2016 BOK Knowledge Partnership Program

Cambodia

Modeling for Macroeconomic analysis and Inflation forecasting

THE BANK OF KOREA   YONSEI UNIVERSITY

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Executive Summary

Cambodia has been growing at an annual average rate of 7% for the past 20 years and recently displays stable inflation, despite its short 25 year experience under a market economy. The Cambodian economy has the potential to become a mid-level developing country if it continues developing at this pace. Despite its fast growth, Cambodia has experienced neither rapid industrialization nor established an advanced economic infrastructure. In addition, under a continued dollarization policy, Cambodia cannot carry out an independent monetary policy.

In this context, this research aims to develop a simple macroeconomic model to support short and long term policy making and continued development. The analysis is based on contemporary macroeconomic theory which can explain the Cambodian economy well. First, we establish a theoretical foundation by adding dollarization to the well-known class of small open economy models. Second, to allow policy makers to understand the structure of the model, and conduct simple analysis, we implement a small scale model and provide basic analytic results. Last, we derive a medium scale model that can be used for empirical analysis. This model is adapted to simulate growth rates and inflation under dollarization, and after abolishment of dollarization. The structure of the model is kept simple as analysis on aggregate demand and the labor market is limited due to lack of data, especially quarterly data.

We conduct intensive training of specialists at the Central Bank of Cambodia to operate, analyze and supplement the Cambodian macroeconomic model in this research. We expect this research to be the basis for the establishment of a large scale macroeconomic model that advanced countries have adopted.

I. Introduction

It has been only twenty five years since Cambodia adopted a constitutional monarchy in 1991 after a long and brutal civil war under the reign of the Khmer Rouge. At that time, Cambodia was one of the poorest countries in the world with a national income of $100 per capita. It had virtually no industrial facilities and suffered from a huge loss of human capital during the civil war. Due to the abolition of the Riel under the previous regime, the U.S. dollar has been used as the official currency for all transactions, and Cambodia is regarded as a dollarized economy.

Despite these unfavorable circumstances, Cambodia has been growing at a rate of 7% per annum for the last two decades, and this remarkable economic growth is expected to continue for a while. Recently, the National Bank of Cambodia (NBC hereinafter) realized the importance of macroeconomic models as frameworks for policy analyses targeting economic growth and development. The BOK-KPP (Bank of Korea Knowledge Propagation Program) has launched this research project jointly with the faculty members of the School of Economics at Yonsei University to build macroeconomic models that are specific to the Cambodian economy. This document is the final report of this project summarizing the last eight months (from March to November 2016) of research activities including the preliminary survey, the local field survey, the interim and final conferences.

Although the NBC, the fiscal authority and the statistical authority are responsible for collecting macroeconomic data of Cambodia, public data is also available through international organizations such as the IMF, the ADB and the World Bank. The crucial data problem is that most macroeconomic data are not publicly available, and if available, they are only at an annual frequency. These make it extremely difficult to estimate short-run macroeconomic models. The sample period spans only twenty years with two episodes of serious external shocks: the Asian Currency Crisis and the US Financial Crisis. This puts an additional burden for effective analysis. Nevertheless, it is fruitful to build a full-fledged small open economy variant of the dynamic stochastic general equilibrium model (Cambodian DSGE model) given the available data. From this Cambodian DSGE model, several practical models are derived and used for analyses on the effects of external shocks on key domestic macro variables under various policy scenarios.

Section II describes the current economic situations in Cambodia based on the local field survey jointly conducted by the Yonsei research team and NBC officials. In Section III, a variant of the small open economy DSGE model is introduced and modified to reflect as closely as possible the Cambodian economy, such as dollarization as the current monetary policy regime. DSGE models are commonly used in modern macroeconomic analyses on aggregate fluctuations over the business cycle, the effects of various types of fiscal policies and monetary policy with sticky prices among others. Under dollarization, the domestic interest rate is effectively tied to the U.S. interest rate so that the NBC can not secure the independency of monetary policy. It should be also noted that the domestic price levels tend to move together with the U.S. Analyses are conducted for three different monetary policy regimes according to the degree of dollarization.

In Section IV, the Cambodian DSGE model built in Section III is reduced to a simple textbook model under the following three monetary policy regimes: 1) complete dollarization where the domestic interest rates are equalized to the U.S. rates, 2) incomplete dollarization where the domestic interest rates are not exactly equal to, but are indexed to the U.S. rates, 3) the NBC employs an independent monetary policy such as a small open economy version of the Taylor rule with the nominal interest rate as key instruments. While the independent monetary policy regime corresponds to a post-dollarization situation, it is an available policy option even under current circumstances. The model is further classified into forward-looking or the backward-looking specifications according to whether the inflation expectation is considered in estimating the real interest rates. In the backward-looking model, the real interest rate is constructed by subtracting the current period inflation from the nominal interest rate. While this method is simple and widely used in estimating macro models, it abstracts away from rational expectations of the agents' optimizing behavior. On the other hand, in the forward-looking model, the ex ante real interest is constructed by subtracting the expected inflation from the nominal interest rate, where the inflation expectation is in turn, constructed from a VAR (vector autoregression). This method may introduce the agents' rational behavior in a minimal way at least, although it does not fully incorporate rational expectations. In Section IV, six different small-scale short-run model specifications are considered and estimated to analyze the shot-run responses of the Cambodian economy to possible external shocks. These models are simple but self contained in the sense that analyses using these models conform to the current situation in Cambodia. Specifically, the forward-looking model with the independent monetary policy regime displays the best fit to the Cambodian economy.

In Section V, a medium-scale macro model is developed with which policy makers in the NBC predict the short and long-run inflation and economic growth rates accurately. The model is close to the fully-fledged small open economy version of the DSGE model built in Section III, but is more practical for Cambodian macroeconomic analyses given the limited data availability. It consists of a system of fewer than ten equations. It is already known from the analyses using small-scale models in Section IV that complete dollarization is not very consistent with the current situation in Cambodia. Therefore this monetary policy regime is excluded, with only the incomplete dollarization and the independent monetary policy regimes considered in analyses with the medium-scale models. The estimated medium-scale models predict that Cambodian GDP is expected to grow at a rate of 7% from 2015 to 2018. Inflation is forecast to be stable at 1~2% per year. The impulse response simulations to changes in several external circumstances are conducted. Specifically, typical demand shocks such as increases in the world trade volume, official development assistance are expected to raise economic growth and inflation. The world trade volume is identified as the most influential. A recession in the world economy and a protectionist trade policy under the Trump administration in the U.S. may bring adverse impacts on the Cambodian economy. The raising of the U.S. interest rate currently in process and expected to continue is forecast to bring adverse impacts on Cambodian economic growth and inflation, but the impacts are estimated to be quantitatively minor. An increase in the real exchange rate is known as an adverse shock to the demand side of economy under an independent monetary policy regime. However those effects in Cambodia under dollarization may be opposite to the usual case and the results generally accord with the theoretic predictions.

The main objective of the BOK-KPP program is to educate and train officials of the NBC to themselves modify and adapt the model proposed in this project for their own use in the future. For these purposes and given the budgetary limitations, we select Eviews as the software for quantitative analysis rather than more flexible and general purpose softwares such as Matlab, SAS and SPSS. While Eviews is intuitive and easy to use, it can not estimate models featuring rational expectations. Although conforming to theory, since the rational expectations model is not much more effective in empirical analysis, Eviews is a readily available software to estimate the practical models developed in this project. The model developed in Section III is first developed using Eviews and proposed to NBC officials, and a training session is to planned to follow as in the intertim conference.

II. Cambodian Economy and Historical Background

1. Overview of Cambodian Economy

Cambodia does not conduct an independent monetary policy because its financial sector is underdeveloped and it follows a dollarization policy. While the real sector is in its "take off" phase and displays a high growth rate, a focus on export oriented industries (clothing, shoes, and tourism) makes it highly dependent on foreign sectors, and Cambodia is vulnerable to external shocks. In the following sections, we introduce and discuss a financial sector, real sector and price level for Cambodia.

A. Financial Sector

The financial sector is underdeveloped in terms of market size and infrastructure. For example, the M2 to GDP ratio, a basic index for financial deepening, is 62.7% in 2014. Compared to other countries, this ratio is very low as shown in Table 2-1.

<Table 2-1> Financial Deepening of Major Neighboring Countries

(in %)

	Korea	China	Japan	Thailand	Vietnam
Financial Deepening (2014)	139.9	193.0	250.5	127.8	131.5

Source: ADB, Economic and Financial Indicator

Since the Cambodian inter-bank market and short term money market is not fully developed, Cambodia cannot conduct market friendly monetary policies, such as open market operations. In addition, the determination of the interest rate does not follow supply and demand, while financial transactions based on the interest rate are not very active. Hence, it seems that interest rates cannot allocate resources as it should.

Capital markets are under-developed both qualitatively and quantitatively, and is at an initial phase of government led development. The expansion of the Riel's distribution is one of the key objectives for further capital market development. Although Cambodia established the Cambodia Securities Exchange (CSX) to trade Riel denominated listed stocks, it has yet to show evident results in terms of trade volume and adoption. There are only three stocks in the CSX, Phnom Penh Water Supply Authority (PWSA) and Grand Twins International(GTI), both listed when the CSX was established, and Phnom Penh Autonomous Port (PPAP). Daily trade volume is less than ten thousand shares. As domestic capital formation in Riel is insignificant, we can say that Cambodia relies on FDI as a basis for growth, rather than internal capital markets.

The most important financial sector feature that influences the Cambodian economy is dollarization.[1)2)] Dollarization is advantageous in that it stabilizes price levels and currency values, allowing for stable economic growth. However, in the long run, it is expected that dollarization has a greater negative side, including a loss of seigniorage. Moreover, as most of currency supply relies on the influx of US dollars[3)], Cambodia cannot carry out an effective monetary policy. In reality, as shown in the next graph, USD makes up more than 90% of money supply in Cambodia, and KHR less than 10%. The FOMC's decision on the Federal Funds Rate has a greater influence on domestic financial markets than the monetary policy of the National Bank of Cambodia. As monetary policy is ineffective, Cambodia is further exposed to external risks being transferred directly to the real sector.

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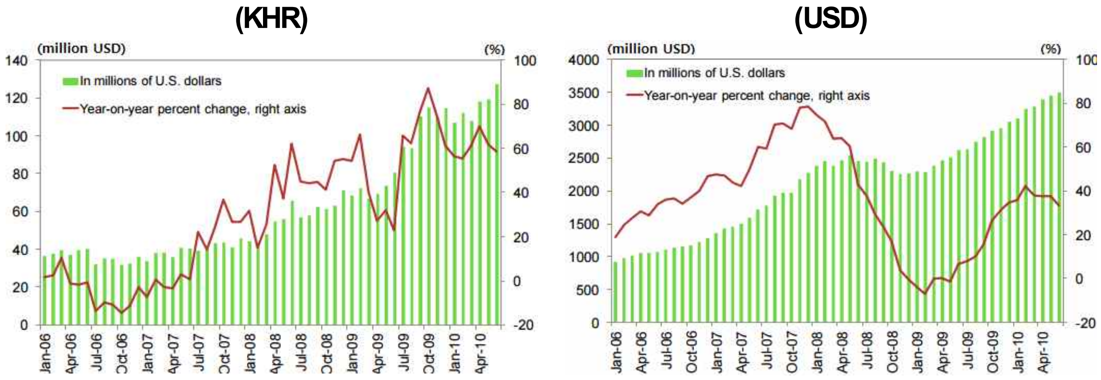
1) Where dollar replaces the domestic currency. Cambodia unofficially uses the US dollar along with Riel.
2) The abolishment of the Riel under the Khmer Rouge regime (1975~1979), followed by failure of macroeconomic policy and lax financial operation relying on loans from the central bank deteriorated the credibility of domestic currency. We believe that such trends naturally turned the Cambodian economy into a dollarized economy.
3) US dollar from tourism, FDI and other routes is used as currency in the domestic market.

<Figure 2-1> Deposit Trend of Cambodia KHR and U.S. Dollar

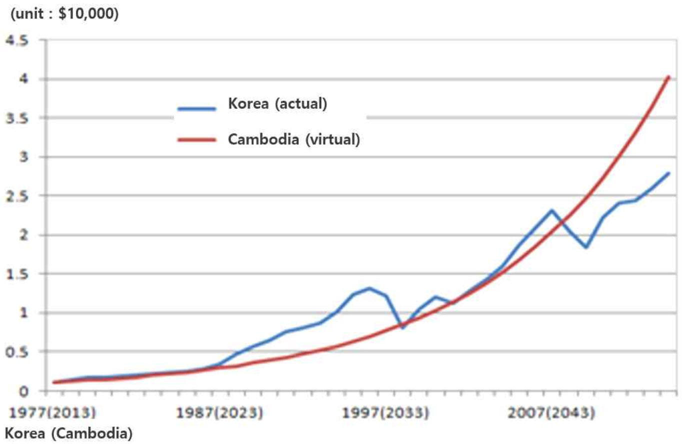


Source : Duma(2011)

B. Real Sector

The real sector of Cambodia has entered its "take off" phase and displays a high growth rate, with fast growth in clothing, shoes and tourism sectors, the real GDP growth rate is maintaining an average rate of 7%.

<Figure 2-2> Projection of GDP per capita



Source: Calculated based on data from ADB

If Cambodia continues to grow at this pace, it can reach a GDP per capita level of $10,000 in 2036. However, Cambodia has an uncertain growth path due to its structural vulnerabilities including lack of infrastructure (electricity, road, water system) and lack of domestic capital. As it is also vulnerable to external shocks, Cambodia will have to use policy wisely to maintain the high growth rate.

Compared to averages for neighboring major countries, Cambodia has a high degree of external openness. Thus, Cambodia is prone to changes in external economic conditions. In 2014, the export and import to GDP ratio was 128.8% and the FDI to GDP ratio was 10%.

<Table 2-2> Export, Import and FDI of Major Neighboring Countries

(in %)

	Korea	China	Japan	Thailand	Vietnam
(Export+Import)/GDP (2014)	95.9	43.9	38.5	131.8	169.5
FDI/GDP (2014)	1.5	2.0	2.4	1.2	4.3

Source: ADB, Economic and Financial Indicator

There are serious business cycle fluctuations from changing external conditions. For example, in 2009, a year after the global financial crisis, the GDP growth rate fell to 0.1% from 6.7% the year before. Furthermore, domestic growth and continued inflow of USD liquidity is causing an expansion of the current account deficit.

<Table 2-3> Current Account of Cambodia

(unit: million USD)

	2000	2005	2010	2012	2014
Current Account	-538.6	-1,010.3	-1,849.7	-2,506.0	-3,207.9

Source: ADB, Economic and Financial Indicator

The industrial structure is highly focused on engines for economic growth, with clothing, shoes and tourism, being the major exporting industries, and this acts as the main cause of external vulnerability. Clothing and shoe industries[4)]

4) The two industries developed based on the increase of exports led by the EU's deregulation on country of origin and tariff preference measures. However, it is worrying that increases in

depend on foreign demand from the US or EU. Not only is it sensitive to the global business cycle, it also faces fierce competition from neighboring countries. Though the tourism sector is growing steadily with the continued increase of tourist inflow, in 2008, however, the growth rate of tourists dropped significantly (-17%) compared to the previous year, demonstrating a sensitivity to external shocks.5)

<Table 2-4>

Annual Tourists in Cambodia

Year	Tourists (unit: 10,000)	Growth rate (in %)
2004	105.5	50.5
2005	142.2	34.7
2006	170.0	19.6
2007	201.5	18.5
2008	212.5	1.5
2009	216.2	1.7
2010	250.8	16.0
2011	288.2	14.9
2012	358.4	24.4
2013	421.0	17.5
2014	450.3	7.0

Note: The shade represents the period of financial crisis from the U.S..
Source: Ministry of Tourism Cambodia, Tourism Statistics Report

<Table 2-5>

Country-wise Tourists in Cambodia

(unit: 10,000)

Rank	Country	Tourists			
		2011	2012	2013	2014
1	**Vietnam**	**61.4**	**76.3**	**85.4**	**90.6**
2	**China**	**24.7**	**33.4**	**46.3**	**56.0**
3	**Laos**	**46.0**	**41.5**	**25.4**	**12.9**
4	**Korea**	**34.3**	**41.1**	**43.5**	**42.4**
5	**Thailand**	**11.7**	**20.1**	**22.1**	**27.9**
6	**Japan**	**16.2**	**17.9**	**20.7**	**21.6**
7	U.S.A.	15.4	17.3	18.5	19.1
8	**Malaysia**	**10.3**	**11.7**	**13.1**	**14.4**
9	France	11.7	12.1	13.1	14.1
10	**Australia**	**10.5**	**11.8**	**13.2**	**13.4**

Note: Bold represents East and Southeast Asia
Source: Ministry of Tourism Cambodia, Tourism Statistics Report

Thus, Cambodia has a vulnerable structure where negative effects can be magnified in the real sector due to a first ripple effect on decreasing clothing and shoes exports, and a second ripple effect on decreasing tourist inflow.

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the minimum wage after massive strikes lead to competitiveness loss relative to neighboring countries, such as Vietnam and Myanmar.

5) Cambodia seems to be sensitive to global business fluctuations as most tourists are from East Asian countries with high foreign dependency.

C. Price Level

Despite the expansion of domestic demand at an annual average growth of 7% since 1994, the consumer price index has been stable, growing at an average rate of 3% per year. Dollarization and a high dependence on imports of necessity goods and raw materials causes indexation of the price level to heavily depend on international prices, independent from the exchange rate. With such features, combined with the recent drop of oil and grocery prices, Cambodia displays a stable price level. However, in 2008 when international oil prices skyrocketed, the CPI growth rate was 19.7%, showing a vulnerability to foreign condition changes. On the other hand, capital from construction, real estate and FDI causes credit expansion, acting as a potential risk factor for both the price level and financial stability.

Meanwhile, there is growing concern regarding the rapid increase of money supply and inflation potentially coming from the expansion of the Riel, following a de-dollarization policy propelled by Cambodian authorities. Until now, despite the liquidity increase of U.S. dollars and the steady growth of the real sector, high lending rate had suppressed the expansion of liquidity. However, as the supply of Riels expands and the Riel acts as a medium of exchange and store of value, we expect rapid increases in market liquidity. Hence, we believe that there are worries concerning hyper-inflation from the implementation of a de-dollarization policy, and risks of a foreign exchange crisis caused by a depreciation of the Riel following a drastic outflow of foreign currencies.

2. Role of National Bank of Cambodia

Although the National Bank of Cambodia targets stable price levels for steady and stable growth, its conditions for policy implementation are limited. It is limited as the economy is dollarized. The Riel is used mainly for small transactions while the dollar is used for major commercial transactions and as a store of value. Not only is it difficult to conduct independent monetary policy – controlling interest rates and money supply – that affects aggregate demand, the National Bank of Cambodia can hardly act as a lender of last resort. Thus, without setting the base rate, MPC conducts monetary policy by controlling reserve rates and intervening in foreign exchange markets. The National Bank of Cambodia is promoting the issue and distribution of KHR denoted NCD's to foster conditions for monetary policy implementation, such as open market operations. The central bank is currently working on the expansion of Riel distribution, to encourage the development of short term financial markets.

In this situation, where the role of the central bank is limited, major international organizations are providing policy consultation and technical support to Cambodia. The National Bank of Cambodia exhibits an active attitude toward exchange and cooperation with international organizations and central banks of advanced countries. Establishing a 10-year financial market development plan with ADB is one clear example. Personnel with managerial positions at the IMF frequently visit the National Bank of Cambodia to meet with the governor and give advice on the macroeconomy and financial markets. The National Bank of Cambodia also signed a partnership with the Czech National Bank in 2011 and is carrying out visiting training programs. In addition, judging that the Cambodian foreign exchange market is underdeveloped, the National Bank of Cambodia assigned the Bank of New York Mellon, a commercial bank, as its foreign reserve management organization in November 2015 to operate foreign reserves in international foreign exchange markets.

III. A Small Open Economy Macroeconomic Model for Cambodia

In this chapter, we develop a small open economy macroeconomic model that reflects real economic constraints Cambodia faces, as provided in Chapter II. Theoretically, there are a number of well-established small open economy macroeconomic models in the context of the dynamic stochastic general equilibrium (DSGE) framework. A set of selected papers we have referred to in this project includes Gali and Monacelli (2005), Justiniano, Primiceri and Tambalotti (2010), Adolfson, Laseen, Linde and Villani,(2007), Kim and Chang (2016), and Kang, Park and Choi (2014). However, we will need to modify the existing models considering the availability of data, dollarization and imperfectly independent monetary policy.

The Cambodian DSGE model constructed in this chapter will be linearized, abridged and adjusted in chapters IV and V, and used to estimate and analyze the real economy. However, the DSGE model will be effective only when there is sufficiently accumulated quarterly data in the future. Nevertheless, through calibration, we can conduct various preliminary analyses as in many academic researches.

1. Background for Constructing a Small Open Economy DSGE Model for Cambodia

In this section, we establish a DSGE model that reflects characteristics of the Cambodian economy and explain its major features. DSGE models were first developed as an analytic framework for Real Business Cycle Theory, first suggested by Kydland and Prescott (1982). It is widely used in contemporary macroeconomics to analyze the effect of various economic policies, not just in the context of Real Business Cycle Theory.

Before the advent of DSGE models, macroeconomic models examined the effects of economic policies through a large system of equations. The coefficients for the system are estimated by econometric methods. The policy effects were determined by how the solution (equilibrium) of the system altered following structural shocks, mainly demand shocks such as changes in taxation and government expenditure, and money supply in the model. Such a macroeconomic framework faces the Lucas critique. First, the model lacks theoretical grounds for the functional form of behavioral equations. Second, as the coefficients are estimated using past data, the model cannot reflect changes in forward looking rational expectations of economic agents induced by such shocks.

A key feature of DSGE models is the optimizing behavior of economic agents with rational expectations. Consumption, investment, labor hours and wage therefore incorporate rational expectations decisions. The aggregate variables are identified by assuming market clearing in every period. The optimization process of individual economic agents is determined by preference, production technology and other basic elements. Hence, A DSGE model is a new macroeconomic analysis framework built on microeconomic foundations and is free from the Lucas critique.

Early DSGE models assumed perfectly competitive markets and flexible prices. These models were used to gauge the contribution of real shocks to the business cycle, such as productivity shocks. However, such models faced criticisms that the model cannot reflect the real world in that nominal variables, such as monetary policy, has no real effect, as prices are assumed to adjust flexibly to every shock. In the 1990’s, researchers following the Keynesian tradition adopted but modified the structure of DSGE models by introducing realistic assumptions such as price or wage stickiness in the short run, and replacing perfectly competitive markets with monopolistically competitive markets where some agents may have some pricing power. This is known as a "New Keynesian" DSGE model or a model featuring the Neo-Classical Synthesis.

A New Keynesian DSGE model is often combined with the Taylor rule, a simple model depicting the decision making process of central banks, to open up the interaction channel between the real sector and monetary sector. This change allows the DSGE model to overcome its criticism of ineffective monetary policy and be positioned as an analytic framework for a wide range of macroeconomic research.

The explanatory and predictive power of the model has been greatly improved by the addition of these factors that better reflect reality. Moreover, not only did it make the model internally consistent with theory, it also allowed the New Keynesian DSGE model to incorporate various demand shocks such as fiscal policy, monetary policy, and price setting markup shocks. Since the 2000's, many central banks and international organizations employ their own DSGE models to analyze policies and forecast the future economy. The medium scale New Keynesian DSGE model developed by Smets and Wouters (2003) is regarded as the baseline form of macroeconomic model and is operated by several major central banks. The ToTEM(2006), SIGAMA(2006), open economy DSGE model of the Bank of Canada and the Federal Reserve System, NEMO(2006) in Norway, RAMSES(2007) in Sweden, GEM(2007) in IMF, BOKDSGE(2007) of the Bank of Korea, MAS(2007) in Chile, and NAWM of the European Central Bank are major examples.

Spurred by the global financial crisis of 2008, some modifications have been made to DSGE models. Prior to the financial crisis, the model's emphasis was on explanatory power assuming nonneutrality of money and sluggish responses of endogenous variables to exogenous economic shocks through the inclusion of factors related to nominal and real price stickiness. Technological advances had allowed Bayesian estimation of parameters to replace calibration and limited information estimation. However, models with almost no friction factors, complete financial markets, forward-looking representative agents with infinite horizon and perfect international capital mobility, could not explain how shocks in financial and foreign exchange sectors were amplified and spread to the real sector. This was a severe limitation in analyzing effects of fiscal expansionary policies in the context of the financial crisis.

DSGE models developed after the global financial crisis adopted different features to improve on these weaknesses. Financial frictions were introduced to reinforce the linkage between the financial and real sectors. Models considered overlapping generations or heterogenous households to better analyze the effect of fiscal expenditures. Others attempted to improve the problems related to the uncovered interest rate parity condition.

For the National Bank of Cambodia to have a policy analysis capability, it is necessary for the bank to have a DSGE model that suits the current situation of Cambodia. Applying a DSGE model with high explanatory power for an advanced market economy, however, seems inadequate as the Cambodian economy currently does not operate a fully functioning market economy nor does it have sufficient infrastructure in the form of data and researchers. In theory, the intertemporal substitution decisions of household based on changes to the interest rate plays a vital role for aggregate demand in DSGE models. However, the Cambodian financial market is underdeveloped, leaving households typically facing liquidity constraints, and its interest rate is not freely determined by the demand and supply of money. The real sector of Cambodia is unstable and the growth rates differ among different sectors, such as consumption and investment, as it is in its early stage of market economy development. Hence, Cambodia is located far from a balanced growth path that a DSGE model often presumes. Furthermore, it lacks quarterly macroeconomic data to estimate parameters for the DSGE model, and it is difficult to calibrate parameters as preceding microeconomic analyses on the Cambodian economy are rare. Given the circumstances, this research aims to construct a simplified medium scale DSGE model that reflects the dollarization of Cambodia, based on a standard small open economy DSGE model, and provides a foundation for future improvement and development of the model as other infrastructure and conditions improve.

2. Cambodian Small Open Economy DSGE Model

A. Overview

This research aims to build a DSGE model that reflects major characteristics of the Cambodian economy as a small open economy. The model is based on Adolfson et al. (2007)[6] and its application on Korean fiscal policy analysis by Kim and Chang (2016). The model here is very similar to that of Kim and Chang (2016), but focuses on two types of monetary policy by simplifying the fiscal policy sector and explicitly assuming dollarization.

The general structure of the model is as follows. Economic agents are divided into firms, households, government, and foreign sector, and every goods and labor market in the economy is considered to be monopolistically competitive. In each market, the nominal prices are assumed to be sticky a la Calvo (1983). The firms are specified into three different types depending on the type of goods they supply: domestic goods, import goods, and export goods. The Phillips curve of each market is derived from the first order conditions of the individual firm's profit maximization problem. Households make decisions on purchases of consumer goods, investment goods, domestic and foreign bonds to maximize utility. The real wage Phillips curve is derived from the labor union's optimization behavior that combines differentiated labor that households supply into homogeneous labor. The government operates tax and fiscal policies to achieve a balanced budget every period. To reflect the "dollarization" policy of Cambodia, monetary policy is assumed as a form of "nominal exchange rate peg." As Cambodia, a small open economy, is unilaterally influenced by changes in the foreign sector, the model treats foreign production, foreign interest rate and foreign inflation to be exogenous.

