Real Business Cycles in Small Emerging Economies: The Role of Financial Frictions and Dollarization

By

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Abstract

The objective of this thesis is to explain and empirically evaluate real business cycle (RBC) models in small and emerging economies. The focus of the thesis is to explore the role of financial sector in propagation and amplification of real business cycle in these economies. This objective is achieved through self-contained chapters (chapter 2-6) where one or more forms of financial features of interest are incorporated. The thesis makes theoretical and empirical contribution to real business cycle literature on small and emerging economies through methodological innovation used to incorporate financial features and empirical estimation of the models using Bayesian framework. The theoretical and empirical work is directed at the establishment of real business cycle properties and processes of the Maldives.

As of my knowledge, there are no empirical studies done to document and explain business cycle in the Maldives. One of the reasons for lack of studies are due to scarcity of relevant data. A small but growing literature is emerging in relation to exchange rate regime and the effect of exchange rate on domestic prices. However, to fully understand the impact of exchange rate in a dollarized economy like the Maldives, an appropriate general equilibrium framework with exchange rate is needed. This thesis therefore contributes to such a framework. Furthermore, using Chapter 3, I have addressed the gap in data availability and quality by comparing a database developed using archives with the secondary sources.

The literature studying role of financial friction and dollarization in the propagation and amplification of business cycle through RBC framework is a growing area. Empirical work incorporating liability dollarization using RBC framework, however, is scarce. The overall result from thesis is summarised as follows: Maldivian business cycle follows the predictions from the literature; dollarization, real exchange rate and risk premium are the main drivers of business cycles and can explain stylised facts observed for some key macroeconomic variables.

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Chapter 1: Introduction

"All models are wrong, but some of them are useful" – George Box

The small and open economy real business cycle (RBC) research agenda has shed light into the financial fragilities' that exist in these economies and their role in driving business cycle. The nature of those financial weaknesses differs among countries based on structural characteristics such as participation in international financial markets, sectoral representation, and the degree of dollarization. The literature also shows that small and emerging economies experience a path to recovery which is different from that of developed economies due to the issues outlined above. At an aggregate level, one can establish the stylised facts on the small and emerging economies business cycle. However, the heterogeneity among the countries also requires models to consider country-specific characteristics for it to be useful for policy makers to understand the role of these factors in propagating and amplifying the business cycle in emerging economies.

This thesis is a collection of four essays aimed at explaining and evaluating the performance of the Real Business Cycle Models in small and emerging economies. The context of this thesis aims to study economies that are small and dollarized. More specifically, this thesis takes the Maldives as the benchmark economy due to its relevance to the context of this research. The constructions of the models used in this thesis take into account country-specific characteristics, and available data, to understand the propagation and transmission mechanism of shocks in the Maldives. In framing the thesis, I have also aimed to establish the extent to which classic RBC models are still valid to explain the business cycle in small and emerging economies compared with new-aged models.

The debate on classic vs new-aged RBC models is far from over. However, one of the consensuses that appears to have been reached in the literature is that for models to be useful, they need to factor in complexities observed in the market. Unlike developed economies, small and emerging economies experience several complexities in the financial markets which affects optimal decision making among all the economic agents. The new-aged RBC models, therefore, incorporate one or more of these complexities in the models such as risk premium, information asymmetry in financial intermediation process, or financial intermediaries' capital dynamics. The focus of these complexities is to establish whether there exists a feedback mechanism between the financial sector, and real variables such as output, and employment, following exogenous disturbances in the economy.

This thesis makes several contributions to small and emerging economies real business cycle literature through its four chapters. First, this thesis aims to study the business cycle properties of the Maldives by estimating empirical moments and evaluation of the performance of the models by taking the model to data. There have been no macroeconomic studies done on the Maldives using neoclassical growth theory. The data that is available on the Maldives, especially prior to 1995, are also limited and often incomplete. The contextualisation of the models to the Maldives, and the collation of secondary data that is relevant to the Maldives for necessary calibration, estimation, and analysis is a key contribution both in terms of validating the existing data and establishment of stylised facts for the Maldives. I started this thesis on the premise that dollarization and financial friction can explain economic fluctuations in the Maldives. The development of a real dollarization model, using RBC framework and validating this belief makes another contribution to the literature. The subsequent paragraphs will summarise each chapter and its key contribution to the literature.

