risk premium shocks induce the appreciation of the real exchange rate and have a negative impact on output and nominal interest rates, but have a positive impact on investment and consumption. With regard to foreign shocks, a temporary foreign interest rate shock has negative effects on investment decisions and it causes a contraction in consumption, but it positively affects output, inflation, nominal interest rates, marginal cost, the net asset position and household employment. It also generates a real depreciation of the currency. Positive foreign inflation shocks have a direct impact on marginal cost which

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causes an increase in inflation and a decrease in both output and employment. Finally a temporary positive foreign output shock has a positive effect on output, consumption, investment and inflation, which adjust at different rates on impact and subsequently move towards their steady state or equilibrium values.

The results from the variance decomposition show analysis indicate that, both monetary policy shock and technology shock are the main driving forces of macroeconomic fluctuations of the real sector's variables (output, consumption, investment) and nominal variables (inflation, nominal interest rates, real exchange rate). The relative importance of each shock varies with the horizon. The remaining shocks such as UIP shock and foreign interest rate shock play only marginal role in the long run. Foreign output shock and foreign inflation shock have minor and insignificant effect on macroeconomic variables. The results also suggest that domestic shocks play a more significant role as sources of macroeconomic fluctuations in the model than do foreign shocks.

There are some issues which I do not address in my empirical research due to the limit of time and the lack of expert supervision in this area of my research. However, this constraint will not prevent my pursuit in this area, particularly in DSGE modeling work which required extensive and rigorous computation tasks. Using a Bayesian methodology, I successfully estimates the structural parameters for the Malaysian economy to be reasonable and generally comparable to the values reported in the literature.

In future work, it would be interesting to expand the model to incorporate other factors of interest to policymakers, including: (a) an explicit government sector with a

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role for fiscal policy and interactions with monetary policy and (b) housing market sector. Lastly, it would also be interesting to investigate the forecasting ability of this type of dynamic model to suit Malaysian economy.

This study has contributed to the knowledge of the quantitative macroeconomic assessment of the Malaysian economy based on the analysis of macroeconomic fluctuations in a Dynamic Stochastic General Equilibrium (DSGE) framework. Despite the importance assumed by these topics in modern macroeconometrics, no attempt had yet been made (to the best of my knowledge) to explore them for the Malaysian economy, which was certainly a major shortcoming in the modeling of the country's macroeconomic fluctuations. I consider my work to be a first step in filling out this gap and I hope that it can contribute to a new strategy in modeling Malaysia's business cycle, in line with the one already in use in many other countries.

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