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6) The model of this paper is one of a representative small open economy DSGE model along Gali and Monacelli (2005)'s model. This model is applied to RAMSES, the DSGE model of Sveriges Riksbank, the central bank of Sweden.

B. Firms

(1) Domestic goods producing firms

Firms producing domestic goods can be divided into two types, intermediate goods producing firms and a final good producing firm. Intermediate goods producing firms buy capital service K from households and labor L from labor packers to produce a differentiated intermediate good i, and the final good producing firm combines all types of intermediate goods to produce a homogeneous good to sell.

The production function of the final goods producing firm combines all intermediate goods in a CES form as equation (1). $\lambda_{d,t}$ represents a stochastic shock to markup of domestic goods and is in inverse to the elasticity of substitution among intermediate goods.

$$Y_t = \left[\int_0^1 Y_{i,t}^{\frac{1}{\lambda_{d,t}}} di \right]^{\lambda_{d,t}}, \quad 1 \leq \lambda_{d,t} < \infty \tag{1}$$

From the profit maximization condition of the final goods producing firm, the demand function for individual intermediate goods is derived as (2).

$$Y_{i,t} = \left(\frac{P_t}{P_{i,t}} \right)^{\frac{\lambda_{d,t}}{\lambda_{d,t}-1}} Y_t \tag{2}$$

Combining equations (1) and (2) yields the aggregate price level of domestic goods, P_t, as shown in equation (3).

$$P_t = \left[\int_0^1 P_{i,t}^{\frac{1}{1-\lambda_{d,t}}} di \right]^{(1-\lambda_{d,t})} \tag{3}$$

The production function of the intermediate goods producing firms follows a Cobb-Douglas function where labor and capital are taken as production factors, and is affected by a permanent technology shock, z_t, and a temporary technology shock, ϵ_t, as equation (4).

$$Y_{i,t} = z_t^{1-\alpha}\epsilon_t K_{i,t}^{\alpha} H_{i,t}^{1-\alpha} - z_t\phi \tag{4}$$

To have zero profits in steady state, the fixed cost $z_t\phi$ is included and is set to increase proportionally to a permanent technology shock to guarantee a balanced growth path. Since a permanent technology shock is nonstationary, the model assumes its log-differenced series $\mu_{z,t}$ to be stationary, and the temporary technology shock ϵ_t is assumed to follow an AR(1) process.

The profit maximization of intermediate goods producing firms can be analyzed in two stages. In the first stage, the firm makes decisions on its purchase of labor and capital, to produce a given quantity, to minimize its cost.

$$\min_{K_{i,t},H_{i,t}} W_t H_{i,t} + R_t^k K_{i,t} + MC_{i,t}\left[Y_{i,t} - z_t^{1-\alpha}\epsilon_t K_{i,t}^{\alpha} H_{i,t}^{1-\alpha} + z_t\phi\right] \tag{5}$$

W_t and R_t^k are nominal wage and nominal rent price of capital, and $MC_{i,t}$ represents the nominal marginal cost of the intermediate goods producing firm. The first order conditions of the cost minimization problem for labor and capital are given in equations (6) and (7). Combining the two equations, we can derive the real marginal cost for every intermediate goods producing firm as equation (8).

$$W_t = (1-\alpha)MC_{i,t} z_t^{1-\alpha}\epsilon_t K_{i,t}^{\alpha} H_{i,t}^{-\alpha} \tag{6}$$

$$R_t^k = \alpha MC_{i,t} z_t^{1-\alpha}\epsilon_t K_{i,t}^{\alpha-1} H_{i,t}^{1-\alpha} \tag{7}$$

$$mc_t = \left(\frac{1}{1-\alpha}\right)^{1-\alpha}\left(\frac{1}{\alpha}\right)^{\alpha}\left(r_t^k\right)^{\alpha}(w_t)^{1-\alpha}\frac{1}{\epsilon_t} \tag{8}$$

In the second stage, the firms set prices for intermediate goods to maximize profit. Since the model assumes a Calvo-type nominal price rigidity in every market, the intermediate goods producing firm can reset the price with probability $1-\xi_d$. Taking its demand function, (2) as a constraint, $\widetilde{P}_t$ is set to maximize the sum of discounted expected profit as equation (9).

$$\max_{\widetilde{P}_t} E_t \sum_{s=0}^{\infty} (\beta\xi_d)^s v_{t+s} \left[\left((\pi_t \pi_{t+1} \cdots \pi_{t+s-1})^{\kappa_d} (\pi^s)^{1-\kappa_d} \widetilde{P}_t \right) Y_{i,t+s} - MC_{i,t+s} (Y_{i,t+s} + z_{t+s}\phi) \right] \tag{9}$$

v_t represents household's marginal utility of nominal wage. The first order condition for optimal pricing is given by equation (10).

$$\begin{aligned} E_t \sum_{s=0}^{\infty} (\beta\xi_d)^s v_{t+s} & \left(\frac{\left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{\kappa_d} (\pi^s)^{1-\kappa_d}}{\left(\frac{P_{t+s}}{P_t}\right)} \right)^{-\frac{\lambda_{d,t+s}}{\lambda_{d,t+s}-1}} Y_{t+s} P_{t+s} \\ & \times \left[\frac{\left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{\kappa_d} (\pi^s)^{1-\kappa_d}}{\left(\frac{P_{t+s}}{P_t}\right)} \frac{\widetilde{P}_t}{P_t} - \frac{\lambda_{d,t} MC_{i,t+s}}{P_{t+s}} \right] = 0 \end{aligned} \tag{10}$$

On the other hand, intermediate goods producing firms that did not have a chance to reset the price with probability of ξ_d follow price the indexation rule, $P_{i,t+1} = \pi_t^{\kappa_d} \pi^{1-\kappa_d} P_{i,t}$.

Taking Calvo-type price stickiness into account, the price of final goods in (3) can be rewritten as follows:

$$P_t = \left[\xi_d \left(P_{t-1} (\pi_{t-1})^{\kappa_d} (\pi)^{1-\kappa_d} \right)^{\frac{1}{1-\lambda_{d,t}}} + (1-\xi_d)(\widetilde{P}_t)^{\frac{1}{1-\lambda_{d,t}}} \right]^{1-\lambda_{d,t}} \tag{11}$$

Combining and log-linearizing equations (10) and (11), we derive the Phillips curve of domestic goods as equation (12).

$$\hat{\pi}_t = \frac{\beta}{1+\kappa_d\beta} E_t \hat{\pi}_{t+1} + \frac{\kappa_d}{1+\kappa_d\beta} \hat{\pi}_{t-1} + \frac{(1-\xi_d)(1-\beta\xi_d)}{\xi_d(1+\kappa_d\beta)} (\widehat{mc}_t + \hat{\lambda}_{d,t}) \tag{12}$$

The variables with hat, ^, represent the difference from the steady state.

(2) Import goods firms

Firms importing goods purchase homogeneous goods at the international market price P_t^*, sell the goods as differentiated imported consumer goods $C_{i,t}^m$ and differentiated imported investment goods $I_{i,t}^m$. The consumers combine differentiated goods by the CES form, making the final import consumption good as in equation (13).

$$C_t^m = \left[\int_0^1 (C_{i,t}^m)^{\frac{1}{\lambda_t^{m,c}}} di \right]^{\lambda_t^{m,c}}, \quad 1 \leq \lambda_t^{m,c} < \infty \tag{13}$$

$\lambda_t^{m,c}$ is the markup shock for imported consumer goods. Hence, the demand curve that this firm faces is given by equation (14).

$$C_{i,t}^m = \left(\frac{P_{i,t}^{m,c}}{P_t^{m,c}} \right)^{-\frac{\lambda_t^{m,c}}{\lambda_t^{m,c}-1}} C_t^m \tag{14}$$

To incorporate the incomplete exchange rate pass-through of exchange rate S_t into the model, local currency price stickiness is introduced. The model also assumes a Calvo-type price stickiness for imported consumer goods as it does for the domestic goods. Individual firms reset the price with probability $1-\xi_{m,c}$ and chooses $\widetilde{P}_t^{m,c}$ to maximize the sum of discounted expected profit subject to the demand for imported consumption goods (14) in the following way:

$$\max_{\widetilde{P}_t^{m,c}} E_t \sum_{s=0}^{\infty} (\beta \xi_{m,c})^s v_{t+s} \left[(\pi_t^{m,c} \pi_{t+1}^{m,c} \cdots \pi_{t+s-1}^{m,c})^{\kappa_{m,c}} (\pi^s)^{1-\kappa_{m,c}} \widetilde{P}_t^{m,c} C_{i,t+s}^m - S_{t+s} P_{t+s}^* (C_{i,t+s}^m + z_{t+s} \phi^{m,c}) \right] \tag{15}$$

$S_t P_t^*$ represents the nominal marginal cost of the firms importing consumer goods. Firms that did not have a chance to reset their prices with probability $\xi_{m,c}$ follow the price indexation rule, $P_{i,t+1}^{m,c} = (\pi_t^{m,c})^{\kappa_{m,c}} (\pi)^{1-\kappa_{m,c}} P_{i,t}^{m,c}$. And the first order conditions for price resetting is given by:

$$E_t\sum_{s=0}^{\infty}(\beta\xi_{m,c})^s v_{t+s}\left(\frac{\left(\frac{P_{t+s-1}^{m,c}}{P_{t-1}^{m,c}}\right)^{\kappa_{m,c}}(\pi^s)^{1-\kappa_{m,c}}}{\left(\frac{P_{t+s}^{m,c}}{P_t^{m,c}}\right)}\right)^{-\frac{\lambda_{t+s}^{m,c}}{\lambda_{t+s}^{m,c}-1}} C_{t+s}^{m}P_{t+s}^{m,c}$$

$$\times\left[\frac{\left(\frac{P_{t+s-1}^{m,c}}{P_{t-1}^{m,c}}\right)^{\kappa_{m,c}}(\pi^s)^{1-\kappa_{m,c}}}{\left(\frac{P_{t+s}^{m,c}}{P_t^{m,c}}\right)}\frac{\tilde{P}_t^{m,c}}{P_t^{m,c}}-\frac{\lambda_{t+s}^{m,c}S_{t+s}P_{t+s}^{*}}{P_{t+s}^{m,c}}\right]=0 \qquad (16)$$

Prices for imported consumption goods can be represented as equation (17), and by substituting (16) and log-linearizing the function, we derive the Phillips curve of imported consumption goods as equation (18).

$$P_t^{m,c}=\left[\xi_{m,c}\left(P^{m,c}\left(\pi_{t-1}^{m,c}\right)^{\kappa_{m,c}}(\pi)^{1-\kappa_{m,c}}\right)^{\frac{1}{1-\lambda_t^{m,c}}}+(1-\xi_{m,c})\left(\tilde{P}_t^{m,c}\right)^{\frac{1}{1-\lambda_t^{m,c}}}\right]^{1-\lambda_t^{m,c}} \qquad (17)$$

$$\hat{\pi}_t^{m,c}=\frac{\beta}{1+\kappa_{m,c}\beta}E_t\hat{\pi}_{t+1}^{m,c}+\frac{\kappa_{m,c}}{1+\kappa_{m,c}\beta}\hat{\pi}_{t-1}^{m,c}+\frac{(1-\xi_{m,c})(1-\beta\xi_{m,c})}{\xi_{m,c}(1+\kappa_{m,c}\beta)}\left(\widehat{mc}_t^{m,c}+\hat{\lambda}_t^{m,c}\right) \qquad (18)$$

The Phillips curve of imported investment goods can also be derived analogously. The household combines differentiated imported investment goods $I_{i,t}^{m}$ by a CES form, and transforms it into the final imported investment goods.[7)]

$$I_t^m=\left[\int_0^1 (I_{i,t}^m)^{\frac{1}{\lambda_t^{m,i}}}di\right]^{\lambda_t^{m,i}}, 1\le\lambda_t^{m,i}<\infty \qquad (19)$$

$\lambda_t^{m,i}$ represents the markup shock for imported investment goods. Hence, the demand function that the individual imported investment goods producing firm faces can be derived as equation (20).

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7) This research follows a standard DSGE model, and sets household as the investment agent as it does not consider financial friction and other factors by incorporating an entrepreneur sector.

$$I_{i,t}^{m}=\left(\frac{P_{i,t}^{m,i}}{P_{t}^{m,i}}\right)^{-\frac{\lambda_t^{m,i}}{\lambda_t^{m,i}-1}}I_t^m \tag{20}$$

Prices of imported investment goods also evolve a la Calvo-type price setting. Each individual import investment goods producing firm resets its price with probability $1-\xi_{m,i}$, and sets $\widetilde{P}_t^{m,i}$ to maximize the sum of discounted expected profit as equation (21), subject to the demand function equation (20). The first order condition is given by (22).

$$\max_{\widetilde{P}_t^{m,i}} E_t\sum_{s=0}^{\infty}(\beta\xi_{m,i})^s v_{t+s}\left[(\pi_t^{m,i}\pi_{t+1}^{m,i}\cdots\pi_{t+s-1}^{m,i})^{\kappa_{m,i}}(\pi^s)^{1-\kappa_{m,i}}\widetilde{P}_t^{m,i}I_{i,t+s}^{m}-S_{t+s}P_{t+s}^{*}(I_{i,t+s}^{m}+z_{t+s}\phi^{m,i})\right] \tag{21}$$

$$\begin{aligned}&E_t\sum_{s=0}^{\infty}(\beta\xi_{m,i})^s v_{t+s}\left(\frac{\left(\frac{P_{t+s-1}^{m,i}}{P_{t-1}^{m,i}}\right)^{\kappa_{m,i}}(\pi^s)^{1-\kappa_{m,i}}}{\left(\frac{P_{t+s}^{m,i}}{P_t^{m,i}}\right)}\right)^{-\frac{\lambda_{t+s}^{m,i}}{\lambda_{t+s}^{m,i}-1}}I_{t+s}^{m}P_{t+s}^{m,i}\\&\times\left[\frac{\left(\frac{P_{t+s-1}^{m,i}}{P_{t-1}^{m,i}}\right)^{\kappa_{m,i}}(\pi^s)^{1-\kappa_{m,i}}}{\left(\frac{P_{t+s}^{m,i}}{P_t^{m,i}}\right)}\frac{\widetilde{P}_t^{m,i}}{P_t^{m,i}}-\frac{\lambda_{t+s}^{m,i}S_{t+s}P_{t+s}^{*}}{P_{t+s}^{m,i}}\right]=0\end{aligned} \tag{22}$$

Firms that did not have a chance to reset the price with probability of $\xi_{m,i}$ follow the price indexation rule, $P_{i,t+1}^{m,i}=(\pi_t^{m,i})^{\kappa_{m,i}}(\pi)^{1-\kappa_{m,i}}P_{i,t}^{m,i}$.

Prices for imported investment goods can be represented by equation (23), and by substituting the first order condition for price resetting rule (22), and log-linearizing the function, we derive the Phillips curve of imported investment goods as equation (24).

$$P_t^{m,i}=\left[\xi_{m,i}\left(P^{m,i}(\pi_{t-1}^{m,i})^{\kappa_{m,i}}(\pi)^{1-\kappa_{m,i}}\right)^{\frac{1}{1-\lambda_t^{m,i}}}+(1-\xi_{m,i})\left(\widetilde{P}_t^{m,i}\right)^{\frac{1}{1-\lambda_t^{m,i}}}\right]^{1-\lambda_t^{m,i}} \tag{23}$$

$$\hat{\pi}_t^{m,i} = \frac{\beta}{1+\kappa_{m,i}\beta} E_t \hat{\pi}_{t+1}^{m,i} + \frac{\kappa_{m,i}}{1+\kappa_{m,i}\beta} \hat{\pi}_{t-1}^{m,i} + \frac{(1-\xi_{m,i})(1-\beta\xi_{m,i})}{\xi_{m,i}(1+\kappa_{m,i}\beta)} \left(\widehat{mc}_t^{m,i} + \hat{\lambda}_t^{m,i} \right) \tag{24}$$

(3) Exporting firms

Export goods producing firms purchase domestic final goods, differentiate them, and sell them to foreign households. Foreign households combine exported goods by CES form and consume them. Their demand is affected by the relative price of foreign goods and exported goods, and foreign income, as in equation (25). The demand for differentiated individual exported goods can be written as (26).

$$X_t = \left[\int_0^1 (X_{i,t})^{\frac{1}{\lambda_{x,t}}} di \right]^{\lambda_{x,t}} = \left[\frac{P_t^x}{P_t^*} \right]^{-\eta_f} Y_t^* \tag{25}$$

$$X_{i,t} = \left(\frac{P_{i,t}^x}{P_t^x} \right)^{-\frac{\lambda_{x,t}}{\lambda_{x,t}-1}} X_t \tag{26}$$

The nominal marginal cost of export goods firms is P_t / S_t, the purchase price of domestic goods divided by the nominal exchange rate. As the price for export goods also follow Calvo-type price stickiness, individual export goods firms reset their prices with probability of ξ_x which they set $\widetilde{P}_t^x$ to maximize the sum of discounted expected profit as (27).

$$\max_{\widetilde{P}_i^x} E_t \sum_{s=0}^{\infty} (\beta\xi_x)^s v_{t+s} \left[(\pi_t^x \pi_{t+1}^x \cdots \pi_{t+s-1}^x)^{\kappa_x} (\pi^s)^{1-\kappa_x} \widetilde{P}_t^x \widetilde{X}_{i,t+s} - \frac{P_{t+s}}{S_{t+s}} (\widetilde{X}_{i,t+s} + z_{t+s}\phi^x) \right] \tag{27}$$

Firms that cannot reset the price follow the price indexation rule, $P_{i,t+1}^x = (\pi_t^x)^{\kappa_x} (\pi)^{1-\kappa_x} P_{i,t}^x$. Combining prices for export goods firms and log-linearizing, we derive the Phillips curve of export goods firms as equation (28).

$$\hat{\pi}_t^x = \frac{1}{1+\beta}\hat{\pi}_{t-1}^x + \frac{\kappa_x}{1+\kappa_x\beta}E_t\hat{\pi}_{t+1}^x + \frac{(1-\beta\xi_x)(1-\xi_x)}{\xi_x(1+\kappa_x\beta)}(\widehat{mc_t^x}+\widehat{\lambda_{x,t}}) \quad (28)$$

C. Households

The household chooses consumption goods (C_t) and work hours (H_t) to maximize the sum of discounted expected utility. The model also considers internal habit formation such that the consumption pattern of the past can affect current utility. The utility maximization problem of the household can be expressed as follows:

$$E_t\left\{\sum_{s=0}^{\infty}\beta^s b_{t+s}\left[\log(C_{t+s}-hC_{t+s-1})-\varphi\frac{H_{t+s}(j)^{1+\nu}}{1+\nu}\right]\right\} \quad (29)$$

where b_t is the intertemporal preference shock that affects the time discount rate.

The household purchases domestic goods and imported goods in a CES form, respectively for consumption goods and investment goods, and these can be written as equations (30) and (31). The prices of consumer goods and investment goods are described in equations (32) and (33).

$$C_t = \left[(1-\omega_c)^{1/\eta_c}(C_t^d)^{(\eta_c-1)/\eta_c} + \omega_c^{1/\eta_c}(C_t^m)^{(\eta_c-1)/\eta_c}\right]^{\eta_c/(\eta_c-1)} \quad (30)$$

$$I_t = \left[(1-\omega_i)^{1/\eta_i}(I_t^d)^{(\eta_i-1)/\eta_i} + \omega_i^{1/\eta_i}(I_t^m)^{(\eta_i-1)/\eta_i}\right]^{\eta_i/(\eta_i-1)} \quad (31)$$

$$P_t^c = \left[(1-\omega_c)(P_t)^{1-\eta_c} + \omega_c(P_t^{m,c})^{1-\eta_c}\right]^{1/(1-\eta_c)} \quad (32)$$

$$P_t^i = \left[(1-\omega_i)(P_t)^{1-\eta_i} + \omega_i(P_t^{m,i})^{1-\eta_i}\right]^{1/(1-\eta_i)} \quad (33)$$

The change of real capital holdings ($\overline{K}$) is given by equation (34).

$$\overline{K}_t = (1-\delta)\overline{K}_{t-1} + \mu_t\left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right)I_t \tag{34}$$

δ is the depreciation rate, $S(\cdot)$ is the investment adjustment cost, and the model assumes $S(\cdot) \geq 0$ (equality holds when $I_t = I_{t-1}$), $S' > 0$, $S'' > 0$. μ_t is the investment shock that affects the transition process of investment to new capital goods.

Households decide the utilization rate of capital as in equation (35), deciding the amount of capital service committed to the production process.

$$K_t = u_t\overline{K_{t-1}} \tag{35}$$

The capital utilization cost is $a(u_t)$ per unit of capital, $a(1) = 0$ in steady state ($u = 1$) and the elasticity is $\chi \equiv a''(1)/a'(1)$.

Household income is composed of wages, capital service rent, net cash inflow from the state-contingent securities $Q_t(j)$, interest payment from bonds, and dividends from firms. The household allocates income into purchasing consumption goods C_t, investment goods I_t, government bonds B_t, foreign bonds B_t^*, and paying a lump sum tax T_t. The budget constraint for household's utility maximization problem is given by (36).

$$\begin{aligned} &P_t^c C_t + P_t^i I_t + T_t + B_t + S_t B_t^* \leq \\ &\quad R_{t-1}B_{t-1} + R_{t-1}^*\Phi(\frac{A_{t-1}}{z_{t-1}}, \widetilde{\phi}_t) + Q_t(j) + \Pi_t + W_{j,t}H_{j,t} + R_t^k u_t \overline{K_{t-1}} - P_t a(u_t)\overline{K_{t-1}} \end{aligned} \tag{36}$$

R_t and R_t^* represent domestic and foreign gross interest rates. As the model economy assumes complete financial markets where state-contingent securities cover all possible risks, income of every household is identical regardless of wage income. As every household is identical ex ante, they make identical decisions except for wage and labor hours. Hence, all variables except for labor in this equation do not have subscript $j \in [0,1]$. $A_t\left(\equiv S_t B_t^*/P_t\right)$ represents net holdings of real foreign assets and $\tilde{\phi}_t$ represents the risk premium shock. The interest rate premium for foreign bonds is expressed as $\Phi(\cdot,\cdot)$. If the domestic economy is a net creditor, the premium is low when bond holding is large, and if domestic economy is a net borrower, the premium is high when debt is large. This enables a steady state to exist in the model despite imperfect international financial market integration.

The first order condition for household utility maximization is given in (37) through (42). Λ_t and Ξ_t are Lagrangian multipliers associated with the budget constraint (36) and change of capital holding (34). As equation (37) shows, the marginal utility of consumption is affected by past and future consumptions as well as present consumption due to the internal consumption habit formation. From the first order condition for optimal bond holding, we derive the Euler equation (38). The first order condition for real capital provides the shadow price of real capital, Ξ_t, and as shown in (40), presented as the sum of discounted future rent income with depreciation and capital operation cost adjusted. Equation (41) is the first order condition for optimal investment, and it can be seen that Tobin's $Q_t(\equiv \Xi_t / P_t \Lambda_t)$ is equal to 1 when there is no investment shock and investment adjustment cost. Equation (42) is the first order condition for the optimal capital utilization rate, which represents equality between the nominal rate of return on capital and nominal marginal cost for adjusting the capital utilization rate.

$$[C_t]:\ P_t \Lambda_t = \frac{b_t}{C_t - hC_{t-1}} - h\beta E_t \frac{b_{t+1}}{C_{t+1} - hC_t} \tag{37}$$

$$[B_t]:\ \Lambda_t = \beta R_t E_t \Lambda_{t+1} \tag{38}$$

$$[B_t^*]:\ S_t \Lambda_t = \beta R_t^* \Phi(a_t, \tilde{\phi}_t) E_t S_{t+1} \Lambda_{t+1} \tag{39}$$

$$[\overline{K}_t]:\ \Xi_t = \beta E_t\left[\Lambda_{t+1}\left(R_{t+1}^k u_{t+1} - P_{t+1} a(u_{t+1})\right)\right] + (1-\delta)\beta E_t \Xi_{t+1} \tag{40}$$

$$[I_t]:\ P_t\Lambda_t = \Xi_t\mu_t\left[1-S\left(\frac{I_t}{I_{t-1}}\right)-\frac{I_t}{I_{t-1}}S'\left(\frac{I_t}{I_{t-1}}\right)\right]+\beta\left[\Xi_{t+1}\mu_{t+1}\left(\frac{I_t}{I_{t-1}}\right)^2 S'\left(\frac{I_{t+1}}{I_t}\right)\right] \tag{41}$$

$$[u_t]:\ R_t^k = P_t a'(u_t) \tag{42}$$

By combining and log-linearizing equations (38) and (39) - the first order conditions for domestic and foreign bond holding, we derive the uncovered interest parity condition (43).

$$\widehat{R_t} - \widehat{R_t^*} = E_t \triangle \hat{S}_{t+1} - \tilde{\phi}_a \widehat{a}_t + \hat{\tilde{\phi}}_t, \tag{43}$$

If the international financial market is perfectly integrated, there is no premium for foreign bonds. Then equation (43) can be rewritten as:

$$\widehat{R_t} - \widehat{R_t^*} = E_t \triangle \hat{S}_{t+1} \tag{44}$$

If $E_t \triangle \hat{S}_{t+1} = 0$ as a consequence of the nominal exchange rate peg, equation (44) becomes $\widehat{R_t} = \widehat{R_t^*}$, showing equality between domestic and foreign interest rates. That is, monetary policy loses it independence completely.

D. Determination of Wages

Households supply differentiated labor to perfectly competitive labor "packers" or the labor "union", which combines labor in CES form, as in equation (45), and supplies homogeneous labor to intermediate goods producing firms.

$$H_t = \left[\int_0^1 H_{j,t}^{\frac{1}{\lambda_{w,t}}} dj\right]^{\lambda_{w,t}},\ 1 \le \lambda_{w,t} < \infty \tag{45}$$

$\lambda_{w,t}$ is a markup shock for wages. This can be interpreted as a labor supply shock because it generates a wedge between the household's marginal rate of substitution and the real wage, thus affecting the first order condition for optimal labor supply. From the profit maximization problem of perfectly competitive labor packers, we derive the labor demand function as:

$$H_{j,t} = \left(\frac{W_t}{W_{j,t}} \right)^{\frac{\lambda_{w,t}}{\lambda_{w,t} - 1}} H_t \tag{46}$$

Labor packers pay $W_{j,t}$ to type j labor, and intermediate goods producing firms pay W_t to labor packers for each unit of homogeneous labor, which can be represented as:

$$W_t = \left[\int_0^1 W_{j,t}^{\frac{1}{1-\lambda_{w,t}}} dj \right]^{(1-\lambda_{w,t})} \tag{47}$$

Every household can set the wage as a monopoly supplier of her differentiated labor, $L_{j,t}$. However, as the model assumes Calvo-type price stickiness, the household can reset nominal wage with probability $1-\xi_w$. In this case, facing the labor demand function (46), the optimal wage $\widetilde{W}_t$ can be derived with disutility of labor supply, and utility of labor earnings taken into account. The first order condition for $\widetilde{W}_t$ is given by:

$$0 = E_t \left\{ \sum_{s=0}^{\infty} \xi_w^s \Lambda_{t+s} \widetilde{Y}_{t+s} \left[\widetilde{W}_t \Pi_{t,t+s}^w - \lambda_{w,t+s} b_{t+s} \phi \frac{\widetilde{H}_{t+s}^{\nu}}{\Lambda_{t+s}} \right] \right\} \tag{48}$$

where $\Pi_{t,t+s}^w = \prod_{k=1}^{s} \left[(\pi \mu_z)^{1-\kappa_w} (\pi_{t+k-1}^c \mu_{z,t+k-1})^{\kappa_w} \right]$.