Chapter 2 provides a brief overview of relevant literature on the real business cycle. The work of Rebelo (2005) and Binbin (2009) brings together the literature on RBC and opens research questions relevant to the published period. Since the publication of the above work, post financial crisis of 2008/2009, the RBC research agenda has moved significantly, exploring the role of various financial market frictions, dollarization, and capital control. Chapter 2, therefore, contributed to the existing literature review on

RBC models by providing a succinct overview on new frontiers of research using the RBC models. Most RBC models are solved in closed form and executed using powerful software such as MATLAB to obtain moments and policy functions. The rationale behind the use of computer algorithm to solve and simulate the model is due to difficulty economist encounter in solving complex models by hand and to become more efficient while minimising any human error in calculations. This practice however keeps the approach through which computers ensures stability of the model and process used in generation of moments hidden in algorithm used by the economists. Therefore, to make principles through which the model is developed, solved, and simulated more transparent, the backbone of RBC model, also known as Ramsey Model or neoclassical growth model is solved by hand and simulated using excel. This contribution therefore makes modelling framework more visible and can contribute to teaching of macroeconomics at undergraduate and postgraduate level more accessible.

Chapter 3 looks at Maldivian business cycle using data. Figure 1.1 plots time series graphs for major macroeconomic aggregates of the Maldives (output, consumption, investment, and current account) available from International Financial Statistics (IFS), Penn World Tables (PWT) and Maldives Monetary Authority (MMA). As described in Chapter 3, and below, each of these databases uses their own approaches in data generation, extrapolation and treatments, the values reported differs between agencies. To ensure one can view the patterns in every series more clearly, IFS data are plotted using a secondary axis. The time series plots for output, consumption, investment, and current account to output ratio shows the differences in data available on the Maldives for these aggregates. Penn World Table (PWT) uses extrapolation based on data available from UN National Accounts Official Country Database. For this reason, as shown in Figure 1.1, PWT data are smoother than MMA and IFS data. The primary source used in constructing IFS data is statistics relevant Maldivian authorities shared with IMF[1]. These data are then transformed by IMF's Statistics Department to derive the IFS series. As shown in Figure 1.1, IFS data and MMA data a closely related except for magnitude due to data transformation used in generating IFS statistics.

[1] A summary on IFS approach can be obtained from https://data.imf.org/?sk=4c514d48-b6ba-49ed-8ab9-52b0c1a0179b