Households unable to reset their nominal wage with probability of ξ_w follow the price indexation rule, $W_{j,t+1} = (\pi_t^c \mu_{z,t})^{\kappa_w} (\pi \mu_z)^{1-\kappa_w} W_{j,t}$. Combining this rule with equations (48) and (47), the relationship between average wage and individual household wage, and log-linearizing the sum, we obtain the following real wage Phillips curve:

$$\widehat{w}_t = \frac{\beta}{1+\beta}E_t\widehat{w}_{t+1} + \frac{1}{1+\beta}\widehat{w}_{t-1} - \kappa_w\widehat{g_{w,t}} + \frac{\beta}{1+\beta}E_t\widehat{\pi}^c_{t+1} - \frac{1+\beta\kappa_w}{1+\beta}\widehat{\pi}^c_t + \frac{\kappa_w}{1+\beta}\widehat{\pi}^c_{t-1} + \frac{\kappa_w}{1+\beta}\widehat{z}_{t-1} - \frac{1+\beta\kappa_w - \rho_z\beta}{1+\beta}\widehat{z}_t + \kappa_w\widehat{\lambda}_{w,t} \tag{49}$$

The real wage is affected by the wage gap ($\hat{g}_{w,t}$), provided in (50), due to the monopolistic factor associated with labor supply.

$$\hat{g}_{w,t} = \hat{w}_t - (\nu\hat{H}_t + \hat{b}_t - \hat{\lambda}_t - \hat{\gamma}^{cd}_t) \tag{50}$$

γ^{cd}_t is the ratio of consumer goods' price divided by domestic goods' price (= P^c_t/P_t).

E. Government

(1) Fiscal sector

The government finances its budget through collecting lump sum tax T_t and issuing short term government bonds B_t, and spends G_t as government expenditure. We assume that the government achieves a balanced budget every period which can be written as:

$$B_t - R_{t-1}B_{t-1} + T_t = P_tG_t \tag{51}$$

Government expenditure is affected by a government expenditure shock g_t as follows:

$$G_t = \left(1 - \frac{1}{g_t}\right)Y_t \tag{52}$$

(2) Monetary policy

The model assumes the short term nominal interest rate as a main monetary policy instrument. We consider an open-economy version Taylor-type rule such that the current interest rate depends on the lagged interest rate, inflation rate, output gap and real exchange rate (x_t) as follows:

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1-\rho_R)(r_\pi \hat{\pi}_t^c + r_y \hat{y}_t + r_x \hat{x}_t) + r_{\triangle_\pi} \triangle \pi_t^c + r_{\triangle_y} \triangle y_t + \varepsilon_{R,t} \tag{53}$$

However, as Cambodia is focusing on stabilizing its nominal exchange rate through dollarization, it is difficult to state that an independent monetary policy is implemented to stabilize the domestic price level. Thus, it is more natural to assume that Cambodian monetary policy follows a nominal exchange rate peg as:

$$\triangle S_t = 0 \tag{54}$$

F. Foreign Sector

As Cambodia is a small open economy, foreign variables are determined independent of domestic variables. We assume that foreign output, interest rate and inflation follow an exogenous stochastic AR(1) process and their functional forms are given by:

$$\begin{aligned} \hat{y}_t^* &= \rho_{y^*} \hat{y}_{t-1}^* + \varepsilon_t^{y^*} \\ \hat{\pi}_t^* &= \rho_{\pi^*} \hat{\pi}_{t-1}^* + \varepsilon_t^{\pi^*} \\ \hat{R}_t^* &= \rho_{R^*} \hat{R}_{t-1}^* + \varepsilon_t^{R^*} \end{aligned} \tag{55}$$

G. Market Clearing Condition

The goods market clearing condition is as follows. In equilibrium, domestically produced goods (net of capital utilization cost) should be equal to the sum of the domestic share of domestically produced household consumption goods, investment goods, goods purchased by government expenditure and export goods:

$$C_t^d + I_t^d + G_t + X_t \le \epsilon_t z_t^{1-\alpha} K_t^\alpha H_t^{1-\alpha} - z_t \phi - a(u_t) \overline{K}_t \tag{56}$$

On the other hand, foreign bond holdings of this period should be in accord with the sum of principal and interest payments of previously held bonds in the previous period and the current account surplus of this period:

$$S_t B_{t+1}^* = S_t P_t^x X_t - S_t P_t^* \left(C_t^m + I_t^m \right) + R_{t-1}^* \Phi(a_{t-1}, \tilde{\phi}_{t-1}) S_t B_t^*, \tag{57}$$

3. Model Solution and Parameter Setting

The equilibrium condition for each market in the model economy developed above is determined by the first order conditions for economic agents' optimization problems and market clearing conditions. The general equilibrium can be expressed as system of equations for the equilibrium for each market. However, due to complexity and nonlinearity of the model, it is impossible to find an analytic solution. In addition, since the model incorporates non-stationary series such as a permanent technology shock (z_t) and steady state inflation (π) is not zero, the endogenous variables have nominal and real trends. Hence, to solve the model, we take the following method. We de-trend endogenous variables and through log-linear approximation we obtain the rate of change. Using these adjusted rates, we numerically calculate the solution near the steady state.

A. Bayesian Parameter Estimation

In previous research, the parameters of the model are estimated by the Bayesian method. They first express equations for general equilibrium conditions in state-space form and apply the Kalman filter. The posterior distribution of structural parameters are then estimated by the Bayesian method subject to pre-specified prior distributions. However, there is virtually no quarterly data needed to estimate model parameters with the Bayesian method.[8] In the following paragraphs, we discuss theoretical grounds for Bayesian estimation for future reference when data are accumulated, and other necessary conditions have been met in the future.

8) We found out that there is no high frequency macroeconomic data, quarterly or more frequent, except for consumer price index data in Cambodia.

The Bayesian estimation method is widely used in the literature to estimate parameters of DSGE models. Unlike GMM or other limited information estimation techniques, Bayesian estimation is a full information estimation that uses all available information. This can alleviate parameter identification problems of maximum likelihood estimation, such as dilemma of absurd parameter estimates and flatness of the likelihood function. There are also advantages of the Bayesian method in that the degree of uncertainty is clearly expressed for every econometric result as it automatically provides distributions for each parameter.

Bayesian estimation finds parameters to maximize posterior distribution computed by combining the prior distribution with the value of the likelihood function using the Bayes' theorem. The posterior distribution $p(\theta | Y_T)$ is proportional to the posterior kernel $K(\theta | Y_T)$, the product of likelihood value $L(Y_T | \theta)$ and prior distribution $p(\theta)$, and it can be expressed as:

$$p(\theta | Y_T) \propto L(Y_T | \theta) p(\theta) \equiv K(\theta | Y_T) \qquad (58)$$

As it is impossible to find analytic forms of the posterior distribution, the posterior distribution is computed numerically by finding parameters maximizing the posterior kernel value with MCMC or other kinds of simulation methods. The Random Walk Metropolis-Hastings (M-H) algorithm is most commonly used. The following is the estimation process of the posterior distribution using the M-H algorithm.

First, prior to conducting the simulation, we find the mode θ^0 and asymptotic covariance estimate Σ_m around the mode. We then set the former as the starting point of the algorithm and use a scale factor c times the latter as the degree of jumping for the next proposal θ^* in each step of simulation. The jumping follows a normal distribution that takes the sample in the previous term as its mean in the following way:

$$J(\theta^* | \theta^{t-1}) = N(\theta^{t-1}, c\Sigma_m) \qquad (59)$$

The acceptance ratio is computed from the ratio of the posterior kernel as follows. Proportional to the acceptance ratio, the acceptance of proposal follows the decision rule specified in equation (61). The posterior distribution of parameters are obtained by repeating this procedure multiple times.

$$r=\frac{p\left(\theta^{*}\mid Y_{T}\right)}{p\left(\theta^{t-1}\mid Y_{T}\right)}=\frac{K\left(\theta^{*}\mid Y_{T}\right)}{K\left(\theta^{t-1}\mid Y_{T}\right)} \tag{60}$$

$$\theta^{t}=\begin{cases}\theta^{*} & with\, probability\, \min(r,1)\\ \theta^{t-1} & otherwise\end{cases} \tag{61}$$

The type of prior distribution is set by selecting type, center and dispersion of a particular distribution. First, the type of distribution is chosen depending on the support where parameters can be realized. For parameters that range from 0 to 1, for example Calvo-type price stickiness, the beta or uniform distribution is selected as a prior distribution. If there is no limit to the parameter, we use the normal distribution. If the parameter is expected to be positive, the gamma or inverse gamma distribution is used. Based on preceeding researches or researcher's belief, the point where it is most likely to be the realized value is chosen as the starting point. The dispersion of distribution is set based on the researcher's confidence of the center.

The posterior distribution derived from MCMC provides crucial information regarding parameters. If the posterior distribution is a single peaked normal distribution, we may conclude that there is no problem in convergence of the parameter. Furthermore, if the center of the posterior distribution is far from that of prior distribution and the distribution is narrow around the center, the data used for the estimation is said to have contributed to the parameter identification.

Equilibrium condition equations in state-space representation can be divided into a transition equation and an observation equation. The transition equation shows theoretic dynamics of endogenous variables. An endogenous variable at current period x_t is generally determined by lagged endogenous variable x_{t-1} and the structural shock of this period ε_t^s. The observation equation, on the other hand, connects the model with observed data. Current observed variable y_t can be explained with the current endogenous variable x_t and the measurement error ε_t^m. These two equations are expressed as:

$$x_t = g(x_{t-1}, \varepsilon_t^s) \tag{62}$$

$$y_t = h(x_t, \varepsilon_t^m) \tag{63}$$

Due to the unit root caused by a permanent technology shock and the existence of non-zero steady states of inflation, endogenous variables of the model are de-trended and log-linearized. Similarly, actual data in the observation equations are log-differenced, as equation (64) below, to make it a stationary process. In the case of stable variables that do not include trends, such as the interest rate and labor hours, we use percentage deviation from mean in the observation equation. This can be obtained by calculating the difference between individual log value and average log value, as in (65).

$$\triangle \log X_t = \hat{x}_t - \hat{x}_{t-1} + \mu_{z,t} \tag{64}$$

$$\log Y_t - \log \overline{Y} = \hat{y}_t \tag{65}$$

B. Calibration

Calibration is a method where a researcher assigns values to parameters based on theoretical relationships in non-stochastic steady state or microeconomic research results. For example, the researcher can set the values so that the ratios of consumption to GDP or investment to GDP (or “Great ratio”) of the model’s steady state are equal to those calculated from national income statistics. Setting markups with respect to the degree of monopoly or setting the Calvo coefficient based on observed price fluctuation cycles can be some examples of applying preceeding microeconomic researches. As Cambodia lacks quarterly data for macroeconomic variables, it is necessary to calibrate the model parameters, until sufficient data becomes available for Bayesian estimation. Table <3-1> shows parameter values used for the Cambodian small open economy DSGE model.

<Table 3-1> Calibration for Parameters

	Explanation	Value		Explanation	Value
μ_z	S-S technology growth rate	1.015	ξ_w	Calvo-type price stickiness of wage	0.675
π	S-S inflation rate	1.0075	κ_d	Price indexation ratio of domestic goods	0.5
g_y	S-S government expenditure ratio	0.2	$\kappa_{m,c}$	Price indexation ratio of imported consumption goods	0.5
H_{ss}	S-S log labor hour	0	$\kappa_{m,i}$	Price indexation ratio of imported investment goods	0.5
α	Capital share of production function	0.33	κ_x	Price indexation ratio of export goods	0.5
β	Rate of time preference	0.99	κ_w	Wage indexation ratio	0.5
δ	Depreciation rate	0.025	ρ_R	Taylor rule interest smoothing coefficient	0.85
h	Consumption habit	0.75	r_π	Taylor rule inflation coefficient	1.7
ν	Inverse Frisch elasticity	1	r_y	Taylor rule output gap coefficient	0.125
χ	Elasticity of capital utilization costs	5	r_x	Taylor rule real exchange rate coefficient	-0.01
S''	Investment adjustment costs	3	$r_{\Delta y}$	Taylor rule output growth rate coefficient	0.1
ϕ_a	Foreign bond premium response factor	0.05	$r_{\Delta \pi}$	Taylor rule inflation fluctuation rate coefficient	0.3
ω_c	Imported consumption goods share	0.5	ρ_{μ_z}	Permanent productivity shock persistence	0.75
ω_i	Imported investment goods share	0.8	ρ_ε	Temporary productivity shock persistence	0.9
η_c	elasticity of substitution between domestic and imported consumption goods	1.5	ρ_b	Preference shock persistence	0.9
η_i	elasticity of substitution between domestic and imported investment goods	1.5	ρ_μ	Investment shock persistence	0.7
η_f	Relative price elasticity of export goods	1.5	ρ_g	Government expenditure shock persistence	0.8
λ_d	S-S domestic goods gross markup	1.2	$\rho_{\tilde{\phi}}$	Foreign bond premium shock persistence	0.9
$\lambda_{m,c}$	S-S imported consumption goods gross markup	1.2	ρ_{λ_d}	Domestic goods markup shock persistence	0.85
$\lambda_{m,i}$	S-S imported investment goods gross markup	1.2	$\rho_{\lambda_{mc}}$	Imported consumption goods markup shock persistence	0.85
λ_x	S-S export goods gross markup	1	$\rho_{\lambda_{mi}}$	Imported investment goods markup shock persistence	0.85
λ_w	S-S wage gross markup	1.1	ρ_{λ_x}	Export goods markup shock persistence	0.85
ξ_d	Calvo-type price stickiness of domestic goods	0.675	ρ_{λ_w}	Wage markup shock persistence	0.85
$\xi_{m,c}$	Calvo-type price stickiness of imported consumption goods	0.5	ρ_{y^*}	Foreign output shock persistence	0.9
$\xi_{m,i}$	Calvo-type price stickiness of imported investment goods	0.5	ρ_{π^*}	Foreign inflation shock persistence	0.4
ξ_x	Calvo-type price stickiness of export goods	0.5	ρ_{R^*}	Foreign interest rate shock persistence	0.95

Note: S.S. stands for steady state

This research uses the average of parameter values generally used in preceeding DSGE models and posterior estimates of prior researches using Bayesian estimation as parameters for the Cambodian DSGE model.

4. Model Simulation

In this section, we conduct simulation using our Cambodian DSGE model to examine output and inflation change caused by foreign and domestic shocks under two different monetary policy scenarios. We compare the responses to a unit positive individual economic shock under two different monetary policies: nominal exchange rate peg or dollarization with the response under monetary policy following the Taylor rule after Riel replaces the dollar as currency[9). A number of analyses will be conducted under the aforementioned monetary policy scenarios in Chapter IV and V as well.

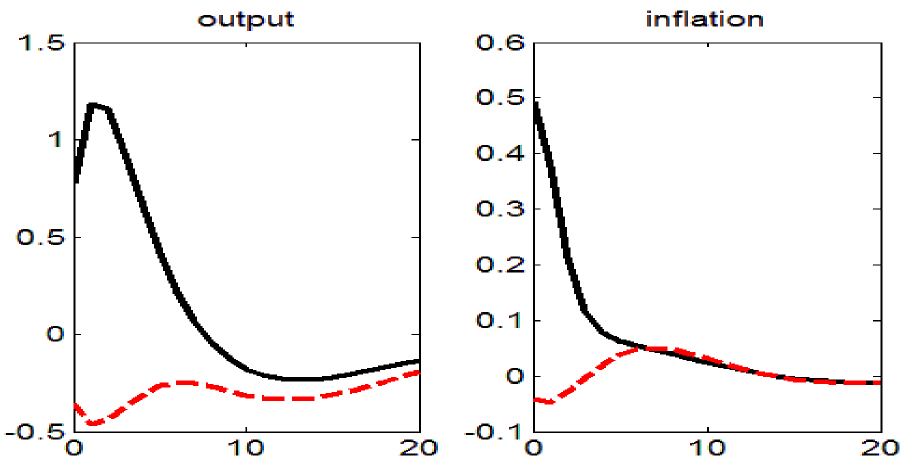
A. Response to Foreign Interest Rate Shock

Figure <3-1> illustrates the response of the output gap and inflation to a foreign interest rate shock. Under standard monetary policy, the exchange rate increases as the foreign interest rate increases. An increase in exchange rate causes imported goods prices to rise, resulting in higher inflation. This increase in exchange rate also causes net exports to rise, resulting in greater output.

Under dollarization, the domestic interest rate rises at an almost identical level with the foreign interest rate. This results in a decrease in consumption and investment, and hence, output. As the nominal exchange rate is fixed, prices of imported goods remain stable while prices of domestic goods decrease due to the stagnant domestic economy. This results in a slight decline of inflation.

9) The simulation use dynare program in Matlab to analyze response to shocks. It is known that using Eviews to conduct such DSGE analysis is considerably difficult.

<Figure 3-1> Response to Foreign Interest Rate Shock



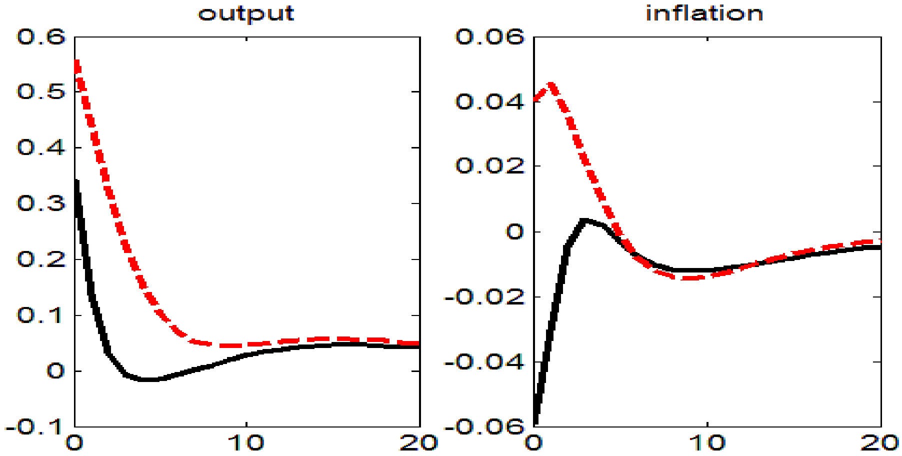
Note: The two figures show the impulse-response functions of the output gap and inflation to a unit positive foreign interest rate shock. The black lines are the responses under the Taylor rule, and the red dotted lines are the responses under the nominal exchange rate peg. Here, inflation is the inflation of all consumption goods, including both domestic and imported.

B. Response to Foreign Output Shock

Figure <3-2> illustrates the responses of output and inflation to a foreign output shock. Under standard monetary policy, demand for exports increase as foreign output increases. An increase in demand for exports in turn causes domestic output to increase. Due to an increase in exports, the exchange rate falls, dropping the prices of imported goods. This also causes the nominal interest rate of the central bank to increase, lowering inflation.

Under dollarization, the increase in foreign output increases demand for exports and domestic output. However, as the nominal exchange rate is fixed, there is no drop in prices of import goods or increases of the nominal interest rate. Hence, the inflation rate rises.

<Figure 3-2> Response to Foreign Output Shock

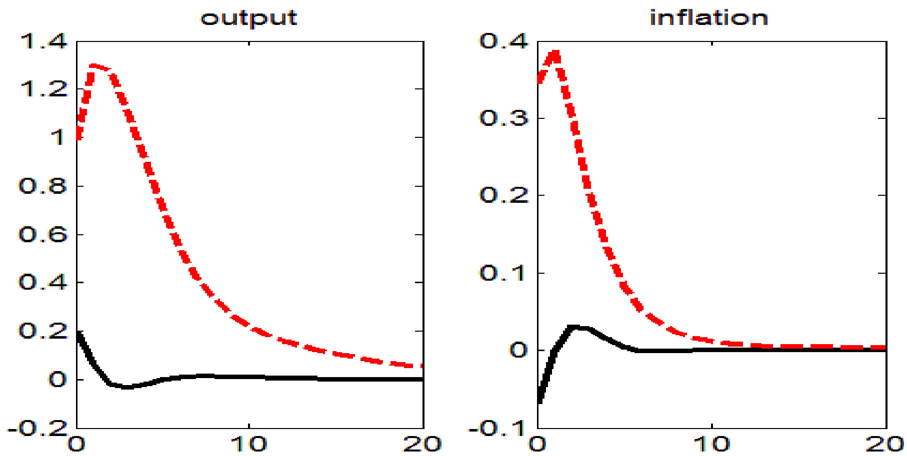


Note: Refer to <Figure 3-1>

C. Response to Foreign Inflation Shock

Figure <3-3> illustrates the responses of output and inflation to a foreign inflation shock. Under standard monetary policy, export increases as a rise in foreign inflation lowers the relative price of domestic goods. An increase in exports causes domestic output to increase. However, due to a decrease in exchange rate, the price of import goods drops and the domestic nominal interest rate rises. Hence, there is no significant impact on domestic inflation.

<Figure 3-3> Response to Foreign Inflation Shock



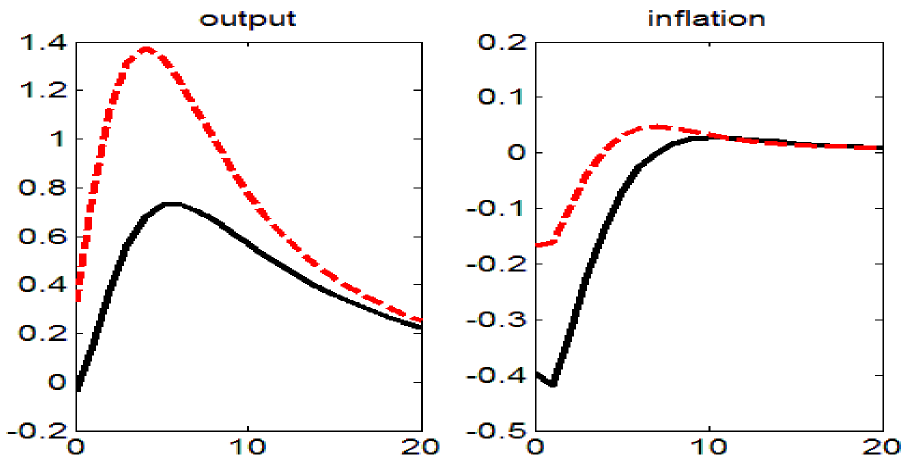
Note: Refer to <Figure 3-1>

Under dollarization, as the nominal exchange rate is fixed, an increase in foreign inflation causes domestic inflation to rise immediately. As a fall in the relative price of domestic goods is greater than the drop under standard monetary policy, an increase in exports and output is greater as well.

D. Response to Temporary Technology Shock

Figure <3-4> illustrates the responses of output and inflation to a temporary technology shock. Under standard monetary policy, a positive technology shock causes a decrease in domestic goods prices. Such a decrease drops the relative price of domestic goods in the international market, and hence, increases exports and output. An increase in exports leads to a decrease in the exchange rate and the price of imported goods. Decreases in the prices of domestic goods and imported goods lead to a fall in the inflation rate.

<Figure 3-4> Response to Temporary Technology Shock



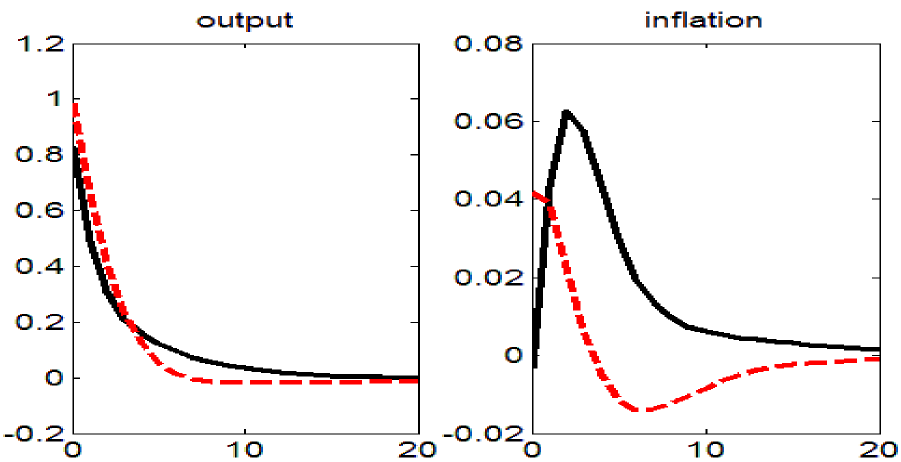
Note: Refer to <Figure 3-1>

Under dollarization, as the nominal exchange rate is fixed, the relative price drop of domestic goods is greater than the drop under standard monetary policy, and this results in a greater increase in exports and output. However, as there is no decrease in the price of imported goods caused by the exchange rate change, the decrease of inflation is not as large as under standard monetary policy.

E. Response to Government Expenditure Shock

Figure <3-5> illustrates the responses of output and inflation to a government expenditure shock. Under standard monetary policy, an increase in government expenditure increases demand for domestic goods, raising both domestic output and price. This lowers exports as the relative price of domestic goods in the international market rises, lowering the exchange rate. The lower exchange rate decreases the prices of imported goods and partially cancels out the price increase in domestic goods, neutralizing its effect on inflation. However, as government expenditure crowds out consumption and investment, imports decrease. This, in turn, increases the exchange rate and price of imported goods. That is, inflation steadily increases for a number of periods after the initial shock.

<Figure 3-5> Response to Government Expenditure Shock



Note: Refer to <Figure 3-1>

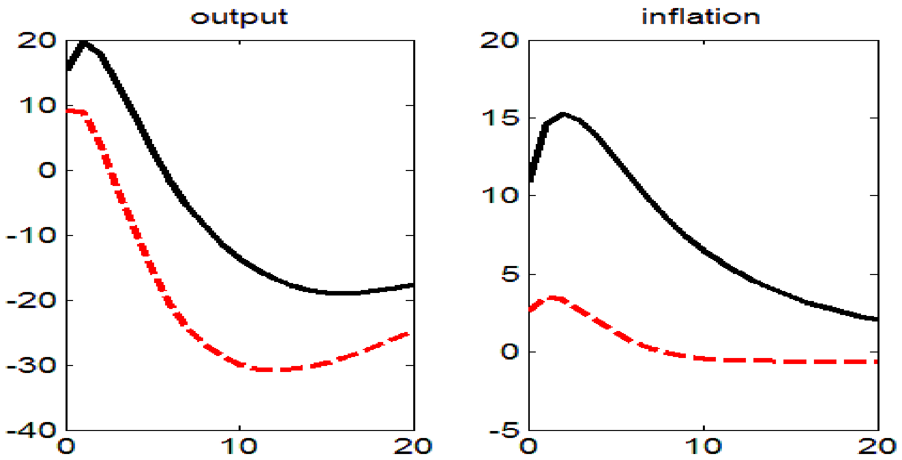
Under dollarization, as the nominal exchange rate is fixed, the price of imported goods does not change. That is, the impact of an increase in government expenditure is fully reflected by the fluctuation of inflation. Hence, there is no steady increase of inflation that is observed under standard monetary policy. As the nominal interest rate is fixed, investment is not crowded out, and the output increase is greater in earlier periods. However, as there is no increase in net exports, increases in output in the long run are smaller than that under standard monetary policy.

F. Response to Consumption Preference Shock

Figure <3-6> illustrates the responses of output and inflation to a consumption preference shock. Under standard monetary policy, a preference shock increases demand for both domestic and imported goods. Although net export decreases, output increases as aggregate demand increases in general. The inflation rate jumps considerably as the increase in demand for domestic goods raises the price of domestic goods, and the increase in the exchange rate caused by the decrease in net exports raises the price of imported goods.

Under dollarization, as the nominal exchange rate is fixed, the price of imported goods does not change. That is, there is a smaller increase in inflation than under standard monetary policy. In addition, the increase in output is smaller than under standard monetary policy as there is no counterbalancing effect of net exports from changes in the exchange rate.

<Figure 3-6> Response to Consumption Preference Shock



Note: Refer to <Figure 3-1>

5. Summary and Task of Cambodian Small Open Economy DSGE Model

In this chapter, we constructed a small open economy DSGE model that reflects characteristics of the Cambodian economy and its current monetary policy, dollarization. The model is close to those managed by the central banks of advanced nations as it incorporates heterogeneity of goods and stickiness of nominal and real prices.

The model economy consists of economic agents optimizing under constraints, and takes the foreign sector as exogenous to reflect the typical characteristics of small open economies. The behavioral equation of the central bank is specified to follow a nominal exchange rate peg rather than a Taylor rule to reflect the dollarization policy of Cambodia. This severely damages the independence of monetary policy as the domestic interest rate is determined by the foreign interest rate.

We conducted simulations to examine the responses of macroeconomic variables to exogenous shocks under standard monetary policy and under dollarization. Due to the lack of quarterly data, we calibrate parameters instead of estimating them using the Bayesian technique. Under dollarization, foreign shocks greatly affect domestic economy, whereas under standard monetary policy, foreign shocks are neutralized to some degree. We can expect to have smaller fluctuations of output and inflation when the monetary policy is standardized. Hence, it is recommended to gradually recover the credibility of the Riel and secure an independent monetary policy.

As mentioned above, the Cambodian small open economy DSGE model calls for a cautious approach because of the lack of data and preceeding researches which hinder the model from reflecting reality. For now, we advise this model to be used as an internal reference for policy analysis at the National Bank of Cambodia and as an initial step to construct its own model that further reflects the Cambodian economy. We emphasize that establishment of adequate infrastructure, including accumulation of quarterly macroeconomic data, microeconomic researches on Cambodia as well as technical knowledge regarding the model, are prerequisites for the analysis using the model.

IV. Short-run Small-Scale Macroeconomy Model

In this chapter, the Cambodian small-scale open economy model proposed in Chapter III is reduced to a practical and predictive model. This simplified small-scale model is not intended to be used in Cambodian monetary policy in reality, but is intended to enable monetary policy makers to understand the structure, composition and the general equilibrium concept of the model in Chapter III. Nevertheless, the model presented in this chapter has data explanatory power in itself to some degree, and it can be said that it is pre-stage of analyzing the medium-scale macroeconomic model to be introduced in Chapter V. However, the long-run feature is omitted and will be covered only in Chapter V.

In Section 1, we review the trends of key macroeconomic variables such as output gap and inflation, introduce the model in Section 2, and report the estimation results in Section 3.

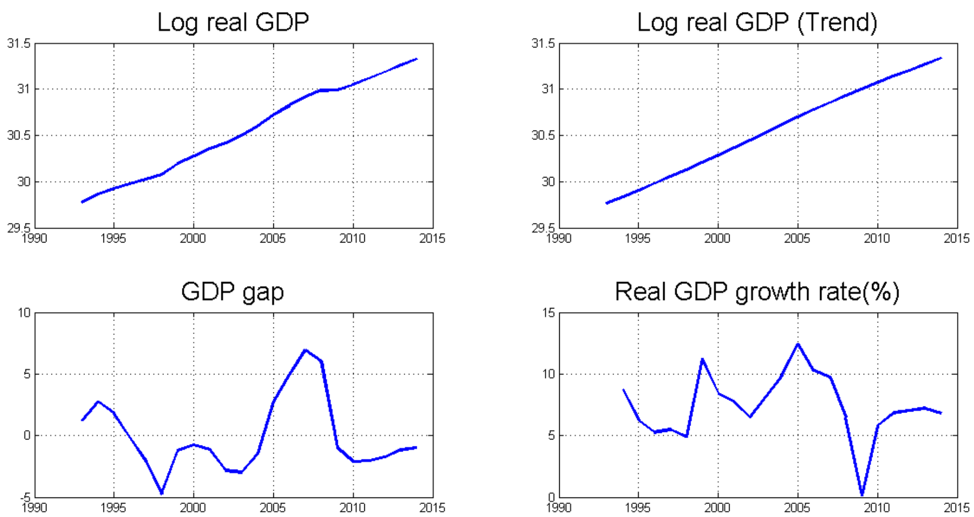
1. Current Macroeconomic Status and Dollarization in Cambodia

As mentioned, Cambodia has experienced an average annual growth rate of 7% in the past two decades. Hereinafter we review the trends of some of the macroeconomic variables necessary for model construction, and introduce various monetary policy scenarios according to dollarization which is the most important issue in model construction. The policy scenario considered in this section will be used in both the basic macroeconomic model here and the medium-scale macroeconomic model to be introduced in the next chapter. We summarize various results of the model according to the scenario.

A. Macroeconomic Data Trend In Cambodia

<Figure 4-1> shows the log real GDP and the trend line, output gap (which is difference between them) and the economic growth rate. In 2008, since the US financial crisis caused the global economy to shrink greatly, the economic growth rate of Cambodia is close to 0% due to its high degree of openness to the outside world, but Cambodia maintained an average growth rate of 7% thereafter.

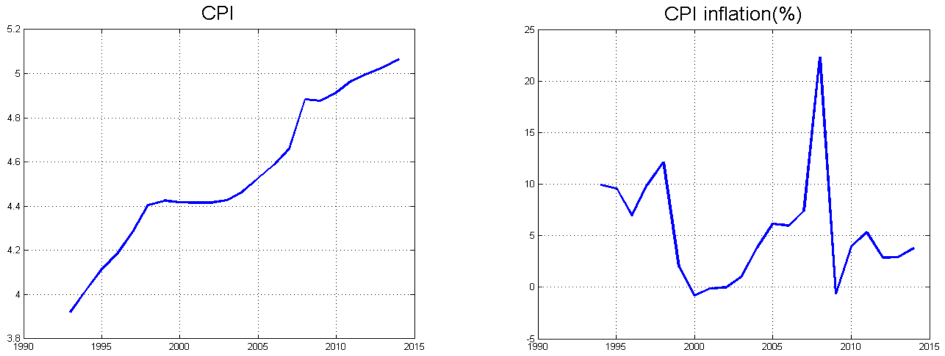
<Figure 4-1> GDP Trend in Cambodia



Note: The GDP data is based on Cambodian Riel real GDP of the World Bank

As can be seen in <Figure 4-2>, inflation is not very serious in the light of the situation in developing countries. In the early 1990s, the inflation rate rose to around 10% and has stabilized since the late 1990s. In 2008, inflation during the US financial crisis exceeded 20%, but it become stable at less than 5%. Dollarization is believed to be responsible for inflation stabilization. This will be verified through the model in what follows.

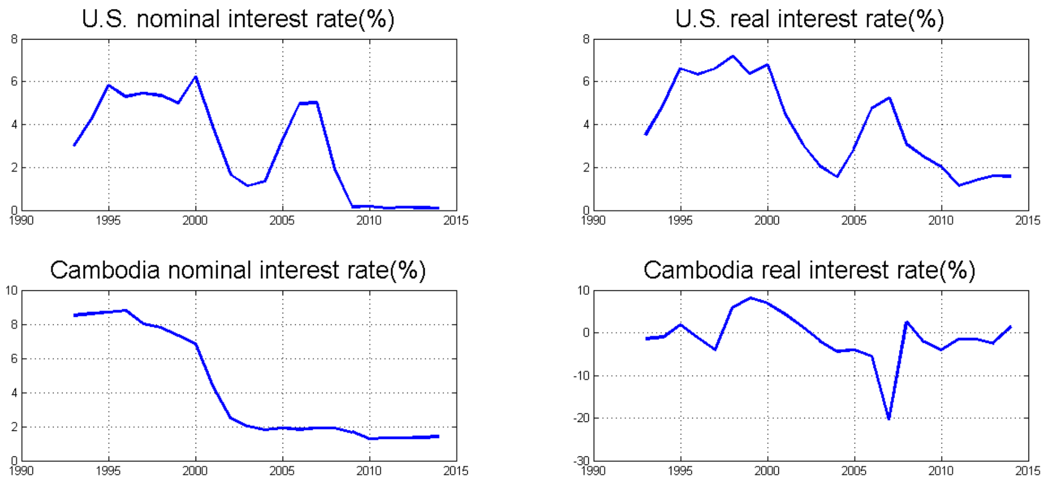
<Figure 4-2> Price Level in Cambodia



Note : Price data is based on the annual average consumer price index of IMF

<Figure 4-3> shows the nominal and real interest rate trends and compares them with the US counterparts to informally examine the role of dollarization.

<Figure 4-3> Interest Rates in Cambodia and the U.S.



Note: 1) The annual deposit rate of Riel obtained from World Bank is used for the Cambodian interest rate.
2) Interest rate data for the US is the annual Federal Fund Rate, aggregated from the Louis Federal Reserve Bank.
3) Real interest rate in Cambodia is calculated using CPI inflation.

The Cambodian central bank has no interest rate corresponding to the US federal fund rate, and it is the most important policy measure to control the reserve requirement ratio of commercial banks. The Cambodian interest rate is assumed to be the deposit rate. The overall trend of the nominal interest rate is similar to that of the United States, but it remains lower than the US interest rate in 2005 until 2008.

B. Monetary Policy Scenario Based on Dollarization

The macroeconomic model proposed in this study differs from other empirical models in that instead of traditional money demand and money supply structures, we consider the nominal interest rates that are currently adopted by most countries as monetary policy instruments and have tested various monetary policy rules. This feature is preserved in the medium-scale model in Chapter V.

Here we consider three different scenarios: monetary policy under perfect dollarization, imperfect dollarization, and independent monetary policy. First, if dollarization is perfect, the nominal interest rate in Cambodia is assumed to equal the US counterpart. But the real interest rates can be different depending on the inflation rates of the two countries. Second, in the case of imperfect dollarization, the US dollar is actually used as currency but Cambodia need not have the same base rate as the United States. In this case, we consider a regression in which the nominal interest rate or the real rate depends on the US counterpart. Here, the real interest rate is considered as it is the variable with which consumers or firms make economic decision. Finally, it is assumed that Cambodia implements an independent monetary policy in the future using an open economy version Taylor-type rule. This scenario is of course for the future, but it can be implemented in reality. These three scenarios can be summarized as follows.

<Table 4-1> Monetary Policy Scenario

Scenario	Nominal Interest rate	Real Interest rate	Monetary policy
Perfect Dollarization	$i_t = i_t^{US}$	$r_t \neq r_t^{US}$	Exogenous Real Interest Rate
Imperfect Dollarization	$i_t \neq i_t^{US}$	$r_t \neq r_t^{US}$	$r_t = f(r_t^{US}; z_t) + e_t$
Independent Monetary policy	$i_t \neq i_t^{US}$	$r_t \neq r_t^{US}$	$i_t = f(\pi_t, y_t, i_{t-1}, rer_t; z_t) + e_t$

Here i_t, r_t, π_t, y_t, rer_t represent the nominal interest rate, the real interest rate, inflation, the output gap, and the real exchange rate, respectively. Variables with superscript US mean the corresponding variables in the United States. $f(\bullet)$ represents the linear function to be estimated, z_t is an additional explanatory variable that may be included depending on specifications of the model. For example, in the case of imperfect dollarization, z_t can be the real exchange rate, the interest rate in China, or the past real interest rate in Cambodia.

Here, there can be several ways to construct the real interest rate. The real interest rate, in principle, implies a expected real interest rate, and this can be defined by the Fisher equation, $r_t = i_t - E_t\pi_{t+1}$. In the theoretical DSGE model developed in Section III, rational expectations equilibria can be obtained by directly solving the model and estimating the model using the methods of Blanchard and Kahn (1980), Sims (2000) or Cho and Moreno (2011). However, the model presented below is a backward-looking model known to have typically higher explanatory power than forward-looking models.

In recent years, the central bank of Korea and other developed countries have introduced the latest DSGE model for real economic forecasting, but in reality, the backward-looking model is still used as a baseline model. In this case, it matters how to compute expected inflation to construct the real interest rate. Generally, in backward-looking models, expected inflation can be computed via a VAR (Vector Autoregression). Specifically, consider a VAR model with a vector x_t that includes inflation, and other variables the output gap, the nominal interest rate and real exchange rate that are related to each other. By estimating the VAR, one can construct one-step ahead predictions of the variables, namely, $E_t(x_{t+1})$ which contains expected inflation. Using this estimated expected inflation, one can construct the real interest rate, $i_t - E_t(\pi_{t+1})$. However, as is well known, the VAR depends on the choice of variables and the number of lags. More seriously, this way of constructing expectations, and is subject to Lucas Critique. Second, we define the real interest rate as $i_t - \pi_t$ in this study. Of course, it is possible to use the ex-post real interest rate $i_t - \pi_{t+1}$, but Cambodia is not likely to have a serious bias as inflation is not so volatile relative to other developing countries. In the following discussion, we will try to use both methods to construct the real interest rate. In conclusion, we can derive a total of six results as the model has three monetary policy scenarios in one dimension and two real interest rate configurations in another. For the sake of the following discussion, each specification of the model is named as follows.

<Table 4-2> Classification of Models

Assumptions on monetary policy	Assumptions on real interest rate	
	$r_t = i_t - \pi_t$	$r_t = i_t - E_t\pi_{t+1}$
Perfect Dollarization	Model 1	Model 4
Imperfect Dollarization	Model 2	Model 5
Independent monetary policy	Model 3	Model 6

2. Small Macroeconomic Model

This section presents a small model suitable for the Cambodian economy. This model, based on the theoretical model presented in Chapter III, is the most basic and textbook-type macroeconomic model. Thus, rather than focusing on actual macroeconomic forecasting, this model is useful for showing how the model presented in Chapter III can be used for actual estimation. A medium-scale model featuring each component of the aggregate demand including consumption, investment, government expenditure, and foreign sector will be presented in chapter V. In each model, we consider three monetary policy scenarios classified by the degree of dollarization and two different real interest rates. Since each of these specifications have pros and cons, we estimate and report the scenario-specific economic model estimates and forecasts, rather than presenting a particular specification. This exercise can help experts in NBC understand the advantages and disadvantages of each specification and design future monetary policy.

Before introducing the empirical model, we first introduce a linear rational expectations model. A canonical New Keynesian macro model such as the one considered by Clarida, Gali, Gertler (1999) consists of the aggregate demand curve, known as the Euler equation (or intertemporal IS curve), the aggregate supply curve (so-called the New Keynesian Phillips curve) and a monetary policy rule:

$$y_t = E_t y_{t+1} - \psi r_t + v_t \tag{1}$$
$$\pi_t = \delta E_t \pi_{t+1} + \lambda_1 y_t + \eta_t \tag{2}$$
$$i_t = \phi_\pi \pi_t + \phi_y y_t + \epsilon_t \tag{3}$$
$$r_t = i_t - E_t \pi_{t+1} \tag{4}$$

Here, y_t, π_t, i_t, r_t represent the GDP gap, inflation, the nominal interest rate and real interest rate, respectively. All variables are defined as differences from steady state. The output gap was constructed in various ways, but our results are not so sensitive. We therefore adopt the most popular Hodrick-Prescott filter method to identify the output gap. Equation (4) represents the Fisher equation. In this model, monetary policy is assumed to be independent and to follow a simple Taylor rule.

The above model can be understood as the simplest version of the theoretical model presented in Chapter III, focusing on the core contents. It is helpful to understand the theoretical aspects of equilibrium using this simple model because it is well known in textbooks and has sound micro-foundation as well. However, because it is purely a forward-looking model that does not depend on past variables, the model has little explanatory power of the data. Thus, it is common to incorporate backward-looking components as well. Cho and Moreno (2006) is one such an example, which can be expressed as follows.

$$y_t = \mu_1 E_t y_{t+1} + \mu_2 y_{t-1} - \psi r_t + v_t \tag{5}$$
$$\pi_t = \delta_1 E_t \pi_{t+1} + \delta_2 \pi_{t-1} + \lambda_1 y_t + \eta_t \tag{6}$$
$$i_t = \rho i_{t-1} + (1-\rho)[\phi_\pi \pi_t + \phi_y y_t] + \epsilon_t \tag{7}$$
$$r_t = i_t - E_t \pi_{t+1} \tag{8}$$

As mentioned above, equilibrium of this type of the model can be derived in principle by solving rational expectations. Although this model has been found to have some data explanatory power, it is true that the data explanatory power is lower than that of Ball (1999), which still relies on traditional lagged variables. Therefore, there is a trade-off between the theoretical background and the empirical fit of the model. The only statistical tool available for this project in performing empirical analysis is the Eviews program, which is very difficult to accommodate and solve the rational expectations model. Moreover, the main interest of the NBC is to have a model that can account for data. Therefore, here we try to estimate a model that depends only on past variables as in Ball (1999).

Lastly, although the model introduced in this section assumes a closed economy, it can be applied to a small open economy in which the external sector is exogenously given. In particular, it can be converted into an open economy model by appropriately selecting monetary policy rules.

(1) Perfect Dollarization

Under perfect dollarization, the nominal interest rate in Cambodia (i_t) is equal to the nominal interest rate in the United States (i_t^{US}), thus it is exogenously given. Under this setting, the model can be written as follows:

$$y_t = \beta_1 y_{t-1} - \beta_2 r_t + v_t \quad (9)$$

$$\pi_t = \lambda_1 y_{t-1} + \lambda_2 \pi_{t-1} + \eta_t \quad (10)$$

$$r_t = i_t^{US} - \pi_t \quad \text{or} \quad r_t = i_t^{US} - E_t \pi_{t+1} \quad (11)$$

The real interest rate can vary depending on the inflation of the two countries. Equation (11) uses $r_t = i_t^{US} - \pi_t$ for Model 1 in table <4-2>, and $r_t = i_t^{US} - E_t \pi_{t+1}$ for Model 4 in which expected inflation is extracted from a VAR analysis. The real interest rate obtained from equation (11) is exogenous because of the assumption that $i_t = i_t^{US}$. In other words, since monetary policy is not independent, the system of equations (9) and (10) constitutes the whole model. The above model is the simplest open economy model with the interest rate, without an explicit consideration of the foreign sector, but it will help understand the structure of a macro model before analyzing the medium scale model.

(2) Imperfect Dollarization

In Cambodia, imperfect dollarization is more realistic because the US dollar and the local currency Riel are both used, although the use of the latter is marginal. Even in the case of full dollarization, the nominal interest rate, such as the yield on the local bond, is not necessarily the same as the US counterpart. Therefore, we add the assumption that the interest rate is not the same as, but dependent of the interest rate of the US. In this case, the model can be written as:

$$y_t = \beta_1 y_{t-1} - \beta_2 r_t + v_t \tag{12}$$

$$\pi_t = \lambda_1 y_{t-1} + \lambda_2 \pi_{t-1} + \eta_t \tag{13}$$

$$r_t = \delta r_t^{US} + \gamma z_t + e_t \tag{14}$$

$$i_t = r_t + \pi_t \text{ or } i_t = r_t + E_t(\pi_{t+1}) \tag{15}$$

Here r_t^{US} is real interest rate of United States, z_t is a variable that can affect the real interest rate in Cambodia such as real interest rate of the previous period, real exchange rate etc. Unlike perfect dollarization, here the real interest rate is endogenous. Constructing the real interest by $i_t = r_t + \pi_t$ corresponds to Model 2, and $i_t = r_t + E_t \pi_{t+1}$ to Model 5. However, since equation (15) is a definition of nominal interest rate irrespective of how to obtain the real interest rate, the model consists of three equations (12), (13) and (14).

(3) Independent Monetary Policy

Cambodia does not, in reality, perform an independent monetary policy based on interest rates. However, one may consider an open economy Taylor-type rule for the hypothetical future economy in which de-dollarization is in force. In this case, not only the monetary policy but also the aggregate demand can be influenced by the exchange rate as in Ball (1999). It is possible to explicitly introduce the theory of the exchange rate determination as in the model of Chapter III, but here it is assumed that the exchange rate follows an exogenous process. Also, the model is simplified as much as possible using the real exchange rate instead of the nominal one. The model can be reduced as follows:

$$y_t = \beta_1 y_{t-1} - \beta_2 r_t + \beta_3 rer_t + v_t \tag{16}$$

$$\pi_t = \lambda_1 y_{t-1} + \lambda_2 \pi_{t-1} + \eta_t \tag{17}$$

$$i_t = \rho i_{t-1} + (1-\rho)[\phi_\pi \pi_t + \phi_y y_t + \phi_{rer} rer_t] + \epsilon_t \tag{18}$$

$$r_t = i_t - \pi_t \text{ or } r_t = i_t - E_t(\pi_{t+1}) \tag{19}$$

The real exchange rate (RER_t) is the value of the nominal exchange rate of the Cambodian Riel against the US dollar multiplied by the US price level and divided by the price level of Cambodia. rer_t is the log value of the real exchange rate, i.e., $rer_t = \ln RER_t$. The output gap, inflation, the real interest rate, and the nominal interest rate are endogenous, and the real exchange rate is the exogenous variable. The model consists of all of the four equations of (16) through (19). The real interest rate computed using $i_t = r_t + \pi_t$ corresponds to model 3, and that using $i_t = r_t + E_t \pi_{t+1}$ to model 6. Since this model assumes an independent monetary policy rule, this model can be applied if Cambodia builds up credibility of monetary policy in the future. However, the monetary policy rules like equation (18) are still a viable policy even currently and show a relatively good account of the actual data.

3. Estimation and Results of Small Macroeconomic Models

In this section, we estimate each of the six specifications of the small scale macroeconomic model considered above and conduct a basic model analysis. The data required for estimation were obtained from several public agencies. Nominal GDP is collected from the Asian Development Bank which is originally from the Cambodian National Institute of Statistics and the unit is Cambodian Riel. The GDP Deflator was used for the price level, which was obtained from the same agency and the base year is 2000. Thus, real GDP is calculated as the ratio of these two series. The Cambodian deposit rate is used for the nominal interest rate, which was obtained from the World Bank. The nominal interest rate in the United States is based on the Effective Federal Fund Rate from St. Louis FED. The nominal GDP and GDP deflator of the United States is obtained from the World Bank and the base year of the price is 2000. The Riel to US Dollar exchange rate has been acquired by the same agency and is expressed as the annual average.

In order to estimate the actual model, dummy variables were added to the model in order to capture potential structural breaks around the Asian financial crisis in 1997 and the US financial crisis in 2008. Specifically, the Asian foreign exchange crisis dummy variable is exogenous variable having value 1 in 1997 and 1998 and 0 in the remaining period, and the US financial crisis dummy variable has value 1 in 2008 and 2009 and 0 otherwise. The rational expectations model should in principle be simultaneously estimated from the equation system to identify the aggregate supply, aggregate demand and monetary policy sectors. As the model considered in this section is a reduced-form or backward-looking model, it is possible to conduct an equation by equation estimation if the structural shocks are mutually independent. Although it is possible to use advanced econometric techniques such as the generalized method of moments and the heteroscedasticity-consistent estimator of White (1980), we estimate the model through simple regression analysis since the purpose of this report is to explain estimation procedures of the basic model.

(1) Perfect Dollarization

In the case of perfect dollarization, the model is given by equations (9) and (10), which express aggregate demand and aggregate supply relations. The estimation results are as follows. Estimated constants and shocks are omitted for parsimony.

The result of estimation of Model 1 reported in table <4-3> reveals that the output gap depends on the previous output gap strongly, and the coefficient of the US financial crisis dummy is statistically significant within a 90% confidence level. Also, although not statistically significant, GDP (or output gap) fell in line with the theory when the real interest rate rose. Intuitively, the output gap reflects persistence observed in consumption and investment, and demand is also a decreasing function of the real interest rate. It is also noticeable that the output gap is negatively affected by the US financial crisis and the Asian financial crisis. The second equation, on the other hand, shows a typical aggregate supply curve where inflation rises as the output gap (demand) increases. It can also be seen that inflation rises as a result of two crises. Taken together with the first equation of aggregate demand, it can be interpreted that the external economic crisis is similar to a negative aggregate supply shock, although it is not statistically significant.

<Table 4-3> Estimation Results under Perfect Dollarization Scenario

Model 1 : case of $r_t = i_t - \pi_t$	R^2
$y_t = 0.924y_{t-1} - 0.038r_t - 4.306D_t^R - 3.045D_t^A$ (0.206)* (0.117) (2.251)* (1.570)	0.64
$\pi_t = 0.624y_{t-1} - 0.223\pi_{t-1} + 1.067D_t^R + 4.501D_t^A$ (0.337)* (0.203) (3.744) (2.505)*	0.39

Model 4: case of $r_t = i_t - E_t\pi_{t+1}$	R^2
$y_t = 0.907y_{t-1} - 0.233r_t - 4.477D_t^R - 1.809D_t^A$ (0.203)* (0.283) (2.145)* (2.082)	0.65
$\pi_t = 0.624y_{t-1} - 0.223\pi_{t-1} + 1.067D_t^R + 4.501D_t^A$ (0.337)* (0.203) (3.744) (2.505)*	0.39

Note: D_t^R and D_t^A capture the recession caused by the US financial crisis in 2008 and the Asian crisis in 1997, respectively.