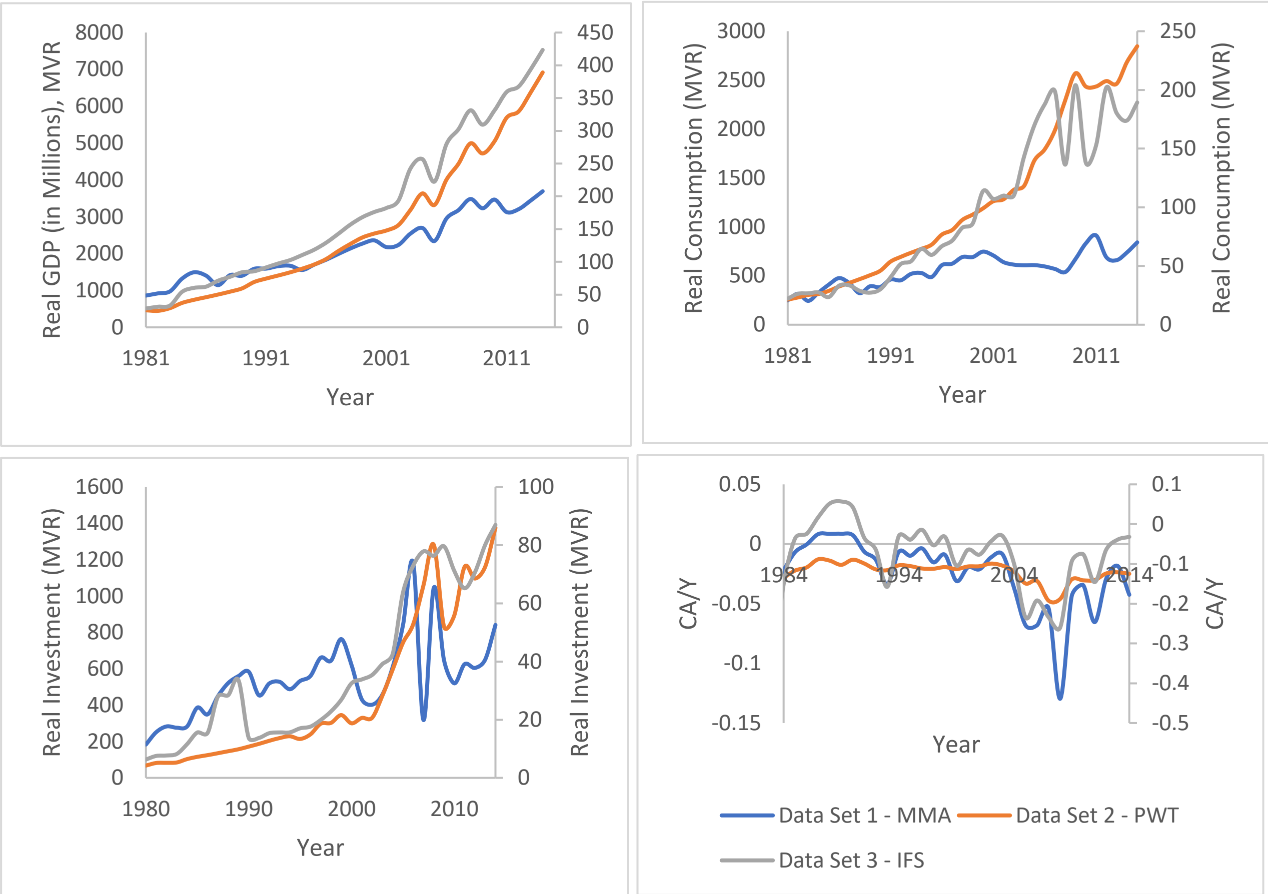


Figure 1.1: Time Series plots of select aggregates (1980-2014)

Source: Own constructions from data

The data presented in Figure 1.1 follows the time series pattern in these aggregates expected in emerging and small open economies where investment is much more volatile than consumption and output is less volatile than consumption. Furthermore, the current account to output ratio shows dramatic cyclicality which is unique to emerging and small open economies. It also shows that for external balances the data from MMA and IFS shows a higher volatility than PWT data.

The series on real GDP shows a smooth increase for PWT and IFS series. However, MMA series for GDP is less smooth. This is due to frequent updates in data collection and approximation by Maldivian authorities. An interesting observation on GDP series is that that following 2000 there has been larger cyclical fluctuation in GDP. The aggregates on consumption, investment and current account to output ratio also has become much more volatile since 2000. One of the main reasons for this observation is the insulated nature of Maldivian economy prior to 2000s. As tourism only started in 1972 in the Maldives, initial growth was slow yet progressive. The first time Maldives experienced over 50,000 tourist visits in a year is 1981. However, since then, there was a steady increase in tourism custom until 2000 making Maldivian economy more susceptible to foreign shocks. The first decade of the year 2000 saw unfolding of several events that disrupted tourism and international travel such as 9/11, Indian Ocean Tsunami, outbreak of SARS and global financial crisis. The impact these events had on tourist arrival to the Maldives is shown in Figure 1.2. A comparison of Figure 1.1 and Figure 1.2 shows remarkable similarities between pattern observed in tourist arrival and GDP series of the Maldives. The subsequent implication of tourism changes on consumption, investment and current account can also be inferred from the respective series.

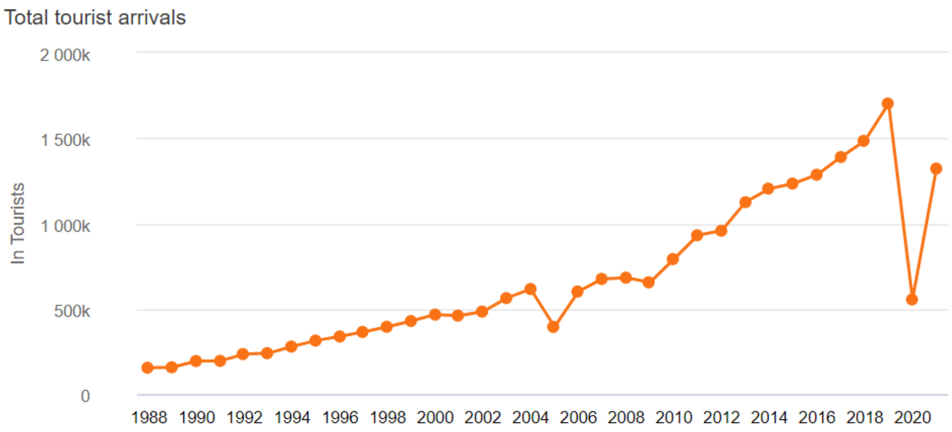


Figure 1.2: Number of Tourist arrival

Source: MMA (2022)