Next, consider Model 4. The real interest rate is the ex-ante rate as it is calculated by taking into account the expected inflation rate, which is economically consistent with theory and in this case the result of estimation is similar to the case of $r_t = i_t - \pi_t$.[10] A remarkable difference is that when the

10) The second equation, which represents the aggregate supply, does not depend directly on the

expected real interest rate is used, the coefficient of the real interest rate to the output gap is -0.233 and the magnitude is much increased compared to the coefficient of −0.038 in the case of Model 1. While this is not statistically significant, it can be interpreted that the economic agents are more responsive to the expected real interest rate in line with the theory. Therefore, although the estimation method of this study does not fully meet rational expectations, it is desirable to estimate the expected real interest rate through VAR as in this study in order to incorporate the forward-looking behavior of economic agents in the model.

The real interest rate has been exogenous in Model 1 and 4 under perfect dollarization, therefore solving the above two equations explicitly yields a unique equilibrium. In this case, we can trace the dynamic paths of the output gap and inflation following aggregate demand and aggregate supply shocks through a basic impulse response analysis. A simulation analysis is also possible when the exogenous real interest rate increases or decreases in the future. However, since this model is a perfect dollarization setting that does not fit reality, this analysis will be conducted only in the case of imperfect dollarization and independent monetary policy.

(2) Imperfect Dollarization

The model under imperfect dollarization consists of equations (12) through (15): the aggregate demand, aggregate supply, real interest rate determination formula and nominal interest rate formula (Fisher equation). Here, the real interest rate becomes an endogenous variable. We estimate two cases, ie Models 2 and 5, depending on the two assumptions about the real interest rate. The estimation results of the model are summarized in Table <4-4>.

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real interest rate, so the results are the same but have been duplicated for ease of exposition and comparison.

<Table 4-4> Estimation Results under the Imperfect Dollarization Scenario

Model 2: Case of $r_t = i_t - \pi_t$	R^2
$y_t = 0.906 y_{t-1} - 0.088 r_t - 4.501 D_t^R - 3.007 D_t^A$ (0.203)* (0.095) (2.129)* (1.521)	0.66
$\pi_t = 0.624 y_{t-1} - 0.223 \pi_{t-1} + 1.067 D_t^R + 4.501 D_t^A$ (0.337)* (0.203) (3.744)* (2.505)*	0.39
$r_t = 0.900 r_t^{US} - 0.037 rer_t$ (0.509)* (0.092)	0.17

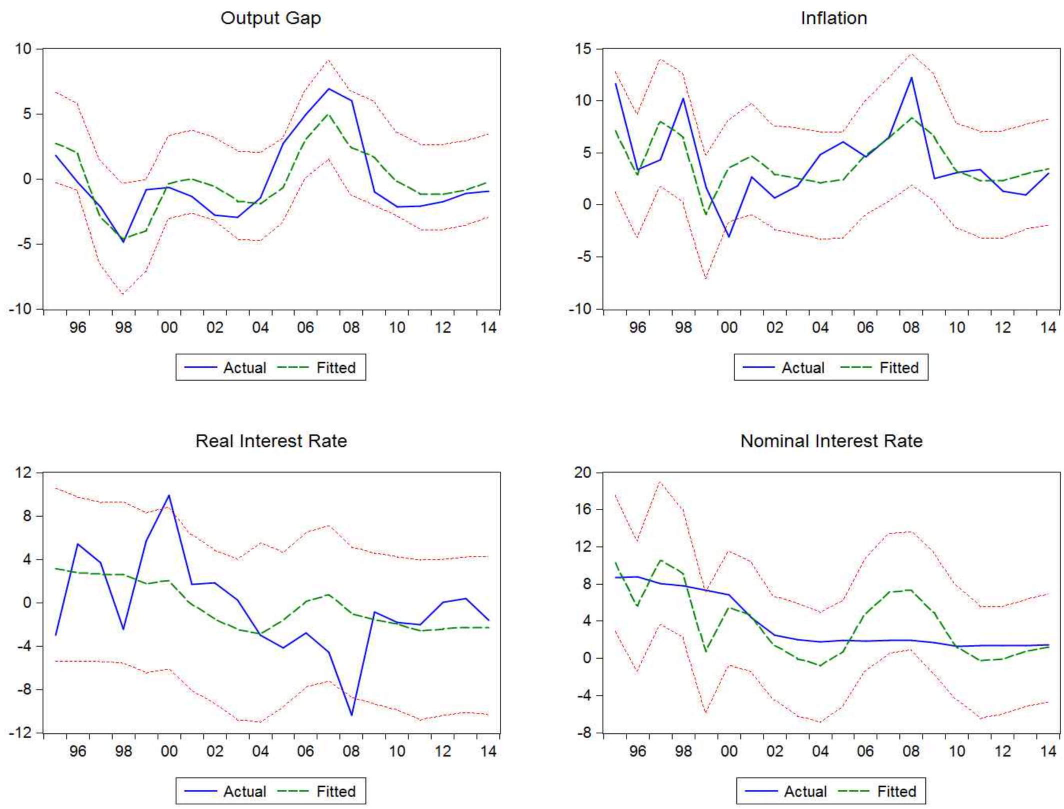
Model 5: Case of $r_t = i_t - E_t \pi_{t+1}$	R^2
$y_t = 0.823 y_{t-1} - 0.348 r_t - 4.194 D_t^R - 0.716 D_t^A$ (0.192)* (0.173)* (1.904)* (1.792)	0.71
$\pi_t = 0.624 y_{t-1} - 0.223 \pi_{t-1} + 1.067 D_t^R + 4.501 D_t^A$ (0.337)* (0.203) (3.744)* (2.505)*	0.39
$r_t = 0.792 r_t^{US} - 0.057 rer_t$ (0.265)* (0.051)	0.38

In this case, the results of aggregate demand and aggregate supply are not much different from those under perfect dollarization. Here, the specification that the real interest rate depends on the US real interest rate and the real exchange rate is consistent with the theoretical aspect to some degree. If prices are sticky in the short term, real exchange rates and real interest rates can be explained by nominal exchange rates and nominal interest rates. Also assuming that the future expected exchange rate does not change significantly under the Uncovered Interest Rate Parity, then the interest rate of Cambodia is expected to rise and Riel can appreciate against the US dollar, i.e. a decrease of the nominal exchange rate of the Riel-dollar can be expected. Conversely, when the interest rate in the US rises, it can be inferred that the nominal exchange rate is likely to rise. We have demonstrated that the interest rate of Cambodia moves similarly to the US interest rate. In the case of the real interest rate equation in Model 2, the coefficients of r_t^{US} and rer_t are 0.9 and －0.037, respectively. In Model 5 with $r_t = i_t - E_t \pi_{t+1}$, the magnitude and sign of the coefficients are similar. However, the coefficient of the real interest rate in the US is statistically significant, while the coefficient of the real exchange rate is not in both models.

On the other hand, in Model 5, explanatory power is much higher than that of the former by 0.38. On the other hand, in Model 5, coefficient of determination R^2 is 0.38 much higher than that of Model 2, which is 0.17. While not sizable, the explanatory power of the aggregate demand equation in Model 5 is 0.71, which is slightly higher than that in Model 2. Measuring the real interest rate as ex-ante by taking into account agents expectations fits the data better as well as it is more consistent with economic theory.

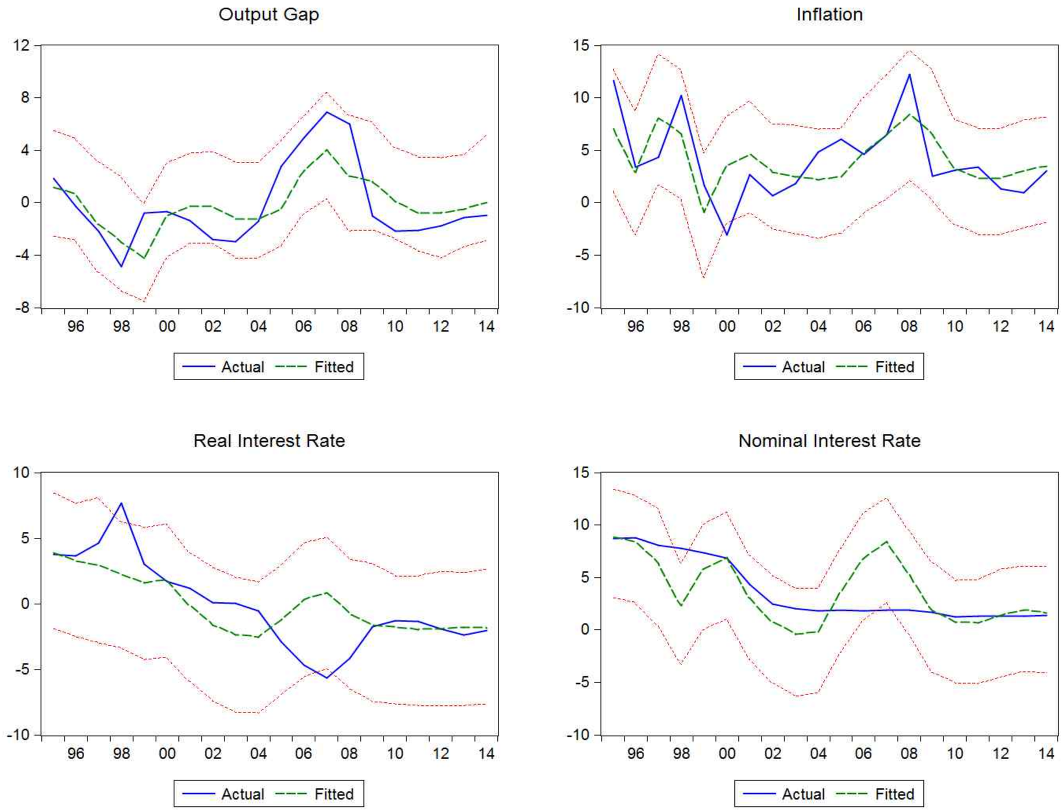
Next, we compare the estimated variables with actual data to gauge the fit of the models. Figures <4-4> and <4-5> show this for Models 2 and 5, i.e., estimated output gap, inflation, real interest rate, nominal interest rate and actual data under assumptions of $r_t = i_t - \pi_t$ and $r_t = i_t - E_t \pi_{t+1}$.

<Figure 4-4> Estimation Results of Small-scale Model 2



Note: The unit of the vertical axis of the Output Gap is the percentage of the long-term average. Inflation and real interest rates and nominal interest rates are also measured in percentage.

<Figure 4-5> Estimation Sesults of Small-scale Model 5



Note: See the notes in <Figure 4-4>

In Figures <4-4> and <4-5>, the blue solid line denotes the actual data, the green dotted line represents the estimate, and the red lines represent the 90% confidence interval. The tentative estimation results of the models show that they follow the data appropriately despite their simplicity. Of course, since the time series data covers only 20 years, the confidence interval is very wide, but the in-sample forecast of inflation, which is considered to be most important by the central bank of Cambodia, is close to actual data. As can be seen from the model's estimates in the case of Model 5, which used the expected interest rate obtained from the estimation of expected inflation, R^2 was relatively higher than in Model 2. In Figure <4-2>, the confidence interval is relatively narrow, and in particular, the estimate of the expected real interest rate is closer to the actual data.

(3) Independent Monetary Policy

Next, we estimate Cambodian interest rate data for Models 3 and 6, assuming the scenario that an independent monetary policy is implemented after exit from dollarization shown in equations (16) through (19).

<Table 4-5> Estimation Results under Independent Monetary Policy

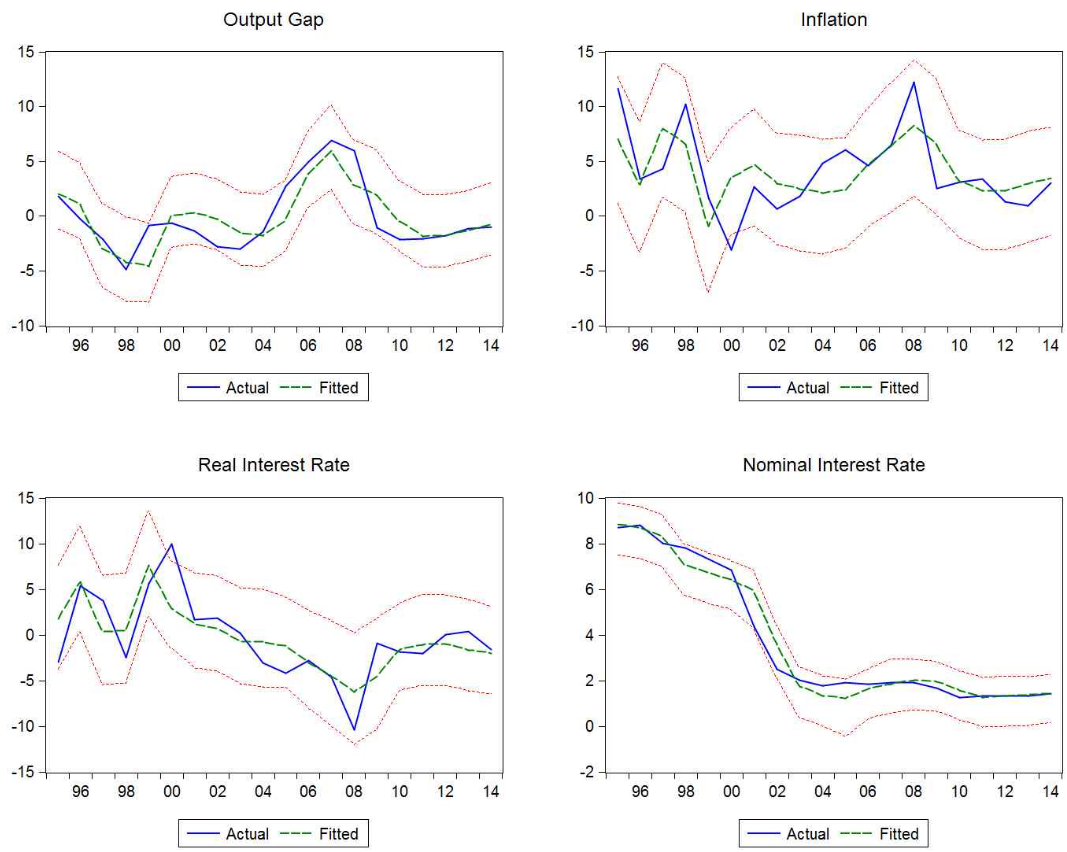
Model 3: Case of $r_t = i_t - \pi_t$	R^2
$y_t = 0.980 y_{t-1} - 0.065 r_t + 0.040 rer_t - 4.763 D_t^R - 2.751 D_t^A$ (0.216)* (0.098) (0.041) (2.146)* (1.543)*	0.68
$\pi_t = 0.624 y_{t-1} - 0.223 \pi_{t-1} + 1.067 D_t^R + 4.501 D_t^A$ (0.337)* (0.203) (3.744)* (2.505)*	0.39
$i_t = 0.918 i_{t-1} - 0.006 \pi_t + 0.059 y_t - 0.030 rer_t$ (0.043)* (0.032) (0.042) (0.011)*	0.97

Model 6: Case of $r_t = i_t - E_t \pi_{t+1}$	R^2
$y_t = 0.867 y_{t-1} - 0.308 r_t + 0.019 rer_t - 4.358 D_t^R - 0.853 D_t^A$ (0.219)* (0.196) (0.041) (1.984)* (1.860)	0.72
$\pi_t = 0.624 y_{t-1} - 0.223 \pi_{t-1} + 1.067 D_t^R + 4.501 D_t^A$ (0.337)* (0.203) (3.744)* (2.505)*	0.39
$i_t = 0.918 i_{t-1} - 0.006 \pi_t + 0.059 y_t - 0.030 rer_t$ (0.043)* (0.032) (0.042) (0.011)*	0.97

Since in this model, the monetary policy of the Taylor rule is implemented by means of the nominal interest rate, The real interest rate is different and therefore the estimation of the aggregate demand curve differs from that of imperfect dollarization. Also in this model, the results of the two definitions of real interest rates are different. Estimates of aggregate demand are similar to those of the previous model, but R^2 is slightly increased. What is noteworthy in this model is the monetary policy rule. As in the US and other developed countries, the nominal interest rate is very persistent and the coefficient of the past nominal interest rate was estimated at 0.918. However, although it is not statistically significant, it is difficult to interpret it as a rule of monetary policy with a negative coefficient of inflation. Specifically, as in equation (18), since the inflation coefficient is negative as $\phi_{\pi} = -0.006/(1-\rho) = -0.073$, it can be judged that the nominal interest rate does not respond to inflation. On the other hand, it can be inferred that the movement of nominal interest rate plays a role of stabilizing the economy to some extent because the response to the output gap is very large as the positive coefficient is $(\phi_{y} = 0.059/(1-\rho) = 0.72)$ in accordance with the theory.

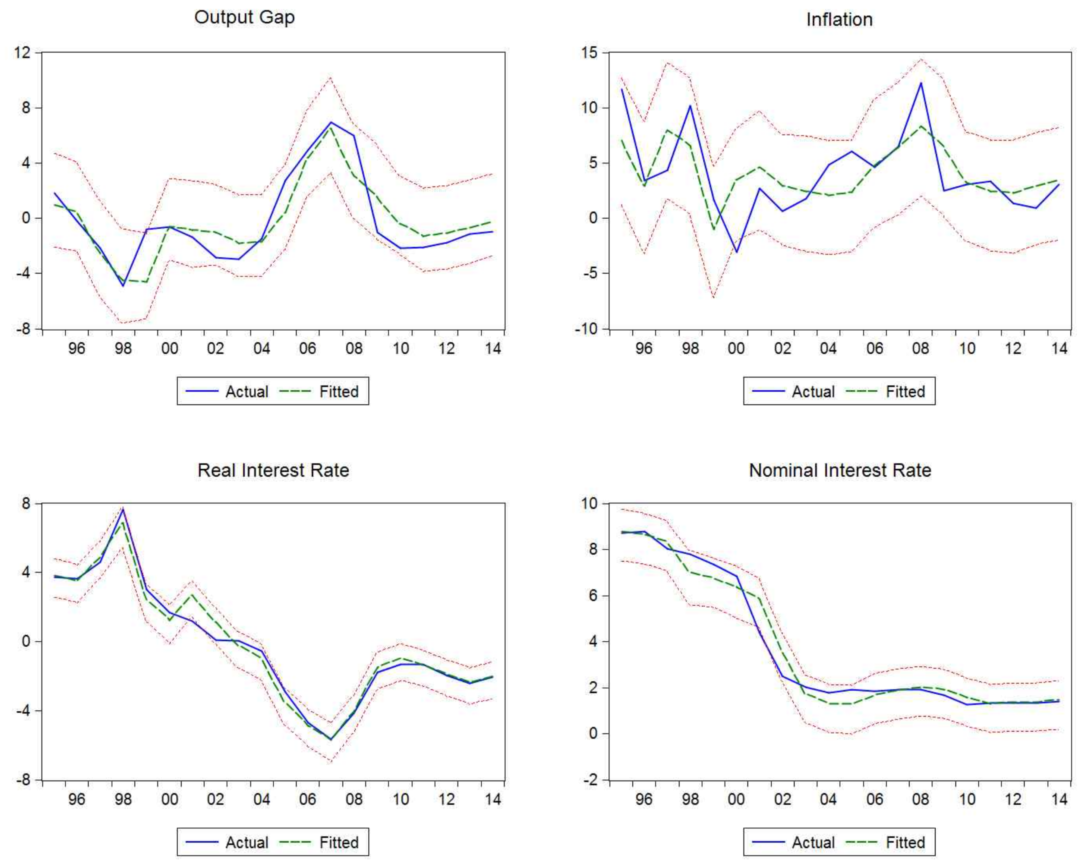
Figures <4-6> and <4-7> show the estimated output gap, inflation, real interest rate, nominal interest rate and actual data for Models 3 and 6.

<Figure 4-6> Estimation Results of Small-scale Model 3



Note: See the notes in <Figure 4-4>

<Figure 4-7> Estimation Results of Small-scale Model 6



Note: See the notes in <Figure 4-4>

The most prominent feature in these figures is that in Models 3 and 6, estimates of nominal interest rates and real interest rates fit the actual data very well, compared to the case of imperfect dollarization. This can be interpreted as the fact that the R^2 of the interest rate equation is very high at 0.97, and accordingly the gap between the output gap and inflation has narrowed considerably. In particular, Model 6 using the ex-ante real interest rate shows better results than the Model 3, and even though the model is a very simple model consisting of four equations, the estimation result is very good.

In summary, the assumptions of perfect dollarization in general can be seen as over-simplifying the Cambodian economy, so the cases of imperfect dollarization and independent monetary policy are more persuasive in explaining the data. In addition, the assumption of the real interest rate, which takes into account expected inflation in general, is has more explanatory power than the case where it is not. This fact shows that it is worth considering a model that explicitly introduces rational expectations in future modeling. Finally, Models 3 and 6, which assume an independent monetary policy, have the greatest explanatory power, but this gives important implications for the central bank of Cambodia: although the current interest rate movements explain the data appropriately, it is necessary to pay more attention to inflation stabilization, since inflation stabilization is the primary monetary policy objective.

Lastly, this model was introduced for easy understanding of the structure of model, and only the analysis focusing on the explanatory power of the model was performed. In the next chapter, we consider a more realistic mid-scale open economy model and analyze the trends of short-run inflation and output gap and long-run estimation of growth rate, which are the most important goals of this study, in addition to the explanatory power of the model.

V. Medium-Scale Macroeconomic Model

This chapter presents a medium-scale general equilibrium macroeconomic model that takes into account aggregate demand and monetary policy, and short-run and long-run output. The short-run model considered in Chapter IV is a new Keynesian small open-economy model in which the components of aggregate demand, such as consumption, investment, and government expenditure, were not analyzed. This chapter explicitly considers aggregate demand components, and doing so, the Cambodian open economy model introduced in Chapter III is modified to be practically applicable with an acceptable level of forecasting power. Nonetheless, it is implausible to include in the model more than 10 equations due to lack of data. The time series data is available only annually for 20 years. There is no reliable data pertaining to factor markets such as the labor market and the components of aggregate demand, apart from net exports. Since the number of available variables is also very limited, we will develop a short-run macroeconomic model with at most up to 10 equations.

Considering the data limitations, we first estimate a simple medium-scale New Keynesian model that takes into account some components of aggregate demand. The in-sample prediction is shown to be relatively good, but the out-of-sample prediction is far from satisfactory. The reason for this low performance in the out-of-sample prediction is that the data covers only 20 years, which makes it difficult to account for economic fluctuations and possible structural changes as a consequence of the Asian financial crisis and the US financial crisis. Given many practical constraints for estimation, we decide to estimate a set of models that assume different monetary policy schemes as considered in Chapter IV, rather than to focus on one specific model.

As in the small-scale model of Chapter IV, the medium-scale macroeconomic model adopts the nominal interest rate as a monetary policy instrument, instead of the traditionally considered monetary demand and monetary supply structure, and takes into account various monetary policy rules. However, as we have seen in the analysis of Chapter IV, the case of perfect dollarization under which the nominal interest rates of Cambodia and the US were the same, produced results which were quite poor. Therefore, we consider only the cases of imperfect dollarization and independent monetary policy in this chapter.

For the determination of long-term GDP, we consider two methods: growth accounting using the GDP function and statistical methods of obtaining GDP trends. The growth accounting method is theoretically superior, but due to lack of reliable labor and capital data, the former is used only to estimate long-run GDP, while the latter by means of Hodrick-Prescott filter is employed for estimating the short-run model. The model consisting of aggregate demand, monetary policy, and aggregate supply will be used to forecast the rate of economic growth and inflation for the next two to four years.

1. Medium-Scale Macroeconomic Model

For the medium-scale macroeconomic model, aggregate demand consists of private consumption, government consumption, investment, exports, and imports. The reason for considering government consumption instead of the usual government expenditure is that Cambodia officially releases government consumption data, not government expenditure data. Another consideration is the lack of reliable tax data.

The model is further simplified by not incorporating an error correction term, which is normally present in a medium-scale empirical macroeconomic model. If we include the error correction term, it would be necessary to employ level variables, such as income and private consumption. Because of the short time series and structural changes we confront however, such an econometric approach relying on asymptotics can lead to wrong inferences in estimation.

The analysis assumes logarithmic linearization. For exposition purposes, assume that $x_{1,t}$ is an endogeneous variable: $x_{2,t},\ x_{3,t},\ \ldots,\ x_{n,t}$ are explanatory variables;, and, $z_{1,t},\ \ldots,z_{m,t}$ are exogeneous variables. Then the equation for $x_{1,t}$ may be written as:

$$x_{1,t} = f(x_{2,t},\ x_{3,t},\ \ldots,\ x_{n,t}; z_{1,t},\ \cdots, z_{m,t})$$

The equation includes a constant term and an error term. The function f typically differs from equation to equation. Strictly speaking, the above equation is a linear function and can be written as:

$$x_{1,t} = \alpha_1 + \beta_2 x_{2,t} + \ldots + \beta_n x_{n,t} + \gamma_1 z_{1,t} + \ldots + \gamma_m z_{m,t} + \epsilon_{1,t}$$

In what follows, we will explain the model by dividing the economy into three sectors of aggregate demand, aggregate supply, and monetary policy. Since a separate account of fiscal policy is beyond the scope of this study, we have included it in the aggregate demand sector under the assumption that fiscal policy is exogenous.

A. Aggregate Demand

As discussed in Chapter III, private consumption needs to take into account the intertemporal optimal decision process, known as the Euler equation. Furthermore, an open-economy setting requires consumption be divided into domestic consumer goods and imported consumer goods. However, there is no individual consumption data for domestic consumer goods and foreign consumer goods. Hence, private consumption itself is used, but is modeled to depend on the real exchange rate as well in order to reflect the effects of imported consumer goods. Specifically, the equation for private consumption is written as follows:

$$\triangle \ln C_t = f(\triangle \ln C_{t-1},\ \triangle r_t,\ \triangle \ln Y_t, \triangle \ln G_t,\ \triangle \ln RER_t) \qquad (1)$$

where C_t is real private consumption, r_t is real interest rate, Y_t is real GDP, G_t is government consumption, RER_t is the real exchange rate. Δ denotes the first difference operator. Equation (1) can be interpreted as a transformation of the linearized Euler equation into a backward-looking setting. To see this, suppose the Euler equation where current consumption depends on future expected consumption and real interest rates. In other words, equation (37) in Chapter III can be expressed as marginal utility and the real interest rate, i.e. $U'(C_t/H_t) = E_t \beta U'(C_{t+1}/H_{t+1})(1+r_t)$, where U' is marginal utility and H_t is a variable that represents habit formation. When considering external habit, H_t can be thought of as dependent on C_{t-1}. Once linearized, an optimal path of consumption by the Euler equation depends on $\Delta \ln C_t$ as well as $\Delta \ln C_{t-1}$. It is also easy to see the effect of the real interest rate. Theoretically, $\Delta \ln C_t$ can be expressed as an increasing function of $\Delta \ln C_{t-1}$, and a decreasing function of the real interest rate.

Linearizing the Euler equation yields $E_t \Delta C_{t+1}$ which depends on all state variables that can affect future consumption. Technically speaking, this means that a solution for the expectation formation in a typical general equilibrium DSGE model depends on the state variables. In principle, an optimal consumption path for consumption will depend on all the state variables described above. Yet, it is a reasonable conjecture that income can be the most influential determinant, as consumption theory suggests. Given this, we include $\Delta \ln Y_t$ as an explanatory variable in the consumption equation. Although disposable income is a more appropriate measure, only the total income is considered due to the absence of tax data. Government expenditure was also considered because transfer payments could directly affect the future expected consumption of households. However, government expenditure data is not available, and nor is the data on transfer payments. Hence, total government consumption is adopted as an explanatory variable. The real exchange rate was included as an explanatory variable, as it can have explanatory power. While imports can also be considered, private consumption has already included this item, so we did not include it here as an explanatory variable.

Next, look at investment expenditures. Investment can proceed in a similar fashion to the consumer's choice, as discussed in the model of Chapter III. If there are no investment shocks and investment adjustment costs, Tobin's $Q_t(\equiv \Xi_t/P_t\Lambda_t)$ in equation (41) of Chapter III becomes 1. If investment adjustment costs exist, it can be seen that an optimal path for investment, just like the optimal consumer's choice, depends on the past variables as in equation (42) of chapter III, and the real interest rate.

As in consumption, investment can depend on future expected returns. Because state variables can affect future expected returns, they can also affect investment. Thus, the investment function is set to respond to changes in current income, changes in government consumption, and changes in real exchange rates. Government consumption was used as a proxy variable for government expenditure as mentioned above. Finally, Official Development Assistance (ODA_t) has been known to play an important role in promoting the economic growth of Cambodia, like other developing countries. To reflect this effect, we have added a setting that investment can be affected by changes in ODA. Taking it all together, the investment function is expressed as follows:

$$\triangle \ln I_t = f(\triangle \ln I_{t-1},\ \triangle r_t,\ \triangle \ln Y_t,\ \triangle \ln G_t,\ \triangle \ln RER_t,\ \Delta ODA_t) \qquad (2)$$

Government consumption is a policy variable, and modeled exogenously. Official government expenditure data exists only in some time periods, thus can not be used for empirical analysis. Government consumption is used as a proxy for government expenditure, and there is no major difference between the two. Government consumption is assumed to be determined by past government consumption, real interest rate, GDP, and real exchange rate, which is given as:

$$\triangle \log G_t = f(\triangle \log G_{t-1},\ \triangle r_t,\ \triangle \log Y_t,\ \triangle rer_t) \qquad (3)$$

As GDP increases, so does government consumption in the long run, just as in private consumption. However, it can also play a role in stabilizing business cycles, suggesting that government consumption and private consumption may respond differently to changes in the explanatory variables. Exports are assumed to be a function of past exports and the real exchange rate. Cambodia is a small open economy, which can be affected by changes in the world economy. To reflect this, we have added the world trade volume (WTV_t) and the U.S. real interest rate as explanatory variables.

$$\ln EX_t = f(\ln EX_{t-1}, \ln WTV_t, r_t^{US}, \ln RER_t) \tag{4}$$

Imports mainly reflect domestic economic conditions, and is modeled to depend on past imports, current income, domestic real interest rate, and the real exchange rate.

$$\ln IM_t = f(\ln IM_{t-1}, \ln Y_t, r_t, \ln RER_t) \tag{5}$$

Finally, adding up the national account identity as shown below completes the description of aggregate demand.

$$Y_t = C_t + I_t + G_t + EX - IM \tag{6}$$

In the time-series context, consumption, investment, and government expenditure show a persistent upward trend with economic growth. In such a case, it is common to construct error correction terms using their levels, and include them in the difference equations of (1) - (3) in estimating short-term fluctuations. However, such an approach is unrealistic for the application at hand, as there are only 20 data points and the number of explanatory variables is over 5. To preserve the much needed degrees of freedom, we decide not to take the error correction term into account, and the model is set up based only on difference variables. Exceptions are exports and imports. While the two variables also exhibit a uptrend, they are quite volatile due to external factors, and the corresponding difference equations show poor explanatory power. Thus we used level variables in these cases.

B. Monetary Policy

In the small open economy model introduced in Chapter IV, monetary policy is considered for three scenarios: perfect dollarization, imperfect dollarization, and independent monetary policy. Here, only two cases are considered by excluding perfect dollarization. For the sake of convenience, let us recall the monetary policies in Chapter IV as:

$$r_t = \delta r_t^{US} + \gamma z_t + e_t \tag{7-1}$$

$$i_t = \rho i_{t-1} + (1-\rho)[\phi_\pi \pi_t + \phi_y y_t + \phi_{rer} rer_t] + \epsilon_t \tag{7-2}$$

Equations. (7-1) and (7-2) show imperfect dollarization and independent monetary policy, respectively.

C. Aggregate Supply

Chapter III explicitly introduced the aggregate supply sector in a small open economy and derived the short-run and long-run aggregate supply curves. It covers comprehensive and detailed accounts of production factor markets and optimal behaviors of firms. Specifically, the new Keynesian supply curve in equation (12) of Section III accommodates the sticky pricing of Calvo (1983), and takes into account intermediate and final products. In addition, the supply curves of imported consumer goods firms, imported investment goods firms, and export firms have been derived from equations (18), (24) and (28) in Chapter III. However, it is typically difficult to distinguish between export and import firms, and the data on capital is unreliable. Most of all, there is no data available on employment, real wages and the unemployment rate which are essential to identify the labor market equilibrium.

Because of these limitations, we introduce a simplified supply curve for estimation. This simplified supply curve is consistent with the prediction implied in the theoretical model that inflation relies on past and future inflation and output gaps, and the real exchange rate is included to reflect the effects of external shocks. Since the state variables affecting future inflation can also be specified as explanatory variables, we estimated various state variables, and found that most cases exhibited poor explanatory power. Hence, we decide to employ a backward-looking setup by ruling out future inflation. The equation is given as:

$$\pi_t = f(\pi_{t-1},\ \ln Y_t - \ln Y_t^P,\ \ln RER_t) \quad (8)$$

where $\ln Y_t - \ln Y_t^P$ is the output gap, and Y_t^P denotes potential GDP.

A standard approach to estimate potential GDP is through the production function. However, there can be many errors in the estimation of unobservable variables such as capital and labor productivity. As an alternative, we calculated the long-term growth rate by means of growth accounting. First, the production function is assumed to be homogeneous of degree one. Then, the sum of incomes distributed to the production factors equals the total value of products, i.e. GDP. The potential growth rate is obtained by summing a weighted average of the growth rate of capital and labor inputs by the ratio of compensation and the growth rate of total factor productivity. Thus, potential growth rate can be expressed as:

$$\frac{\triangle Y_t}{Y_t} = \frac{\triangle A_t}{A_t} + \alpha \frac{\triangle K_t}{K_t} + (1-\alpha)\frac{\triangle L_t}{L_t}$$

where Y_t is real GDP, and K, L, A are capital inputs, labor inputs and total factor productivity respectively.[11] Potential GDP is estimated using a quadratic function of the form:

$$\ln Y_t = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + e_t$$

11) L_t may be decomposed as $L_t = h_t N_t$, where N_t is quantitative labor and h_t is qualitative labor. Then, it would be more appropriate to look at the effects of quantitative labor and qualitative labor separately. However, this was not attempted here due to the lack of data on real wages and labor productivity.

Based on the parameter estimates, potential GDP can be determined as:

$$\ln Y_t^P = \hat{\alpha}_0 + \hat{\alpha}_1 t + \hat{\alpha}_2 t^2$$

Then, the growth rate of potential GDP is obtained as $g_t^P = \ln Y_t^P - \ln Y_{t-1}^P$. The same rule applies to labor and capital. Suppose $\overline{g_t^L}$ and $\overline{g_t^K}$ are the estimated trend growth rate of labor and capital, respectively. Then, the growth rate of total factor productivity, $\overline{g_t^A}$, can be obtained from equation (9). Letting T denote the most recent time point, an estimate on the future growth rate of potential GDP can be obtained as follows:

$$g_{T+i}^P = \overline{g_T^A} + \alpha \overline{g_{T+i}^K} + (1-\alpha)\overline{g_{T+i}^L}$$

where $i = 1, 2, \ldots$, and total factor productivity is assumed to be maintained at the last point in time. Since the ratio of capital to GDP is approximately constant in most countries, it is also assumed that $\alpha = 0.3$.

2. Estimation Results of the Medium-Scale Macroeconomic Model

The short-run and long-run models in Section 1 have the characteristics of a neoclassical synthesis. Therefore, long-run GDP is independent of short-run economic fluctuations, as is determined by the production function and factors on the supply side. Then, estimating and forecasting the potential growth rate by the above method can proceed without recourse to the short-run model. To ensure consistency throughout the system, it is also desirable to construct an output gap measure using estimated long-run GDP, and to include this output gap in the short-run model. However, the accurate estimation of long-run GDP requires reliable data on the production function and factors. If these data are unavailable, it may be more practical to statistically infer the long-run GDP, as adopted in many business cycle studies. There are a number of statistical methods for extracting the long-run GDP, but the most popular is the Hodrick-Prescott filter. Based on this discussion, we use the production function approach to estimate the long-run GDP, and project its growth rate for the next four years. The short-run model however, estimates the long-run GDP by means of the Hodrick-Prescott filter.

Data on real private consumption, government consumption, fixed capital investment, exports and imports are obtained from the Asia Development Bank, and those on the number of workers and Official Development Assistance from the World Bank. The size of world trade is obtained from the Netherlands Bureau of Economic Analysis (CPB), and the capital stock is obtained from the Federal Reserve Bank of Saint Louis.

<Table 5-1> lists the equations and formulas and identifiers that make up the model, two different monetary policies and two different settings for the real interest rate. The equations are equilibrium conditions in the model, and the identities are auxiliary relationships necessary for model estimation. Equations (7-1) and (7-2) show the imperfect dollarization and independent monetary policy regimes, respectively. Equation (9-1) defines the real interest rate as simply subtracting the current inflation from the current nominal interest rate, and the real interest rate in (9-2) is defined as subtracting expected inflation from the nominal interest rate. Since the model takes into account both the real interest rates of Cambodia and the U.S., a measure of expected inflation is needed and is obtained by applying a VAR for both countries. The equation for expected inflation is shown in equation (10). In the case of Cambodia, the VAR model consists of inflation, output gap, the nominal interest rate, and the real exchange rate, and the estimate of expected inflation is obtained from the first equation, that is $E_t\pi_{t+1} = \hat{\pi}_{t+1}$. In the case of the U.S., the real exchange rate was excluded. Thus, a total of four different models (excluding perfect dollarization) can be summarized as follows:

<Table 5-1> Summary of Medium-scale Model

Classification	Model	Division
Equation	(1) $\triangle \ln C_t = f(\triangle \ln C_{t-1},\ \triangle r_t,\ \triangle \ln Y_t, \triangle \ln G_t,\ \triangle \ln RER_t)$	aggregate demand
	(2) $\triangle \ln I_t = f(\triangle \ln I_{t-1},\ \triangle r_t,\ \triangle \ln Y_t, \triangle \ln G_t,\ \triangle \ln RER_t,\ \Delta ODA_t)$	
	(3) $\triangle \ln G_t = f(\triangle \ln G_{t-1},\ \triangle r_t,\ \triangle \ln Y_t,\ \triangle \ln RER_t)$	
	(4) $\ln EX_t = f(\ln EX_{t-1}, \ln WTV_t, r_t^{US}, \ln RER_t)$	
	(5) $\ln IM_t = f(\ln IM_{t-1}, \ln Y_t, r_t, \ln RER_t)$	
	(6) $Y_t = C_t + I_t + G_t + EX - IM$	
	(7-1) $r_t = \delta r_t^{US} + \gamma \ln RER_t + e_t$	monetary policy
	(7-2) $i_t = \rho i_{t-1} + (1-\rho)[\phi_\pi \pi_t + \phi_y(\ln Y_t - \ln Y_t^P) + \phi_{rer} \ln RER_t] + \epsilon_t$	
	(8) $\pi_t = f(\pi_{t-1},\ \ln Y_t - \ln Y_t^P,\ \ln RER_t)$	aggregate supply
	(9-1) $r_t = i_t - \pi_t, \qquad r_t^{US} = i_t^{US} - \pi_t^{US}$	Fisher equation
	(9-2) $r_t = i_t - E_t \pi_{t+1}, \qquad r_t^{US} = i_t^{US} - E_t \pi_{t+1}^{US}$	
	(10) $\hat{\pi}_t = \hat{\alpha} + \hat{\beta}_1 \pi_{t-1} + \hat{\beta}_2 (\ln Y_{t-1} - \ln Y_{t-1}^P) + \hat{\beta}_3 i_{t-1} + \hat{\beta}_4 \ln RER_{t-1}$	inflation expectations
	$\hat{\pi}_t^{US} = \hat{\alpha} + \hat{\beta}_1 \pi_{t-1}^{US} + \hat{\beta}_2 (\ln Y_{t-1}^{US} - \ln Y_{t-1}^{P,US}) + \hat{\beta}_3 i_{t-1}^{US}$	
	(11) $\ln Y_t^P = HP(\ln Y_t)$	long-run GDP
Identity	(1) $\ln Y_t = \ln Y_{t-1} + \triangle \ln Y_t$	
	(2) $\ln RER_t = \ln RER_{t-1} + \triangle \ln RER_t$	
	(3) $\log G_t = \log G_{t-1} + \Delta \log G_t$	
	(4) $r_t = r_{t-1} + \Delta r_t$	
	(5) $Y_t = \exp(\ln Y_t)$	
	(6) $C_t = \exp(\ln C_t)$	
	(7) $I_t = \exp(\ln I_t)$	
	(8) $G_t = \exp(\ln G_t)$	
	(9) $EX_t = \exp(\ln EX_t)$	
	(10) $IM_t = \exp(\ln IM_t)$	

Note: The VAR estimate $\hat{\pi}_{t+1}$ is used for $E_t \pi_{t+1}$. HP denotes the Hodrick-Prescott filter, and $HP(\ln Y_t)$ is the long-term trend of log GDP obtained using this filter.

<Table 5-2> Classification of Medium-scale Model and Equilibrium Condition of <Table 5-1>

Assumptions on Monetary Policy	$r_t = i_t - \pi_t$	$r_t = i_t - E_t \pi_{t+1}$
Imperfect Dollarization	Model 2: 1~6,8,11,7-1,9-1	Model 5: 1~6,8,10,11,7-1,9-2
Independent Monetary policy	Model 3: 1~6,8,11,7-2,9-1	Model 6: 1~6,8,10,11,7-2,9-2

In Models 2 and 3, there are 10 equations, and 10 endogenous variables which are $C, I, G, EX, IM, Y, r, i, \pi, Y_t^P$. Models 5 and 6 additionally include equation (10) and $\hat{\pi}_{t+1}$, making up 11 equations and endogenous variables, respectively. The exogenous variables are the real exchange rate, world trade volume, and the nominal and real interest rates of the U.S., $(RER, WTV, i^{US}, r^{US})$. We also considered the trade volume with China and the exchange rates of neighboring countries including China as exogeneous variables, but the explanatory power was generally low. A more serious concern is that if the number of explanatory variables is large given such a small dataset like that of the present study, the loss in the degrees of freedom would be severe, resulting in a large estimation error. Consequently, those variables were not included in the final model. Our strategy for improving the accuracy of estimation is secure as many degrees of freedom as possible by using only the variables known to have high explanatory power. The contribution of these explanatory variables was evaluated using the R^2 statistic.[12)]

A. Estimation Results

In Chaper IV, the results were compared between Models 2 and 5 corresponding to imperfect dollarization, and then, between Models 3 and 6 corresponding to independent monetary policy. Here we compare the results of Models 2 and 3 assuming the real interest rate as $r_t = i_t - \pi_t$, and then compare Models 5 and 6 assuming $r_t = i_t - E_t\pi_{t+1}$. For the sake of brevity, the constant and error terms are omitted in reporting the results.

Equations (1) to (5) in Table <5-3> show the estimation results of aggregate demand. Consumption, investment, and government expenditure were all estimated in differences so that R^2 is relatively low. Consumption shows a slight decrease,

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12) In econometrics, $\overline{R}^2$ would be a more reliable measure for determining the explanatory power of variables. However, if there are only 20 data points, and the explanatory variable is more than 5, this statistic will be very low. On the other hand, if the key explanatory variables are dropped, the explanatory power of the model becomes low too. Taking these considerations into account, R^2 rather than $\overline{R}^2$ is adopted as a yardstick. If quarterly data become available in the future, the situation can be improved, and a more comprehensive analysis would be in order.

as the real interest rate increases, but the decrease is not statistically significant. Real GDP has a coefficient estimate of 1.02 on consumption and is strongly significant, the results of which are consistent with consumption theory. In the literature, it is well known that the movement in investment is hard to account for, compared to other components in aggregate demand. This also looks true in the case of Cambodia, as the estimated coefficients of the real interest rate, the real exchange rate, and real GDP growth are statistically insignificant. Yet, it is worth noting that an increase in official development assistance leads to a statistically significant increase in investment.

<Table 5-3> Estimation Results of Medium-scale Models 2 and 3

Model	Equilibrium Condition	R^2
2,3	(1) $\triangle \ln C_t = -0.53\triangle \ln C_{t-1} - 0.04\triangle r_t + 1.02\triangle \ln Y_t - 0.03\triangle \ln G_t + 0.12\triangle \ln RER_t)$ (0.25) (0.24) (0.44)* (0.04) (0.29) $+0.98D_t^R - 4.25D_t^A$ (3.83) (5.02)	0.53
2,3	(2) $\triangle \ln I_t = -0.27\triangle \ln I_{t-1} + 1.38\triangle r_t + 1.20\triangle \ln Y_t - 0.001\triangle \ln G_t - 0.36\triangle \ln RER_t$ (0.29) (1.10) (1.52) (0.16) (1.35) $+0.48\Delta ODA_t - 8.61D_t^R + 10.42D_t^A$ (0.24)* (14.90) (24.37)	0.42
2,3	(3) $\triangle \ln G_t = -0.56\triangle \ln G_{t-1} - 0.49\triangle r_t - 0.65\triangle \ln Y_t + 0.98\triangle \ln RER_t$ (0.26)* (1.47) (2.31) (1.71) $+31.80D_t^R - 22.48D_t^A$ (22.48) (29.48)	0.41
2,3	(4) $\ln EX_t = 0.20\ln EX_{t-1} + 1.68\ln WTV_t - 0.02r_t^{US} + 0.44\ln RER_t + 0.11D_t^R - 0.13D_t^A$ (0.16) (0.41)* (0.02) (0.21)* (0.09) (0.09)	0.99
2,3	(5) $\ln IM_t = 0.86\ln IM_{t-1} + 0.12\ln Y_t + 0.01r_t - 0.01\ln RER_t - 0.12D_t^R - 0.02D_t^A$ (0.20)* (0.24) (0.01) (0.01) (0.07)* (0.14)	0.99
2	(7-1) $r_t = 0.90r_t^{US} - 0.04\ln RER_t$ (0.51)* (0.09)	0.17
3	(7-2) $i_t = 0.92i_{t-1} + 0.006\pi_t + 0.059(\ln Y_t - \ln Y_t^P) - 0.03\ln RER_t$ (0.043)* (0.032) (0.042) (0.011)* $\rho = 0.92,\ \ \phi_\pi = 0.075,\ \ \phi_Y = 0.726,\ \ \phi_{RER} = -0.366$	0.97
2,3	(8) $\pi_t = -0.31\pi_{t-1} + 0.90(\ln Y_t - \ln Y_t^P) - 0.12\ln RER_t + 9.71D_t^R + 6.11D_t^A$ (0.20) (0.42)* (0.06)* (3.36)* (2.66)*	0.48

Note: Figures in in parentheses are the standard errors, and * indicates significance at the 10% level. Constant and error terms are omitted for simplicity.

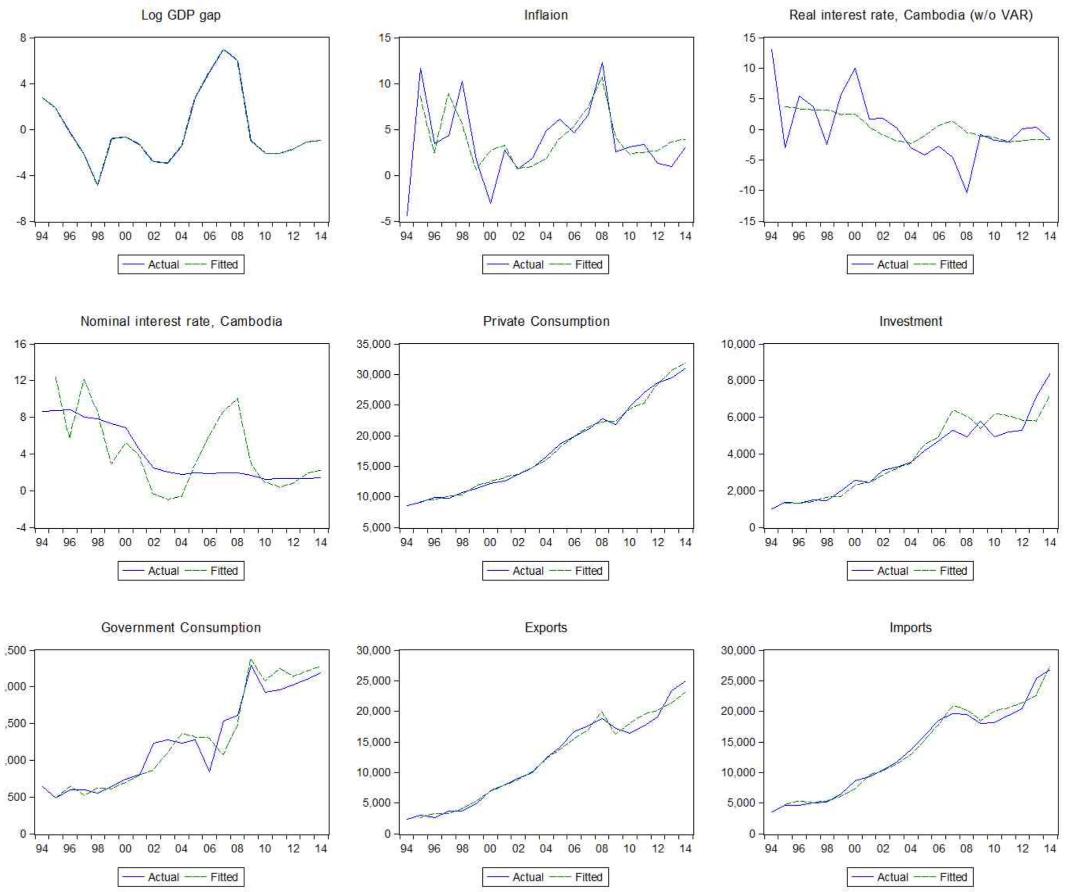
Cambodia is still in the developing stage, and it may be the case that the foreign official development assistance plays a positive role in economic growth through the increase of investment expenditure. The regression of government expenditure shows that none of the explanatory variables, except previous government expenditure, have any significant explanatory power.

Exports are heavily dependent on world trade volume, which reflects the economic situation in the world market. The estimated coefficient variable is 1.66 and statistically significant. Cambodia exports mainly light-industry products such as garments, and the major trading partners are China and Europe. The results confirm that the Cambodia’s exports are largely affected by the economic conditions in these areas. Another main contributor of Cambodia’s exports is the tourist industry centered on Angkor Wat. Since the tourist industry is also very sensitive to overseas economic conditions, Cambodia's exports would depend heavily on exogenous factors, such as world trade volume. Results also show that depreciation in the real exchange significantly increases exports through improved international competitiveness of domestic products. However, this finding is somewhat difficult to understand, given the fact that the major currency in Cambodia is the U.S. dollar. As a dollarization economy, the real exchange rate is unlikely to exhibit a large impact on Cambodia's travel industry as well as exports. Imports are heavily dependent on domestic economic conditions, and therefore, not significantly affected by external variables such as exchange rates.

Equations (7-1) and (7-2) representing monetary policy are the same as those of the small-scale model in Chapter IV. Equation (8) is the aggregate supply curve, where the coefficient of the output gap for inflation is large at 0.9 and statistically significant. Inflation falls in response to a depreciation of the real exchange rate. Given that Cambodia is a dollarized economy, depreciation is consistent with the fact that the Cambodian price index is relatively lower than the US price index. The Asian financial crisis and the U.S. financial crisis significantly increase inflation, and affects the aggregate supply curve unlike aggregate demand and monetary policy.

Next, compare the estimation results of Models 2 and 3. Model 3 shows that the equation for the nominal interest rate is estimated far more accurately, just like the case of Model 3 in the small open-economy model of Chapter IV. The expectation is that the overall results of estimation would be better as well. Figures <5-1> and <5-2> show estimates and actual data for Models 2 and 3, respectively.

<Figure 5-1> Estimation Results of Medium-scale Model 2



Note: Real GDP, consumption, investment, government expenditure, exports, and imports are denominated in the local currency, and the nominal and real interest rates, and inflation are measured annually in percentages. The solid line indicates actual data, and the dotted line indicates forecasts.

<Figure 5-2> Estimation Results of Medium-scale Model 3

Note: See the notes in figure <5-1>

The crucial difference between the two models is that the estimation results for the nominal interest rate and the real interest rate are significantly better in Model 3. Apart from this, the explanatory power of Models 2 and 3 is similar. In both cases, the forecasts of real GDP, inflation, and individual aggregate demand components also account for the corresponding actual data to a great extent. For inflation, however, there is a considerable gap between estimates and actual values, which should be associated with its large volatility over time.

Next, we compare the results of Models 5 and 6, in which the real interest rate is estimated taking into account inflation expectations. Estimation results are summarized in table <5-4>.