Chapter 3 outlines the business cycle properties of the Maldives based on data collected through the sources above. The stylised facts estimated are compared with stylised facts reported by Uribe and Schmitt-Grohe (2017) for small open economies to understand the extent to which Maldivian business cycle facts are similar to those of small and emerging economies. Furthermore, the Maldivian moments obtained were also compared with two of closest regional neighbours - India and Sri Lanka, to explore the behaviour of macroeconomic aggregates between these countries. Finally, a comparison between Maldivian estimates were made with Peru to establish the degree to which dollarized economies experience similar business cycle properties. Peru and the Maldives shares several similarities when it comes to dollarization and main export. For instance, Maldives deposit and loan dollarization between 1990-2015 stands at 50-60% while the loan dollarization for this period averaged over 50% (Adam 2016). Contreras et. al (2017) for 2001-2016 reported for Peru an average deposit and loan dollarization of over 50% despite the de-dollarisation initiatives. In addition, both the economies derive its main exports from nature where Peru focuses on agriculture and mining while the Maldives export is based on tourism. Furthermore, in terms of GDP per capita, both economies have a comparable values. For these reasons, it appears appropriate to benchmark Maldives results with Peru to understand how similar countries business cycle properties are when the profile of dollarization is similar. During this process, I have made several contributions to the literature. The first contribution is development of a data set using existing archives and records kept by the Maldivian Central Bank to ensure a series of sufficient length is available. The data set is then validated by comparing the estimates computed from the data with those obtained from data held by the International Monetary Fund and Penn World Tables. The second contribution is the estimation of business cycle moments for the above countries using the Hamilton (2017) filter and Hodrick-Prescott filter (1981, 1997). The Hamilton filter has gained popularity in recent years due to its ability to overcome some of the criticisms of the Hodrick-Prescott Filter. To my knowledge, there has not been any effort made in RBC literature to compare moments generated by these two filters. The third contribution to the literature is to document the business cycle moments for the Maldives. This is a novel effort as no systematic real business cycle studies have been made on the Maldives. The results show that business cycle moments for the Maldives are consistent with the moments observed for small and emerging economies. The results also show that dollarized economies tend to share similar moments, suggesting that the macroeconomic characteristics of economies vary, based on structural characteristics. The exercise relating to different data sets shows sufficient variation in results, owing to different approaches used by data collection agencies in generating the data.

Chapter 4 provides the simplest possible real business cycle model using the Schmitt-Grohe and Uribe (2004) framework to explain the business cycle in the Maldives. The model allows for interest rate shock to compete with technology shock by defining interest rate as an exogeneous process. The theoretical estimated model, based on calibrated parameters, was then taken to data using the Bayesian estimation method. The estimated model was able to match the parameters observed in the literature. In terms of matching with the observed moments, both formal and informal estimation shows that the model can match the observed standard deviation for investment, hours, and capital. The standard deviation for output and external balances is overestimated. In terms of correlation of aggregates with the output, the estimated model was only able to match the observed value for investment, while the calibrated model fared slightly better. The Bayesian estimated moments also showed a higher degree of persistence in shock parameters, and was only able to match the persistence of external balances and investment with data. The variance decomposition shows that only 1% change in aggregates can be explained by interest rate. The main contribution of Chapter 4 to the literature is the estimation of a simple RBC model in the context of the Maldives. This is a novel task since, to my knowledge, there has not been any similar work undertaken with the Maldives. The results also contribute to the literature by validating conclusions around the inability of simple RBC models to fully capture empirical moments observed in data.

Chapter 5 aims to validate the existence of a financial accelerator framework by introducing a collateral constraint and debt-elastic interest rate premium indexed to domestic conditions. The motivation for this chapter arises from two fronts. First, Chapter 4 demonstrated that there is a negligible role which exogenous interest rate plays in driving the business cycle. It is also acknowledged in the literature, that the RBC framework which uses an exogeneous process to formulate interest rate, may cause part of the effect of interest rate shock to be subsumed into the technology shock. I have, therefore, tried to validate this by specifying the interest rate faced by domestic agents as a function of the macroeconomic state of a country, to determine the extent to which such a formulation improves the predictions. Second, the literature and investigation done on the Maldives highlights that risk premium is correlated with output. To systematically determine if this relationship can generate the business cycle, I have relied on financial friction framework. The main theoretical contribution from this chapter is, that the model developed combines the two established frameworks aimed to study the role of interest rate shock – Uribe and Yue (2006) and Neumeyer and Perri (2005). In doing so, a more complete theoretical model that captures the dynamics of intra-period loan market is developed. The calibration and estimation of the model is done to fit the Maldivian economy, making a further contribution from the Chapter. The result from the calibrated model shows that the evidence on the existence of a financial accelerator mechanism is weak. It further shows that when technology shock competes with interest rate shock and financial friction shock, the latter is not as influential as technology and interest rate shock. Technology shock continues to dominate business cycle moments observed in real variables. One normative observation, through a reduced model with no financial friction shock, shows that technology shock absorbs the effect of financial friction shock.

The final chapter is the last instalment in establishing the extent to which structural characteristics of the Maldivian economy explains the business cycle. To achieve this, the model used in Chapter 5 is modified to include liability dollarization. One of the main contributions of this Chapter, and thesis, is the development of the real dollarization model in the context of RBC models. Much of the work done on liability dollarization is within nominal models. I have, therefore, attempted to expand the frontier of RBC modelling by incorporating real dollarization. This model is calibrated and estimated using the Bayesian method to the Maldives. I have also compared the performance of the full model with a modified model with collateral constraint, as introduced in Chapter 5. The estimated results show that the model with liability dollarization explains some of the saliant features of the Maldivian economy. It also highlights the role of the real exchange rate in driving the business cycle of the Maldives.