<Table 5-4> Estimation Results of Medium-scale Models 5 and 6

Model	Equilibrium Condition	R^2
5,6	(1) $\triangle \ln C_t = -0.42\triangle \ln C_{t-1} + 1.42\triangle r_t + 1.69\triangle \ln Y_t - 0.02\triangle \ln G_t + 0.31\triangle \ln RER_t$ (0.23)* (1.10) (0.66)* (0.04) (0.26) $+0.97D_t^R - 7.75D_t^A$ (3.47) (4.79)	0.59
5,6	(2) $\triangle \ln I_t = -0.32\triangle \ln I_{t-1} - 4.25\triangle r_t - 0.95\triangle \ln Y_t - 0.001\triangle \ln G_t + 0.27\triangle \ln RER_t$ (0.29) (6.15) (3.56) (0.18) (1.38) $+0.42\Delta ODA_t - 3.01D_t^R + 2.92D_t^A$ (0.26)* (14.84) (27.67)	0.37
5,6	(3) $\triangle \ln G_t = -0.46\triangle \ln G_{t-1} - 4.49\triangle r_t - 3.01\triangle \ln Y_t - 0.13\triangle \ln RER_t$ (0.23)* (6.28) (4.04) (1.57) $+23.06D_t^R - 2.45D_t^A$ (21.21) (29.52)	0.43
5,6	(4) $\ln EX_t = 0.20\ln EX_{t-1} + 1.68\ln WTV_t - 0.02r_t^{US} + 0.44\ln RER_t + 0.11D_t^R - 0.14D_t^A$ (0.16) (0.41)* (0.02) (0.22)* (0.09) (0.09)	0.99
5,6	(5) $\ln IM_t = 0.70\ln IM_{t-1} + 0.24\ln Y_t - 0.01r_t - 0.001\ln RER_t - 0.12D_t^R - 0.05D_t^A$ (0.13)* (0.17) (0.01) (0.004) (0.07)* (0.19)	0.99
5	(7-2) $r_t = 0.79r_t^{US} - 0.06\ln RER_t$ (0.27)* (0.05)	0.38
6	(7-3) $i_t = 0.92i_{t-1} + 0.006\pi_t + 0.059(\ln Y_t - \ln Y_t^P) - 0.03\ln RER_t$ (0.043)* (0.032) (0.042) (0.011)* $\rho = 0.92,\ \phi_\pi = 0.075,\ \phi_Y = 0.726,\ \phi_{RER} = -0.366$	0.97
5,6	(8) $\pi_t = -0.31\pi_{t-1} + 0.90(\ln Y_t - \ln Y_t^P) - 0.12\ln RER_t + 9.71D_t^R + 6.11D_t^A$ (0.20) (0.42)* (0.06)* (3.36)* (2.66)*	0.48
5,6	(10) $\hat{\pi}_t = -0.20\pi_{t-1} + 0.64(\ln Y_{t-1} - \ln Y_{t-1}^P) + 0.13i_{t-1} - 0.02\ln RER_{t-1}$ (0.21) (0.27)* (0.31) (0.08) $\hat{\pi}_t^{US} = 0.61\pi_{t-1}^{US} + 0.03(\ln Y_{t-1}^{US} - \ln Y_{t-1}^{P,US}) - 0.05i_{t-1}^{US}$ (0.27)* (0.12) (0.06)	0.28 0.39

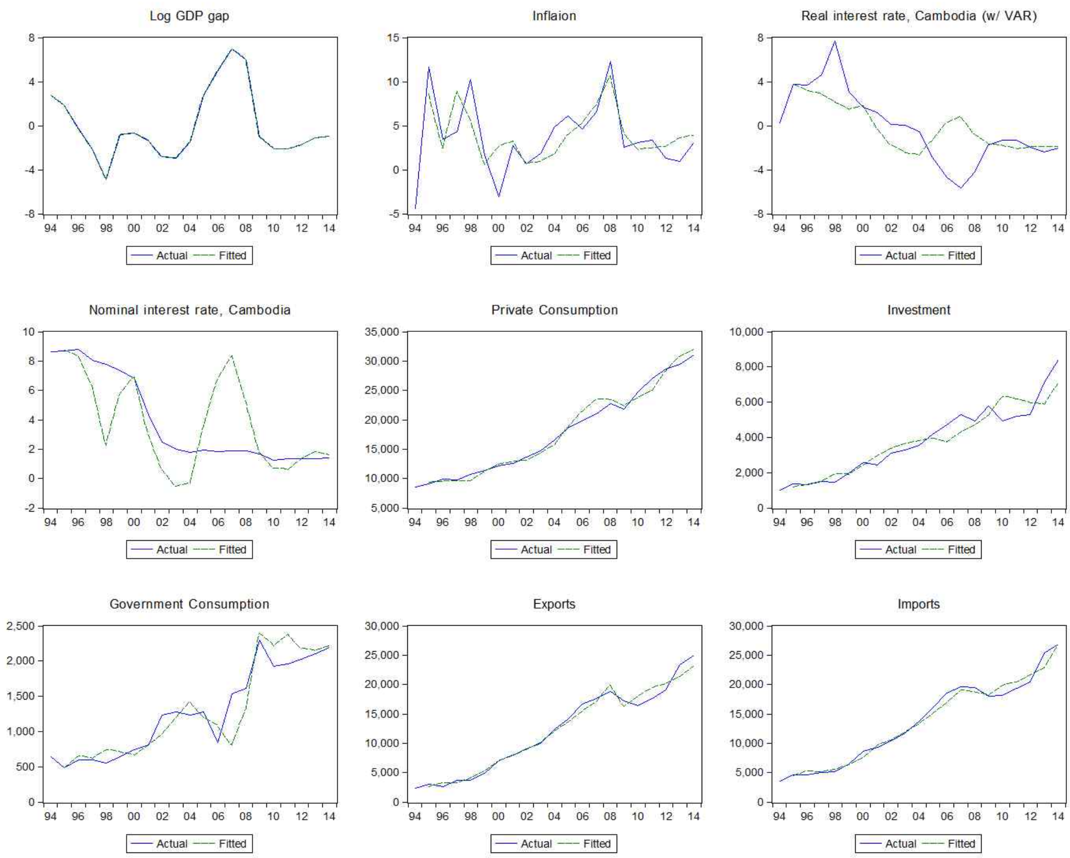
Note: Figures in parentheses are the standard errors, and * indicates significance at the 10% level. Constant and error terms are omitted for simplicity.

First, equation (10) produces inflation forecasts using the VAR model for Cambodia and the United States. The inflation forecasts are used to construct the real interest rates which enter other equations as an explanatory variable. While the results are not significantly different between Models 2 and 3, the overall R^2 has increased in general, except for the investment equation. It appears that Models 5 and 6 using the ex-ante real interest rate are somewhat superior to

Models 3 and 4 from both theoretical and empirical perspectives. However, the low R^2 in the inflation forecasting equation suggests that there may be a measurement error in the expected real interest rate, which is calculated using inflation forecasts. A recommendation is that the central bank of Cambodia needs to obtain more accurate information for the estimation of the expected real interest rate. Overall, the estimation results of Models 5 and 6 are similar to those of Models 2 and 3, and we do not repeat their interpretations here.

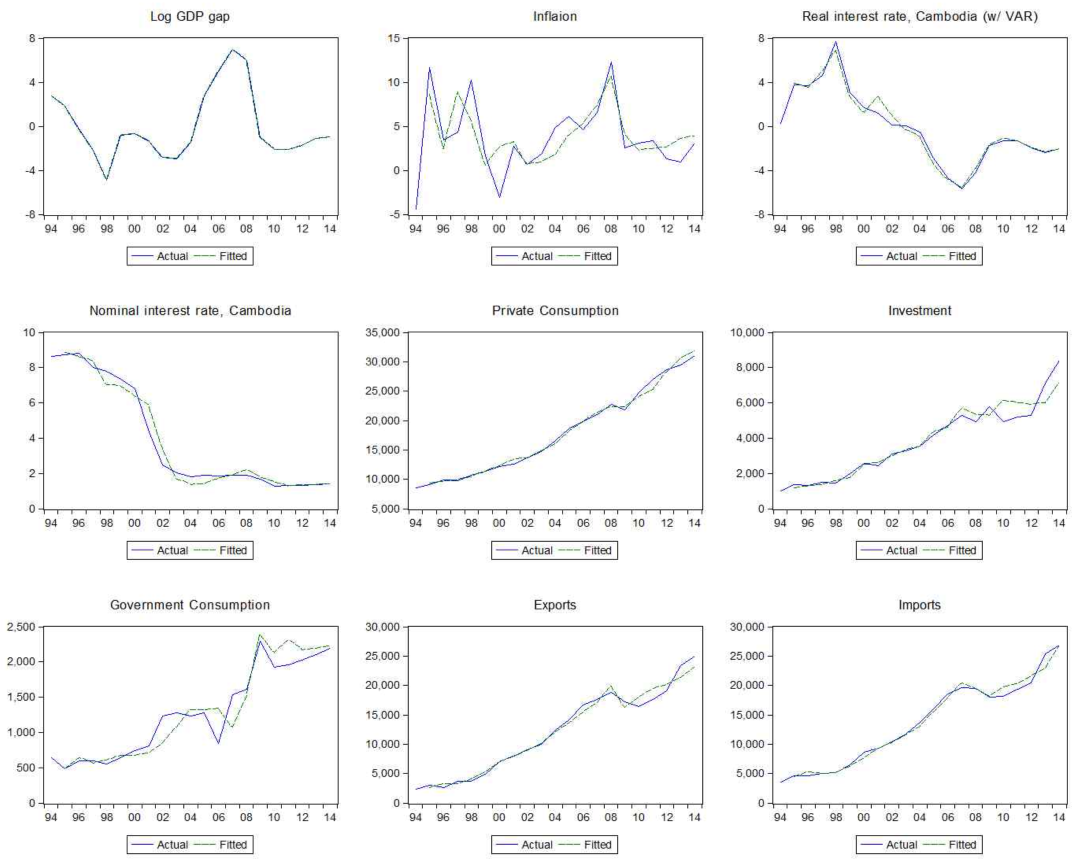
Figures <5-3> and <5-4> show the estimates and actual data of Models 5 and 6.

<Figure 5-3> Estimation Results of Medium-scale Model 5



Note: See the notes in Figure <5-1>.

<Figure 5-4> Estimation Results of Medium-scale Model 6



Note: See the notes in Figure <5-1>.

Since these figures are very similar to <Figure 5-1> and <Figure 5-2>, we do not repeat their interpretations, but refer to those for Models 2 and 3 above. The difference between Models 5 and 6 is that the estimates of nominal interest rates and real interest rates are more accurate in the latter.

In conclusion, Model 6 is the most desirable specification given the data available, followed by Model 3. Strictly speaking, the central bank of Cambodia has not been able to implement independent monetary policies. Even in the dollarization situation however, there are some interest rates that can be manageable to some extend by the bank, such as the deposit rates and the loan rates. In setting these rates, the interest rate equation reported in the present study may be of some help. Furthermore, it is recommended that the Bank may as well need to respond to inflation movements more actively.

3. Simulation based on a Medium-scale Macroeconomic Model

This section presents mid and long-run forecasts of economic growth and inflation and analyzes how they are affected by changes in internal and external factors. Economic growth can be forecast for both the long run and short run, but inflation can only be forecasted based on short-run models.

The long-run trend of GDP is independent of short-run fluctuations, whether it is generated using either growth accounting or the statistical Hodrick-Prescott filter. The potential GDP growth rate in the long run is estimated by means of growth accounting in Section 1, and then is projected over the period of 2015 to 2018, the results of which are shown in <Table 5-5>, together with actual values for the earlier three years.

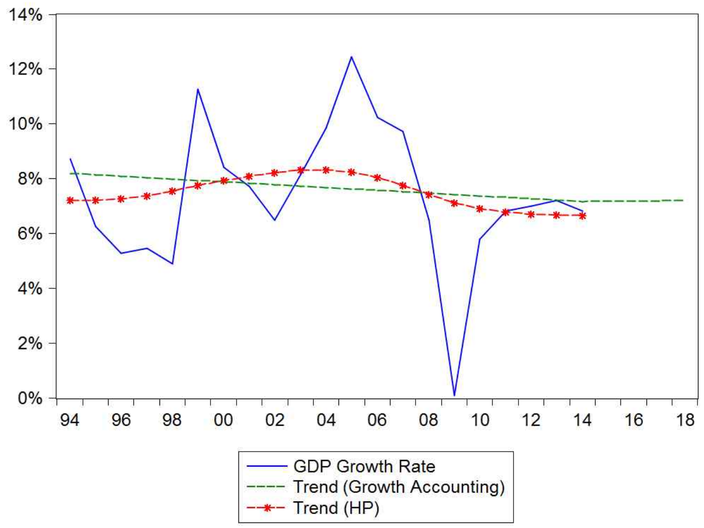
<Table 5-5> Estimation of Potential Growth Rate by Growth Accounting

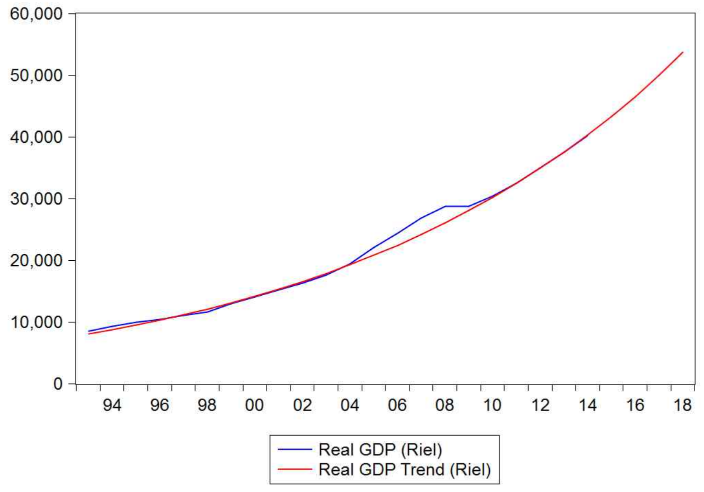
	Actual			Estimated			
Year	2012	2013	2014	2015	2016	2017	2018
GDP Growth Rate	7.00	7.21	6.83	7.17	7.18	7.19	7.20

In 2014, the potential growth rate fell to 6.8%, but this fall appears to be temporary. It is expected that the potential growth rate bounces back to 7.17% in 2015, and hovers around that level until 2018. It should be noted that these estimates correspond to potential growth rates, which may differ from actual economic growth rates due to short-term disturbances.

The full estimation results are depicted in <Figure 5-5>. From 1994 to 2014, the actual growth rate has been around 7% on average, but exhibits a substantially high volatility. In particular, it was 0% in 2009, just after the US financial crisis, but recovered rapidly to around 7%. The dotted line shows the trend growth rate produced by growth accounting. This trend growth rate falls slowly over time, but it is also possible that it may have actually risen, if the huge fall in 2009 is taken out. On the other hand, the trend growth rate using the Hodrick-Prescott filter gradually rises until 2004, and then falls before levelling out in 2012. Although the latter method can provide a more accurate output gap measure that can be used to diagnose booms and recessions of the economy, the key shortcoming is that it cannot predict future growth rates.

<Figure 5-5> Potential Growth Rate and Potential GDP by Growth Accounting





Note: The upper graph shows real GDP by 2014, the potential growth rate by growth accounting method until 2018, and the potential growth rate by HP filter until 2014. The bottom graph shows real GDP and potential GDP in one billion Riel.

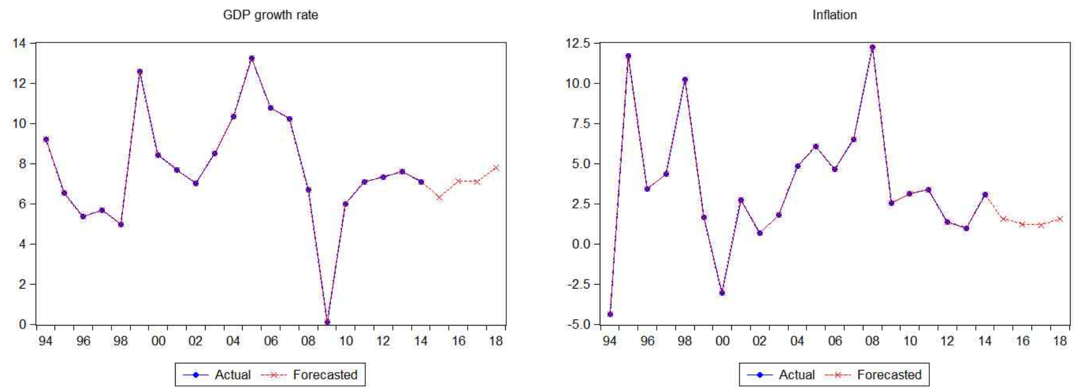
The bottom panel in <Figure 5-5> shows the estimates of the long-run growth rate by 2014, and the forecasts from 2015 to 2018 in parallel with actual GDP growth. In 2014, the nominal exchange rate was 4,000 Riel per 1 U.S. dollar, making the GDP of 40.3 trillion Riel worth about 10 billion U.S. dollars. In 2018, the potential real GDP is projected to about 53.7 trillion Riel, or, 13.43 billion U.S. dollars.[13)]

Now, we look at the short-run growth rate forecast generated through the medium-scale model. To estimate this growth rate, we need to make assumptions about the exogenous variables in the model, as described in Appendix B. There, the structural shock is assumed to be zero over the forecasting period, as it is a random variable with a mean of 0. The exogenous variables are: potential growth rate, world trade size (WTV), official development assistance (ODA), the real exchange rate (RER), U.S. real interest rate, and Cambodia's expected inflation.

To attenuate excessively large volatility, these variables are expressed as their five-year moving averages between 2014 and 2018. For potential growth rates, we can use either the estimate from the long-run model or from the HP filters in the short-run model. Theoretically, the former case can be more consistent with the model. As shown in <Figure 5-5> however, there was little change in that potential growth rate, making the resulting output gap overly volatile. This led to a poor forecast of the short-run growth rate. In the latter, we calculate a moving average of potential growth rate using the last 5-year data points over the period of 1994 to 2014, and then its sample average is assumed to be the potential growth rate for the prediction period of 2015 to 2018. We have done the same for the remaining exogenous variables in setting up their values over the prediction period. Using these assumed paths of the exogenous variables, the endogenous variables can then be forecasted by 2018. A moving-average is also applied to the forecasts of economic growth and inflation, as they have exhibited large standard errors.

13) The nominal GDP would be much higher because the data is the real GDP of 2000.

<Figure 5-6> Medium-scale Model Growth Rate and Inflation Forecast



Note: The graph on the left shows actual real GDP (solid line) by 2014 and the forecasts of growth rate (dotted line) from the short-run model until 2018. The graph on the right shows actual inflation (solid lines) by 2014 and inflation forecasts from the short-run model by 2018 (dotted line).

<Figure 5-6> shows the forecasts of economic growth and inflation. The projected short-run growth rate is shown to be slightly below the potential growth rate, while inflation is projected to stabilize at 1%. This partly reflects that the average growth rate of Cambodia since 2010 has stabilized around 7% with little fluctuation. Since 2010, inflation also drops to 1-3%, and its volatility has fallen sharply. Table <5-6> reports the forecasts of potential growth rate, short-run growth rate, and short-run inflation.

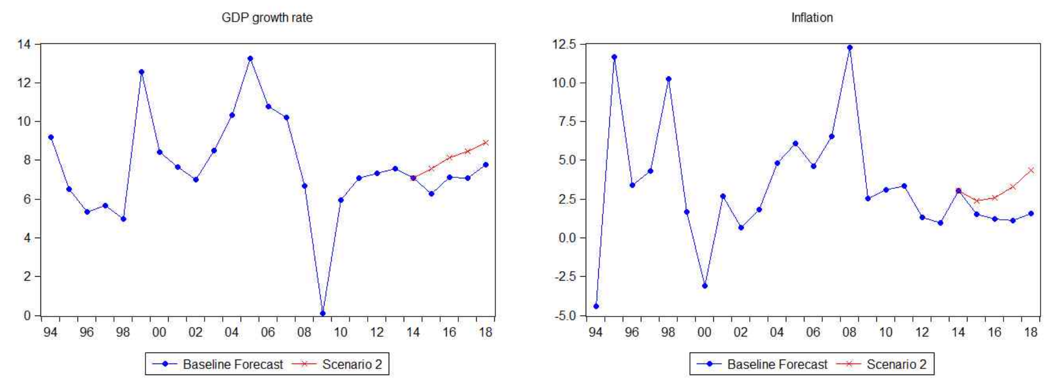
<Table 5-6> Estimates of Economic Growth and Inflation by Medium-scale Short-run Model

Model	2015	2016	2017	2018
Potential GDP Growth Rate (Long-run Model)	7.17	7.18	7.19	7.20
Short-run GDP Growth Rate (Short-run Model)	6.28	7.13	7.09	7.77
Short-run Inflation (Short-run Model)	1.53	1.22	1.13	1.55

The long-run and short-run estimates of the models appear to be very consistent with the data, but the standard errors of estimation are very large, as the sample period covers only 20 years. Therefore, it should be cautioned that even if the assumed values of exogenous variables happen to coincide with the actual values, there can be a substantial discrepancy between the predicted and actual values of endogenous variables.

Finally, we analyze how the short-run growth rate and inflation respond when the exogenous variables change. This analysis provides important information for monetary policy setting because it can identify which of the exogenous factors affects Cambodia's economy most. First, let us examine the prediction of the growth rate and inflation under the assumption that world trade will increase by about 5% over the next four years. <Figure 5-7> compares the results with the baseline predictions shown in <Figure 5-6>. The rate of GDP growth is forecasted to increase by a relatively large magnitude of 7.58%, 8.11%, 8.45% and 8.91% from 2015 to 2018, respectively. This seems plausible given that Cambodia has a relatively high trade share and exhibits large effects of world trade on exports, as found in the short-run model. The increase in world trade typically reflects positive aggregate demand shocks and hence, inflation is expected to rise. Indeed, inflation rises considerably by 2.37%, 2.58%, 3.31% and 4.35%, respectively. The world economy is currently in downturn, and the president-elect of the U.S. has expressed a shift in policy toward protectionism. Considering these observations, the results suggest that the rate of economic growth and inflation in Cambodia may decline in the future.

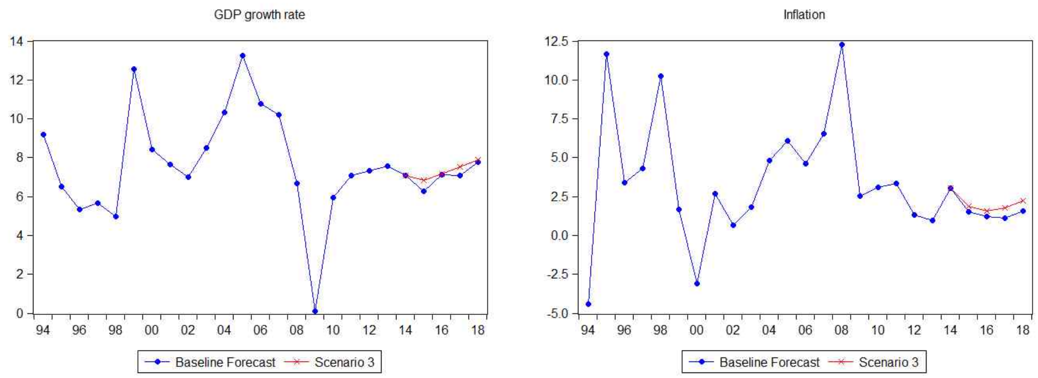
<Figure 5-7> Forecasts for a 5% Increase in World Trade over 2015-2018



Note: The left graph shows the forecasts of short-run GDP growth rate in <Figure 5-6> (marked by •), and those when the world trade volume increases by 5% (marked by ×). The right panel shows the corresponding results for inflation.

Second, we analyze possible effects on investment when official development assistance increases by 20%. <Figure 5-8> depicts forecasts about the growth rate and inflation. Official development assistance can be interpreted as an aggregate demand shock, as it increases investment. Then, an expectation is that both the rate of economic growth and inflation would rise, and this is empirically shown in the results. However, investment in Cambodia is of a small scale, and has a relatively small effect on GDP. As such, the GDP growth rate and inflation are projected to rise only by about 0.1-0.5% and 0.3-0.7%, respectively. Nevertheless, it should not be ignored that official development assistance still contributes to stabilizing the Cambodian economy. The positive role of official development assistance may be particularly beneficial when the world economy is expected to undergo a downturn, and there is little capacity for fiscal policy to counteract the resulting effects on the domestic economy.

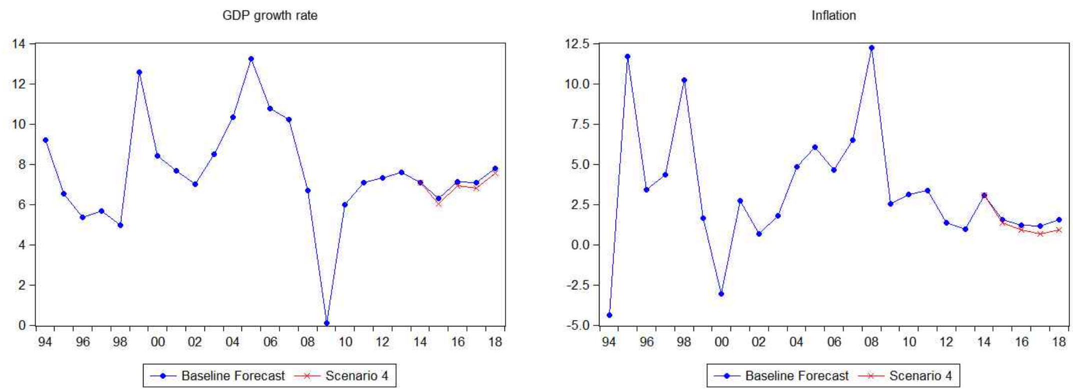
<Figure 5-8> Forecasts for a 20% Increase in ODA over 2015-2018



Note : See the notes in <Figure 5-7>

Third, we consider a case in which the U.S. real interest rate increases by 1%. The U.S. is expected to raise the Federal Funds rate from the end of 2016. Given that U.S. inflation is highly stabilized, this implies a rise in the real interest rates. A rise in the foreign real interest rate can be interpreted as a negative aggregate demand shock because the interest rate in Cambodia is likely to follow suit. Consequently, the economic growth rate and inflation are expected to decline, and these effects appear in <Figure 5-9>. In this case, however, it is predicted that the economic growth rate falls by 0.2-0.3% over the next four years and inflation falls by 0.2-0.6%. This suggests that the U.S. interest rate policy may not have a serious adverse impact on the economy of Cambodia.

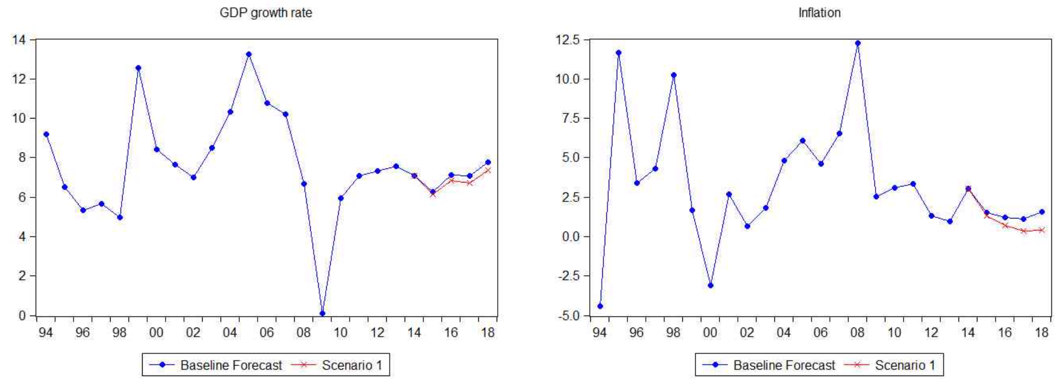
<Figure 5-9> Forecasts for a 1% Rise in U.S. Real Interest Rate over 2015-2018



Note : See the notes in <Figure 5-7>

Finally, we analyzed possible effects of a change in the Cambodian real exchange rate on future economic growth and inflation. <Figure 5-10> shows these results.