The work produced as part of this thesis is far from perfect. However, it is also a significant step in understanding the causes of real business cycle fluctuations in a specific group of emerging and small open economies which exhibit one or more forms of dollarization. In developing this thesis, I have stayed true to the 'real' nature of the dynamic model. The aim of this thesis, as outlined at the start, is to understand the propagation and amplification mechanism following exogenous shocks, while evaluating the performance of the model through Bayesian estimation. The model developed, although it has several assumptions that restrict its full application to the real world, nevertheless has shed light on how the economy reacts to certain disturbances. Understanding such a mechanism aids with prudent long-term policymaking aimed at insulating the economy from collapse. There is still significant work that can be done in the context of these models to incorporate policy functions.

Chapter 2: EME Real Business Cycle Models: characteristics and evolution in RBC research agenda since 2000s

2.1 Introduction

This chapter introduces the real business methodology and its associated literature in the context of small and emerging open economy research agenda. I will first introduce the conceptual RBC framework to develop reader's understanding behind microeconomic foundations under pinning RBC models and present a closed form simple RBC model to demonstrate the mathematical techniques used to solve the model. This will be complemented by a simulation exercise using Excel to demonstrate the principles through which model's solutions and its policy function(s) become the vehicle to generate impulse response function which demonstrate the path economic variable takes following disturbances and how theoretical series for each endogenous variable are generated which form the basis for model moment comparison.

Following the exercise above, I will be presenting a succinct summary of the literature which contributed to the development of new waves of RBC models currently used to study EME business cycles. The remainder of this literature review will look at emerging and small open economy research agenda with the particular emphasis on new extensions to RBC models to study EMEs business cycle. While the thesis aims to specifically look at the role of financial market frictions and dollarization as the cause of real business cycle, to balance the view, alternative competing theories on causes on business cycle will be presented.

2.2 Simple RBC framework using Ramsey Model

This section presents a simple RBC model using the stochastic growth model or commonly known as a modified Ramsey Model. The model economy is assumed to have infinitely lived population who are identical. This assumption simplifies the model to a representative agent problem. The representative agents consume, saves the difference between their income and consumption by investing in physical capital and supply one unit of labour. The household discounts the future where $0 < \beta < 1$. The firm produce output using capital and labour using a constant return to scale production function. The firms are owned by the household. This representative agent model is similar to the model economy presented by Campbell (1994).

2.2.1 Model Specification

The model features preferences using a utility function subject to Constant Relative Risk Aversion (CRRA). The representative consumer aims to maximise lifetime utility where σ is relative risk aversion.

$$\max_{C_t} \qquad E_t \sum_{i=0}^{t} \beta^i \frac{C_{t+i}^{1-\sigma}}{1-\sigma} \qquad 2.1$$

Production function Y_t is given of the form $Y_t(A_t H_t^{1-\alpha})K_t^{\alpha}$ where A_t is technology, H_t is hours worked, and K_t is capital. The parameter α represent the relative share of capital and labour used in production. As labour supply is fixed, we set it as numeraire in which $H_t = 1$. Therefore, production function becomes:

$$Y_t = A_t K_t^{\alpha} \qquad 2.2$$

Capital evolves through the following motion:

$$K_{t+1} = (1-\delta)K_t + Y_t - C_t \qquad 2.3$$

In the capital accumulation equation in (2.3), δ is the depreciation rate for capital and C_t is the consumption. The expression states that capital stock in next period is a sum of total undepreciated capital and investment (total income minus expenditure). The gross return R_{t+1} on one period investment in capital is defined as

$$R_{t+1} = \alpha A_t K_t^{\alpha-1} + (1-\delta) \qquad 2.4$$

The expression in (2.4) shows that return on one period capital is marginal product of capital and undepreciated capital. As this is a stochastic growth model, the economy is subject to an exogenous shock process for technology (commonly referred as total factor productivity shock).

The technology follows an Autoregressive order of 1 AR(1) process as defined by

$$InA_t = \rho InA_{t-1} + \epsilon_t \qquad \epsilon_t\ (0,1), 0 \leq \rho \leq 1 \qquad 2.5$$

where ρ measures the persistence of technology shock.

2.2.2 Model Solution

The representative agents aim to maximise their utility by choosing the sequence $\{C_{t,}, K_{t},\}_{t=0}^{\infty}$ subject to their budget constraint in (2.3). Since the solution to the above problem will involve a series of non-linear difference equations arising from (2.1) and (2.2), to obtain a numerical solution all non-linearities must be eliminated. To achieve this one will need to use approximation techniques around steady state also known as perturbation. The two most common approaches are using linear quadratic approximation around steady state as introduced by Kyland and Prescott (1982) in their seminal work. Alternative approach introduced and popularised by Christiano (1988) and King, Plosser, and Rebelo (1987) is log-linear quadratic approximation. As noted by Campbell (1994), the latter can provide exact solutions in special cases and establishes a closer relationship between the model parameters with the underlying model.