<Figure 5-10> Forecasts for an 1% Increase in the Real Exchange Rate over 2015-2018



Note : See the notes in <Figure 5-7>

A depreciation in the real exchange rate can be regarded typically as a positive aggregate demand shock. However, this interpretation may not hold if a country is dollarized like Cambodia. The depreciation means a stronger U.S. dollar, and this can erode the competitiveness of Cambodian exports in the world market. A tourist trip to Cambodia becomes more expensive, further weakening aggregate demand. The economic growth rate and inflation are expected to fall by about 0.2% and 0.7%, respectively. The results also suggests a message for the modeling perspective. What emerges is that if a country under study is dollarized, it is important to take explicit account of dollarization for accurate inferences.

The results in this section argue strongly for the usefulness of the empirical medium-scale open-economy model built upon solid theoretical predictions. However, there are many assumptions used in the model, and the analysis is limited to the case where monetary policy is independent and expected inflation is explicitly accounted for. Accordingly, the results can differ if the underlying assumptions change. As a final cautionary note, the monetary policy authorities may refer to the results of this study, but it would be more desirable to develop a refined model that reflects more of the features in the Cambodian economy with a more realistic scenario.

VI. Conclusion

This report is intended to provide the National Bank of Cambodia with macro-economic models that can be used to forecast the economic growth rate and inflation, and to devise effective policies in response to changes in the economic situations. Cambodia has been transforming to a market-orientated economy, and growing rapidly at a rate of 7% per annum during the past two decades. Nevertheless, Cambodia has not industrialized fully yet and is still viewed as a less-developed country. However, it is believed that Cambodia will maintain its high growth performance for a considerable time. Judging from the Korean experience of economic development, Cambodia can reach a middle income country status through sustained economic growth in the coming decades. At an early stage of economic development, the government and the monetary authority should play key roles in planning and fostering industrialization. For this purpose, the government and the monetary authority must be equipped with the ability to make appropriate and timely economic policies that shift limited resources efficiently as the economy develops.

The models proposed in this report are expected to help the NBC to predict the future deployments of economic environment accurately. They are developed to reflect the Cambodian economy, and can be used to analyze the macroeconomic issues based on various feasible scenarios. In order to accomplish this goal, the first task of the joint research team with the NBC officials is to take in the situation of Cambodia during the past two decades. The largest industry of Cambodia is still agriculture although its share has been shifting to manufacturing industries such as clothing. The tourism industry is also growing gradually surrounding the Angkor Wat regions. The financial industry is generally underdeveloped, and the U.S. dollar is circulated as the official currency. Hence, the only possible monetary policy of the NBC is to regulate the market interest rates. Moreover, it is not clear how monetary policy operations are being transmitted through the real sectors of the economy. While many attempts have been made to circulate the Riel, the U.S. dollar is expected to remain the major currency in Cambodia for a long while. Dollarization is a double-edged monetary policy. On the one hand, dollarization impairs the effectiveness of the NBC as an independent monetary authority. On the other hand, thanks to the stability of the U.S. dollar as the international key currency, dollarization helps stabilize the domestic price level and smooth international transactions. It testifies to the benefits of dollarization that the price levels in Cambodia have been relatively stable compared to neighboring South-East Asian countries amid the global financial crisis originating from the U.S.

The Cambodian macro models are built to reflect as closely as possible the economic environment of Cambodia such as dollarization for the prevailing monetary policy. Theoretical consistency and practicality of the models are also carefully considered given the limited data availability. While an empirical analysis of macroeconomic issues practically requires the aggregate data at a quarterly frequency, Cambodia has only compiled aggregate data for the last twenty years only at an annual frequency. Therefore, the immediate advice for the NBC is to build the data collecting system. Despite the data limitation, it is meaningful from the theoretical perspective to build a fully-fledged DSGE model that can be employed for policy analyses when enough data are available. This project proposes a variant of the small open economy version of DSGE models with optimizing agents adapted to the Cambodian economy under dollarization. The model is calibrated to economies at a similar stage of development as Cambodia. Then quantitative analyses are conducted using the calibrated DSGE model for various scenarios regarding changes in the economic environment, especially the effects of foreign exogenous variables on the domestic inflation and the economic growth rate. One caveat in interpreting the results from these exercises is that they should be understood as "qualitative" guidance regarding how the Cambodian economy may respond to external shocks although the analyses are "quantitative". The reason is that the parameters of the model are not exactly calibrated based on Cambodian data due to their limited availability.

The Cambodian DSGE model is reduced to a simple textbook model with which the following three monetary policy regimes are introduced, respectively 1) complete dollarization, 2) incomplete dollarization, 3) independent monetary policy. Then the model is further classified into forward-looking or backward-looking models according to whether the inflation expectation is considered in estimating the real interest rates. In total, six different small-scale model specifications are considered and estimated to analyze the shot-run responses of the Cambodian economy to possible external shocks. These models are simple enough to be used as educational tools with which the NBC officials can get acquainted with the theoretical and empirical analyses of monetary policy experiments under various regimes. Nevertheless, these small-scale short-run models are also self contained in the sense that analyses using these models conform to the current situation in Cambodia. Specifically, the forward-looking model with the independent monetary policy regime displays the best fit to the Cambodian economy.

The medium-scale macro model is developed from the small-scale short-run models described above. This is closer to the full-fledged small open economy version of DSGE model mentioned above, but is more practical for macroeconomic analyses given the limited data availability. This is also the most preferred model of this report and is proposed to the NBC. The demand side components of the model economy such as private consumption, government expenditures, exports and imports are described to be consistent with the agents' optimizing behavior in Section III. The aggregate supply curves are derived explicitly for the short-run and long-run, respectively. The model is estimated with dummies for the periods of financial crises from Asia and the U.S. The estimated model performs well despite the short horizon of time-series data. Reflecting the lack of physical capital, investment is modeled explicitly to be affected by official development assistance from outside Cambodia, which indeed explains a significant fraction of the variations of investment.

It is already known from the previous analyses using small-scale models that complete dollarization is not consistent with the current situation in Cambodia.

Therefore this monetary policy regime is excluded, but only the incomplete dollarization and the independent monetary policy regimes are considered in analyses of the medium-scale models.

According to estimation using the medium-scale models Cambodian GDP is expected to grow at the rate of 7% for the subsequent three to four years, which is the average growth rate it has enjoyed in the last twenty years. These growth rate estimates of 7% are robust even for the short-run macro models under various scenarios. The medium-run and long-run forecasts of inflation using the short-run macro models are stable at 1~2% per year. These results can be interpreted that Cambodia benefits from the stable U.S. dollar to stabilize domestic inflation. It should be also noticed that the forecasts of inflation and GDP growth rates can be negatively affected by declines in ODA and real exchange rate, and an increase in the US interest rate. The results from the quantitative analyses on the adverse impact of these external factors generally accord with the theoretic predictions.

The macro models that this report proposes are believed to contribute to the NBC as useful frameworks to forecast the future economic situation of Cambodia, and plan an appropriate monetary policy accordingly. Compilation of aggregate data and complementation of the analysis algorithms will enrich the details of the models, and improve their ability as planning devices for the Cambodian economy.

Appendix

A. Logarithmic Linearization of Open-economy Macroeconomic Models Specialized for Cambodia in Chapter III

The models in Chapters IV and V are backward-looking, where they are already linearized and do not consider rational expectations explicitly. On the other hand, the model in Chapter III consists of economic agents' optimization behaviors, market clearing conditions, and exogenous stochastic processes. The model needs to be linearized to illustrate the local stability of equilibrium conditions in the steady state and dynamic properties in the vicinity of the steady state. Because the linearized model takes explicit account of rational expectations, solutions of the linear rational expectation model are needed to express it in a reduced-form model. Here, we fully present the linearized form discussed in Chapter III. As the empirical model considered in this report does not require solving the linearized model, we do not discuss the solution methods here, but refer interested readers to Sims (2002) and Cho and Moreno (2011) for details.

A1. Firm's Problem

A firm's production function for intermediate goods:

$$\hat{y}_t = \frac{y+\phi}{y}\left(\hat{\epsilon}_t + \alpha\left(\hat{k}_t - \hat{\mu}_{z,t}\right) + (1-\alpha)\hat{H}_t\right)$$

Firm's cost minimization condition for intermediate goods : $\hat{r}_t^k = \hat{w}_t + \hat{H}_t - \hat{k}_t$

Firm's marginal cost for intermediate goods: $\widehat{mc}_t = \alpha\hat{r}_t^k + (1-\alpha)\hat{w}_t - \hat{\varepsilon}_t$

Firm's Philips curve for intermediate goods:

$$\hat{\pi}_t = \frac{\beta}{1+\kappa_d\beta}E_t\hat{\pi}_{t+1} + \frac{\kappa_d}{1+\kappa_d\beta}\hat{\pi}_{t-1} + \frac{(1-\xi_d)(1-\beta\xi_d)}{\xi_d(1+\kappa_d\beta)}(\widehat{mc}_t + \hat{\lambda}_{d,t})$$

Firm's Phillips curve for imported consumer goods:

$$\hat{\pi}_t^{m,c} = \frac{\beta}{1+\kappa_{m,c}\beta} E_t \hat{\pi}_{t+1}^{m,c} + \frac{\kappa_{m,c}}{1+\kappa_{m,c}\beta} \hat{\pi}_{t-1}^{m,c} + \frac{(1-\xi_{m,c})(1-\beta\xi_{m,c})}{\xi_{m,c}(1+\kappa_{m,c}\beta)} \left(\widehat{mc}_t^{m,c} + \hat{\lambda}_t^{m,c}\right)$$

Firm's marginal utility for imported consumer goods: $\widehat{mc}_t^{m,c} = -\widehat{mc}_t^{x} - \hat{\gamma}_t^{x,*} - \hat{\gamma}_t^{mc,d}$

Firm's Philips curve for imported investment goods:

$$\hat{\pi}_t^{m,i} = \frac{\beta}{1+\kappa_{m,i}\beta} E_t \hat{\pi}_{t+1}^{m,i} + \frac{\kappa_{m,i}}{1+\kappa_{m,i}\beta} \hat{\pi}_{t-1}^{m,i} + \frac{(1-\xi_{m,i})(1-\beta\xi_{m,i})}{\xi_{m,i}(1+\kappa_{m,i}\beta)} \left(\widehat{mc}_t^{m,i} + \hat{\lambda}_t^{m,i}\right)$$

Firm's marginal utility for imported consumer goods: $\widehat{mc}_t^{m,i} = -\widehat{mc}_t^{x} - \hat{\gamma}_t^{x,*} - \hat{\gamma}_t^{mi,d}$

Firm's Phillips curve for export goods:

$$\hat{\pi}_t^{x} = \frac{\beta}{1+\kappa_x\beta} E_t \hat{\pi}_{t+1}^{x} + \frac{\kappa_x}{1+\kappa_x\beta} \hat{\pi}_{t-1}^{x} + \frac{(1-\beta\xi_x)(1-\xi_x)}{\xi_x(1+\kappa_x\beta)} \left(\widehat{mc}_t^{x} + \widehat{\lambda_{x,t}}\right)$$

Firm's marginal cost for export goods: $\widehat{mc}_t^{x} = \widehat{mc}_{t-1}^{x} + \hat{\pi}_t - \hat{\pi}_t^{x} - \triangle \hat{S}_t$

A2. Household's Problem

First order condition (F.O.C.) of consumption:

$$\hat{\lambda}_t + \hat{\gamma}_t^{cd} = \frac{h\beta\mu_z}{(\mu_z - h\beta)(\mu_z - h)} E_t \hat{c}_{t+1} - \frac{\mu_z^2 - h^2\beta}{(\mu_z - h\beta)(\mu_z - h)} \hat{c}_t + \frac{h\mu_z}{(\mu_z - h\beta)(\mu_z - h)} \hat{c}_{t-1} + \frac{h\beta\mu_z - h\mu_z}{(\mu_z - h\beta)(\mu_z - h)} \hat{\mu}_{z,t} + \frac{\mu_z - h\beta\rho_b}{(\mu_z - h\beta)(\mu_z - h)} \hat{b}_t$$

F.O.C of domestic bonds: $\hat{\lambda}_t = \hat{R}_t + E_t(\hat{\lambda}_{t+1} - \hat{\mu}_{z,t+1} - \hat{\pi}_{t+1})$

F.O.C. of capital utilization rate: $\hat{r}_t^k = \chi \hat{u}_t$

F.O.C. of real capital:

$$\hat{\chi}_t = (1-\delta)\beta\mu_z^{-1} E_t(\hat{\chi}_{t+1} - \hat{\mu}_{z,t+1}) + (1-(1-\delta)\beta\mu_z^{-1}) E_t(\hat{\lambda}_{t+1} - \hat{\mu}_{z,t+1} + \hat{r}_{t+1}^k)$$

F.O.C of investment:

$$\hat{\lambda}_t + \hat{\gamma}_t^{id} = \hat{\chi}_t + \hat{\mu}_t - \mu_z^2 S''(\hat{i}_t - \hat{i}_{t-1} + \hat{\mu}_{z,t}) + \beta\mu_z^2 S'' E_t(\hat{i}_{t+1} - \hat{i}_t + \hat{\mu}_{z,t+1})$$

Relationship between real capital and capital services: $\hat{k}_t = \hat{u}_t + \hat{\bar{k}}_{t-1} - \hat{\mu}_{z,t}$

Law of motion for real capital:

$$\hat{\bar{k}}_t = (1-\delta)\mu_z^{-1}(\hat{\bar{k}}_{t-1} - \hat{\mu}_{z,t}) + (1-(1-\delta)\mu_z^{-1})(\hat{\mu}_t + \hat{i}_t)$$

Modified uncovered interest parity (UIP) condition:

① Normal monetary policy case: $\hat{R}_t - \widehat{R_t^*} = E_t \triangle \hat{S}_{t+1} - \tilde{\phi}_a \hat{a}_t + \hat{\tilde{\phi}}_t$

② Pegged nominal exchange rate case: $\hat{R}_t - \widehat{R_t^*} = -\tilde{\phi}_a \hat{a}_t + \hat{\tilde{\phi}}_t$, $(E_t \triangle \hat{S}_{t+1} = 0)$

A3. Wage Setting

Wage Phillips curve :

$$\widehat{w_t} = \frac{\beta}{1+\beta} E_t \hat{w}_{t+1} + \frac{1}{1+\beta} \hat{w}_{t-1} - \iota_w \widehat{g_{w,t}} + \frac{\beta}{1+\beta} E_t \hat{\pi}^c_{t+1} - \frac{1+\beta\kappa_w}{1+\beta} \hat{\pi}^c_t + \frac{\kappa_w}{1+\beta} \hat{\pi}^c_{t-1} + \frac{\kappa_w}{1+\beta} \hat{\mu}_{z,t-1} - \frac{1+\beta\kappa_w - \rho_{\mu_z}\beta}{1+\beta} \hat{\mu}_{z,t} + \iota_w \hat{\lambda}_{w,t}$$

Definition of wage mark-up : $\hat{g}_{w,t} = \hat{w}_t - (\nu \hat{H}_t + \hat{b}_t - \hat{\lambda}_t - \hat{\gamma}^{cd}_t)$

A4. Monetary Policy

Normal monetary policy (Taylor Rule):

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1-\rho_R)(r_\pi \widehat{\pi^c_t} + r_y \hat{y}_t + r_x \hat{x}_t) + r_{\triangle_\pi} \triangle \pi^c_t + r_{\triangle_y} \triangle y_t + \varepsilon_{R,t}$$

Monetary policy under dollarization (pegged nominal exchange rate):

$$E_t \triangle S_{t+1} = 0$$

A5. Relative Price and Definitions

Relative prices of imported and domestic consumer goods: $\hat{\gamma}^{mc,d}_t = \hat{\gamma}^{mc,d}_{t-1} + \hat{\pi}^{m,c}_t - \hat{\pi}_t$

Relative price of imported and domestic investment goods:

$$\hat{\gamma}^{mi,d}_t = \hat{\gamma}^{mi,d}_{t-1} + \hat{\pi}^{m,i}_t - \hat{\pi}_t$$

Relative prices of export and foreign goods: $\hat{\gamma}^{x,*}_t = \hat{\gamma}^{x,*}_{t-1} + \hat{\pi}^x_t - \hat{\pi}^*_t$

Relative prices of domestic and foreign goods : $\hat{\gamma}^f_t = \widehat{mc}^x_t + \hat{\gamma}^{x,*}_t$, where

$$\gamma^f_t \equiv \frac{P_t}{S_t P^*_t}$$

Relative price of consumer goods and domestic goods : $\hat{\gamma}^{c,d}_t = \omega_c (\gamma^{mc,c})^{1-\eta_c} \hat{\gamma}^{mc,d}_t$

Relative prices of investment goods and domestic goods : $\hat{\gamma}^{i,d}_t = \omega_i (\gamma^{mi,i})^{1-\eta_i} \hat{\gamma}^{mi,d}_t$

Inflation of consumer goods : $\hat{\pi}_t^c = \left((1-\omega_c)(\gamma^{d,c})^{1-\eta_c}\right)\hat{\pi}_t + \left(\omega_c(\gamma^{mc,c})^{1-\eta_c}\right)\hat{\pi}_t^{m,c}$

Real exchange rate : $\hat{x}_t = -\omega_c(\gamma^{c,mc})^{-(1-\eta_c)}\hat{\gamma}_t^{mc,d} - \hat{\gamma}_t^{x,*} - \widehat{mc}_t^x$

Real GDP : $\widehat{gdp}_t = \hat{y}_t - \frac{r^k k}{y}\hat{u}_t$

A6. Market Clearing Condition

Clearing condition of goods market :

$$(1-\omega_c)(\gamma^{c,d})^{\eta_c}\frac{c}{y}\left(\hat{c}_t + \eta_c\hat{\gamma}_t^{c,d}\right) + (1-\omega_i)(\gamma^{i,d})^{\eta_i}\frac{i}{y}\left(\hat{i}_t + \eta_i\hat{\gamma}_t^{i,d}\right)$$
$$+\frac{y^*}{y}\left(\hat{y}_t^* - \eta_f\hat{\gamma}_t^{x,*}\right) + \frac{r^k k}{y}\hat{u}_t = \frac{1}{g}(\hat{y}_t - \hat{g}_t)$$

Relation between foreign bonds and current account:

$$\hat{a}_t = -y^*\widehat{mc}_t^x - \eta_f y^*\hat{\gamma}_t^{x,*} + y^*\hat{y}_t^* + (c^m + i^m)\hat{\gamma}_t^f - c^m\left(-\eta_c(1-\omega_c)\left(\gamma^{c,d}\right)^{-(1-\eta_c)}\hat{\gamma}_t^{mc,d} + \hat{c}_t\right)$$
$$-i^m\left(-\eta_i(1-\omega_i)\left(\gamma^{i,d}\right)^{-(1-\eta_i)}\hat{\gamma}_t^{mi,d} + \hat{i}_t\right) + \frac{R}{\pi\mu_z}\hat{a}_{t-1}$$

A7. Exogenous Process

Permanent technology: $\hat{\mu}_{z,t} = \rho_{\mu_z}\hat{\mu}_{z,t-1} + \varepsilon_t^{\mu_z}$, $\quad \varepsilon_t^{\mu_z} \sim N(0,\, \sigma_{\mu_z}^2)$

Preference of consumption: $\hat{b}_t = \rho_b\hat{b}_{t-1} + \varepsilon_t^b$, $\quad \varepsilon_t^b \sim N(0,\, \sigma_b^2)$

Wage mark-up: $\hat{\lambda}_t^w = \rho_{\lambda_w}\hat{\lambda}_{t-1}^w + \varepsilon_t^{\lambda_w}$, $\quad \varepsilon_t^{\lambda^w} \sim N(0,\, \sigma_{\lambda^w}^2)$

Efficiency of investment: $\hat{\mu}_t = \rho_\mu\hat{\mu}_{t-1} + \varepsilon_t^\mu$, $\quad \varepsilon_t^\mu \sim N(0,\, \sigma_\mu^2)$

Government expenditure: $\hat{g}_t = \rho_g\hat{g}_{t-1} + \varepsilon_t^g$, $\quad \varepsilon_t^g \sim N(0,\, \sigma_g^2)$

Monetary policy: ε_t^R, $\quad \varepsilon_t^R \sim N(0,\, \sigma_R^2)$

Transitory technology: $\hat{\epsilon}_t = \rho_\epsilon\hat{\epsilon}_{t-1} + \varepsilon_t^\epsilon$, $\quad \varepsilon_t^\epsilon \sim N(0,\, \sigma_\epsilon^2)$

Domestic goods mark-up: $\hat{\lambda}_t^d = \rho_{\lambda_d}\hat{\lambda}_{t-1}^d + \varepsilon_t^{\lambda_d}$, $\quad \varepsilon_t^{\lambda^d} \sim N(0,\, \sigma_{\lambda^d}^2)$

Imported consumer goods mark-up: $\hat{\lambda}_t^{m,c} = \rho_{\lambda_{m,c}}\hat{\lambda}_{t-1}^{m,c} + \varepsilon_t^{\lambda_{m,c}}$, $\quad \varepsilon_t^{\lambda^{m,c}} \sim N(0,\, \sigma_{\lambda^{m,c}}^2)$

Imported investment goods mark-up: $\hat{\lambda}_t^{m,i} = \rho_{\lambda_{m,i}} \hat{\lambda}_{t-1}^{m,i} + \varepsilon_t^{\lambda_{m,i}}, \quad \varepsilon_t^{\lambda^{m,i}} \sim N(0, \sigma_{\lambda^{m,i}}^2)$

Export goods mark-up: $\hat{\lambda}_t^x = \rho_{\lambda_x} \hat{\lambda}_{t-1}^x + \varepsilon_t^{\lambda_x}, \quad \varepsilon_t^{\lambda^x} \sim N(0, \sigma_{\lambda^x}^2)$

Risk premium of foreign bonds: $\hat{\tilde{\phi}}_t = \rho_{\tilde{\phi}} \hat{\tilde{\phi}}_{t-1} + \varepsilon_t^{\tilde{\phi}}, \quad \varepsilon_t^{\tilde{\phi}} \sim N(0, \sigma_{\tilde{\phi}}^2)$

Foreign output: $\hat{y}_t^* = \rho_{y^*} \hat{y}_{t-1}^* + \varepsilon_t^{y^*}, \quad \varepsilon_t^{y^*} \sim N(0, \sigma_{y^*}^2)$

Foreign inflation: $\hat{\pi}_t^* = \rho_{\pi^*} \hat{\pi}_{t-1}^* + \varepsilon_t^{\pi^*}, \quad \varepsilon_t^{\pi^*} \sim N(0, \sigma_{\pi^*}^2)$

Foreign interest rate: $\hat{R}_t^* = \rho_{R^*} \hat{R}_{t-1}^* + \varepsilon_t^{R^*}, \quad \varepsilon_t^{R^*} \sim N(0, \sigma_{R^*}^2)$

B. Derivation and Analysis of Equilibrium in the Backward-looking Linear Model in Chapter IV

Empirical analysis of the small-scale model in chapter IV and the medium-scale model in section V can be implemented conveniently by the Eviews program. Yet, it is important to understand the underlying structure pertaining to how the equilibrium is calculated and how the simulation proceeds. Here, we provide related information for the analysis of the backward-looking model in use. The backward-looking model rules out rational expectations, and even when the real interest rate is constructed using an expected inflation estimate, there is still no need to explicitly resolve expectations formation, as the real interest rate is used as data. The small-scale model in Chapter IV could be readily linearized. However, the model in chapter V exhibits complicated nonlinear relations, such as logs, log differences, and the sums of variables, as well as the variables themselves. In this case, linearization manipulation is required and Eviews has a facility of executing this linearization. The linear or linearized models can be expressed in the form of:

$$Ax_t = a + Bx_{t-1} + Cz_t + Du_t \qquad \text{(A2-1)}$$

where x_t, z_t, and u_t are $(n\times 1)$, $(m\times 1)$, and $(k\times 1)$ vectors containing endogeneous variables, exogenous variables, and structural shocks, respectively. a is a constant vector of dimension $(n\times 1)$. A, B, C, and D are matrices of dimension $(n\times n)$, $(n\times n)$, $(n\times m)$, and $(n\times k)$ that record the coefficients on endogenous variables at t, endogenous variables at t-1, exogenous variables at t, and structural stocks at t, respectively. Take an example of equations (16) - (19) in Model 3 of Chapter VI representing the independent monetary policy of $r_t = i_t - \pi_t$. This gives that $x_t = [y_t\ \pi_t\ i_t r_t]'$, $z_t = rer_t$ and $u_t = [v_t\ \eta_t\ \epsilon_t]'$.

In this model, the constant term is 0, as all the variables are defined as e gaps from their long-term averages. However, the medium-scale model in Chapter V includes a constant term, and the discussion below is proceeded with the presence of a constant term for the sake of generality. The coefficient matrices are defined as follows:

$$a = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} A = \begin{bmatrix} 1 & 0 & 0 & \beta_2 \\ 0 & 1 & 0 & 0 \\ -(1-\rho)\phi_y & -(1-\rho)\phi_\pi & 1 & 0 \\ 0 & 1 & -1 & 1 \end{bmatrix}$$

(A2-2)

$$B = \begin{bmatrix} \beta_1 & 0 & 0 & 0 \\ \lambda_1 & \lambda_2 & 0 & 0 \\ 0 & 0 & \rho & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}, \quad C = \begin{bmatrix} \beta_3 \\ 0 \\ (1-\rho)\phi_{rer} \\ 0 \end{bmatrix}, \quad D = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix}$$

Suppose that all equations apart from the identities can be estimated by the OLS (Ordinary Least Squares) method. Then, multiplying both sides of the estimated equation of (A2-1) by A^{-1} yields equation (A2-3):

$$x_t = \alpha + Fx_{t-1} + Gz_t + Hu_t \quad \text{(A2-3)}$$

where $\alpha = A^{-1}a$, $F = A^{-1}B$, $G = A^{-1}C$, and $H = A^{-1}D$. Equation (A2-3) represents the equilibrium of the model. To analyze short-term impulse responses, it is assumed that the exogenous variables do not change from their current values over the prediction period. Impulse response analysis shows how the endogenous variable x_t evolves over time, when one of the structural shocks u_t changes with the assumption that it does not affect the remaining structural shocks. Suppose that the endogenous and exogenous variables at t have a zero value. Then, the impulse response function can be written as:

$$x_{t+k} = F^k H u_t \quad \text{(A2-4)}$$

When there is a shock to u_t, x_t changes by Hu_t in the current period t. Since x_t changes F from the next period, its response at $t+k$ corresponds to equation (A2-4).

Finally, let us turn to the scenario analysis. The scenario analysis projects the path of the endogenous variable over time, when the exogenous variable z_t is assumed to have a different value from the present one in the future. For example, consider a scenario that the real exchange rate is set to rise in the future, $\tilde{z}_{t+k}$, $k=1,2,3,.....$ The future path of endogenous variables can be written as:

$$x_{t+k} = \alpha + Fx_{t+k-1} + G\tilde{z}_{t+k} \quad \text{(A2-5)}$$

x_{t+k-1} is calculated sequentially from the initial point of $k=1$, and x_{t+k} will follow the form of equation (A2-5). This procedure has been used for the scenario analysis in Chapter V.

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