The solution to the model will involve reducing non-linear equations to three log-linearised equations. The first is consumption which is a forward looking variable (jump variable) as its value will change immediately following the realisation of shock. Capital stock is also known as the state variable due to its value being pre-determined today by previous period values. The third equation will be the shock process. In the following section I will be solving this model in its closed form using perturbation and demonstrating the solution technique. Excel will be then used to generate model's response and associated impulse responses.

2.2.3 Maximisation problem and steady state

Representative consumer maximises (2.1) subject to (2.3) and (2.5). To solve the maximisation problem, I have set up a lagrangian problem in (2.6) whose first order conditions will determine the solutions to problem.

$$\mathcal{L} = \sum_{i=0}^{t} \beta^{t+i} \left[\frac{C_{t+i}^{1-\sigma}}{1-\sigma} - \lambda_t \big((1-\delta)K_t + A_t K_t^{\alpha} - C_t - K_{t+1} \big) \right] \qquad 2.6$$

The first order conditions relation to optimisation problem in (2.6) are:

$$\frac{\partial \mathcal{L}}{\partial C_t}: \beta^t C_t^{-\sigma} - \beta^t \lambda_t = 0 \;\rightarrow\; \lambda_t = C_t^{-\sigma} \quad 2.7$$

$$\frac{\partial \mathcal{L}}{\partial K_{t+1}}: \beta^t \lambda_t - E_t \beta^{t+1} \lambda_{t+1}\left(\alpha A_{t+1} K_{t+1}^{\alpha-1} + (1-\delta)\right) = 0$$

$$\rightarrow \lambda_t = \beta E_t \lambda_{t+1}\left(\alpha A_{t+1} K_{t+1}^{\alpha-1} + (1-\delta)\right) \quad 2.8$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_t}: (1-\delta)K_t + A_t K_t^{\alpha} - C_t = K_{t+1} \quad 2.9$$

Combining (2.6) and (2.7) we have the Euler equation which is expressed as:

$$C_t^{-\sigma} = \beta E_t C_{t+1}^{-\sigma}\left(\alpha A_{t+1} K_{t+1}^{\alpha-1} + (1-\delta)\right) \quad 2.10$$

The expression (2.5), (2.9) and (2.10) are the system of non-linear equations which will determine the solution to the representative consumer problem and determine the transition path following a one period shock to technology. The above problem is simple enough to solve for closed form solution via hand and one can draw the impulse responses either via hand or using excel.

The steady state of the model can be solved as follows. Taking steady state as where $K_{t-1} = K_t = K_{t+1} = K$, I can pin down the steady state consumption, output, capital as function of model parameters. Set technology at steady state $A = 1$, expression (2.10) can be used to pin down steady state capital.

$$C^{-\sigma} = \beta C^{-\sigma}(\alpha K^{\alpha-1} + (1-\delta))$$

$$K = \left(\frac{\frac{1}{\beta} - (1-\delta)}{\alpha}\right)^{1/(\alpha-1)} \quad 2.11$$

Steady state output will be given using production function in (2.2) as:

$$Y = K^{\alpha} \quad 2.12$$

Steady state consumption can be solved using (2.3) where

$$C = Y - \delta K \quad 2.13$$

I have assumed the time to be in annual terms. The calibration of the model is performed using parameters used in standard RBC literature where $\alpha = 0.67$; $\delta = 0.10$; $\sigma = 2.00, \rho = 0.80$; and β is caliberated to set steady state annual interest rate, $R = 0.05$. This therefore makes $\beta = \frac{1}{1+R} = 0.95$.

2.2.4 Solving the model

The discrete time optimisation, as shown above reduces the model to a system of non-linear three difference equations. Perturbation technique can be used to derive the approximate solution. This technique involves log-linearising the above system at some fixed point (the common approach is at steady state) which translate the non-linear system to a linear system of difference equation. This would allow one to derive the policy functions for each endogenous variable. Farmer (1999) proposed a method to solve the linearised system. Subsequently Hokari et. al. (2004), Sims (2017) and Bongers et. al (2020) has used this methodology to solve the model. The approach to solving the model in this section closely follow the numerical techniques used by Sims (2017). The excel simulation follows the approach used by Hokari et. al. (2004) and Bongers et. al (2020).

Using Taylor's theorem and for each variable X_i denoting $\hat{x}$ as the percentage deviation in steady state where $\widehat{x_t} = \frac{X_t - X}{X}$, expression (2.5), (2.9) and (2.10) can be linearised at steady state as

$$\widehat{a_t} = \rho \hat{a}_{t-1} + \epsilon_t \qquad 2.14$$

$$\widehat{c_t} = \hat{c}_{t+1} - \frac{\beta R}{\sigma} \hat{a}_{t+1} - \frac{\beta(\alpha-1)R}{\sigma} \hat{k}_{t+1} \qquad 2.15$$

$$\hat{k}_{t+1} = k^{\alpha-1} \hat{a}_t - \frac{\beta R}{\sigma} \hat{a}_{t+1} - \frac{c}{k} \hat{k}_t \qquad 2.16$$

Suppose $\mathbf{X_t}$ is a $(n+m) \times 1$ vector of variables expressed as percentage deviations from steady state where n is the number of jump variables and m is the number of state variables. In the above neoclassical growth model, $n = 1$ (consumption) and $m = 2$ (capital and technology). The linearised solutions above can be written in linear algebra notation where matrix **M** represent the coefficients from the closed form solution to the model in terms of model parameters accompanying each variable.

$$E_t \mathbf{X}_{t+1} = \mathbf{M} \mathbf{X}_t \qquad 2.17$$

The vectors containing the variables are portioned in which the vector $x_{1,t}$ is a $n \times 1$ vector comprising of jump variables while $x_{2,t}$ is a $m \times 1$ comprising of state variables. The arrangement in (2.17) will therefore take form of the following.

$$E_t \begin{bmatrix} x_{1,t+1} \\ n \times 1 \\ x_{2,t+1} \\ m \times 1 \end{bmatrix}_{(n+m)\times 1} = \underset{(n+m)\times(n+m)}{\mathbf{M}} \begin{bmatrix} x_{1,t} \\ n \times 1 \\ x_{2,t} \\ m \times 1 \end{bmatrix}_{(n+m)\times 1} \qquad 2.18$$

The dimension of each matrix is denoted below each matrix and vector. The expressions in (2.14), (2.15) and (2.16) when inserted to (2.18) will be as follows.

$$E_t \begin{bmatrix} \hat{c}_{t+1} \\ \hat{k}_{t+1} \\ \hat{a}_{t+1} \end{bmatrix} = \begin{bmatrix} 1 - \frac{\beta(\alpha-1)R}{\sigma}\frac{c}{k} & \frac{(\alpha-1)R}{\sigma} & \frac{\beta R(\rho + (\alpha-1)k^{\alpha-1}}{\sigma} \\ -\frac{c}{k} & -\frac{1}{\beta} & k^{\alpha-1} \\ 0 & 0 & \rho \end{bmatrix} \begin{bmatrix} \hat{c}_t \\ \hat{k}_t \\ \hat{a}_t \end{bmatrix}$$

I can arrive closed formed solution to **M** which demonstrate evolution of variables in the system given the initial values. While initial values for state variables are available, the starting values for jump variables are determined by imposing the stability condition for existence of a saddle point solution, also known as Blanchard and Khan (1980) condition. Blanchard and Khan (1980) condition require that the number of eigenvalues associated with **M** to be greater than one and must be equal to number of state variables (also known as explosive roots). Any eigenvalue less than one is a stable root.

The parameterisation applied in this model and its steady state values for expression (2.11)-(2.13) are shown in the table below. The parametrisation is based on common values obtain in RBC literature.

Parameters			
Beta	0.95	Sigma	2
Alpha	0.33	R	0.05
Delta	0.1		
Sigma_e	0.10		
Rho	0.80		

Steady state	***Initial***
Capital Stock	3.16
Consumption	1.15
Output	1.46
Investment	0.32
TFP	1

Table 2.1: Parameterisation and steady state of the model

Using the parameters and steady state values in Table 2.1, the numerical solutions associated with **M** is written as below.

$$\mathbf{M} = \begin{bmatrix} 1.0058 & -0.01675 & 0.01164 \\ -0.36252 & 1.05263 & 0.46252 \\ 0 & 0 & 0.8 \end{bmatrix}$$

Using the $|\mathbf{M} - \boldsymbol{\lambda}\mathbf{I}| = 0$ where λ and **I** are eigenvalues and an identity matric of order **M** I can arrive to the characteristics polynomial which will provide the eigenvalues associated with the matrix **M**. In this case, the eigenvalues are 0.80, 0.95 and 1.11 respectively. As there are two stable and one explosive eigenvalues, a saddle path stable solution exists for the above system. The eigenvalues determine the rate of convergence following a disturbance into the economy. In the model economy presented in this section, capital is the pre-determined variable and consumption is the jump variable. When a shock hits the economy the state variable (pre-determined) remains constant but jump variable will have a new saddle path trajectory defined as

$$\Delta\widehat{c_t} = \lambda_i\widehat{c_t} \qquad 2.19$$

Defining a matrix $\boldsymbol{\Gamma}$ which comprises eigen vectors associated with associated with **M**, and a diagonal matrix of eigenvalues $\boldsymbol{\Lambda}$ one can re-write (2.17 and 2.18) as

$$E_t\boldsymbol{\Gamma}^{-1}\mathbf{X}_{t+1} = \boldsymbol{\Gamma}\boldsymbol{\Lambda}\boldsymbol{\Gamma}^{-1}\mathbf{X}_t \qquad 2.20$$

consistent with Sims (2017) I define an auxiliary variable $\mathbf{Z_t}$ and re-write (2.20) as

$$\mathbf{Z_t} = \boldsymbol{\Gamma}^{-1}\mathbf{X}_t \qquad 2.21$$

Expression in (2.21) can be written as an AR(1) process using the notations in (2.20) and (2.21) as

$$E_t\mathbf{Z}_{t+1} = \boldsymbol{\Lambda}\mathbf{Z}_t \qquad 2.22$$

The partitioning described in (2.18) implies that (2.22) will take the form of

$$E_t\begin{bmatrix} Z_{1,t+1} \\ Z_{2,t+1} \end{bmatrix} = \begin{bmatrix} \Lambda_1 & 0 \\ 0 & \Lambda_2 \end{bmatrix}\begin{bmatrix} Z_{1,t} \\ Z_{2,t} \end{bmatrix}$$

Where $\mathbf{\Lambda}$ and $\mathbf{Z_t}$ are partitioned matrices comprise of two partitions. Λ_1 is the first partition which comprises stable eigenvalues (the case where in absolute value the eigenvalue is less than 1) in the form of a diagonal matrix. Λ_2 comprise of all unstable eigenvalues. As I have expressed the solution in (2.21) as an AR(1) process the partitions in diagonal coefficient matrix, $\mathbf{Z_t}$ evolves independently from each other. As the second partition belongs to explosive eigenvalues, to ensure transversality constraint is maintained, we need to set $Z_{2,t+1} = 0$ as $T \to \infty$.

In the context of this model, the inverse of the matrix of eigenvectors where columns are arranged based on the smallest eigenvalues are as follows.

$$\mathbf{\Gamma^{-1}} = \begin{bmatrix} 0 & 0 & 1 \\ 2.2243 & 0.3566 & 1.2905 \\ -2.2243 & 0.6439 & 0.8757 \end{bmatrix}$$

Components of the Z matrix is as follows:

$$Z_{1,t+1} = \begin{bmatrix} 0 \\ 2.2243 \end{bmatrix} \widehat{c_t} + \begin{bmatrix} 0 & 1 \\ 0.3566 & 1.2905 \end{bmatrix} \begin{bmatrix} \hat{k}_t \\ \hat{a}_t \end{bmatrix}$$

$$Z_{2,t+1} = -2.2243\widehat{c_t} + \begin{bmatrix} 0.6439 & 0.8757 \end{bmatrix} \begin{bmatrix} \hat{k}_t \\ \hat{a}_t \end{bmatrix}$$

The stability condition requires $Z_{2,t} = 0$ as its is associated with explosive eigenvalues. This implies that

$$\widehat{c_t} = \frac{1}{2.2243} \begin{bmatrix} 0.6439 & 0.8757 \end{bmatrix} \begin{bmatrix} \hat{k}_t \\ \hat{a}_t \end{bmatrix} \qquad 2.23$$

The formulation in (2.23) can be used to arrive the policy function where

$$\widehat{c_t} = 0.2895\hat{k} + 0.8757\hat{a}_t \qquad 2.24$$

Given the policy function in (2.24) and initial values of for $\hat{k}$, this provides the mechanism through which shocks to technology $\hat{a}_t$ will enter into the real economy through which the system will generate the impulse responses showing the transition path to steady state following realisation of shock.

The path for consumption can be worked from policy function in (2.24) by expanding on the linearisation used where each variable $\widehat{x_t} = \frac{X_t - X}{X}$. This process will define c_t as

$$C_t = 0.2895\frac{C}{K}k_t + 0.8757\frac{C}{A}a_t + 0.3168C \qquad 2.25$$

The value of consumption for each period in (2.25) can be used to pin down all other aggregate variables.

2.2.5 Excel Interface used in Solving the Model

The Excel interface used to solve the model and its associated matrix M as shown in Figure 2.1. The model is assumed to have a 1% shock to technology. Table 2.2 demonstrate the paths of each variable where C is coded in excel notations to represent policy function in (2.25) while Y, K and A follows the expression (2.2), (2.3) and (2.5). $\widehat{c_t}$, $\hat{k}_{t+1}$, $\widehat{a_t}$, and $\widehat{y_t}$ are respective log linearised expressions in (2.14)-(2.16).

The impulse responses following 1% shock to technology are shown in Figure 2.2.

Dynamic General Equilibrium model

Endogenous variables	*Change with respect to time*
Y: Output	Δĉ: Change in ĉ with respect to time
K: Capital stock	Δk̂: Change in k̂ with respect to time
C: Consumption	
I: Investment	

Deviations to the steady state
ĉ: Deviation of C to the steady state
k̂: Deviation of K to the steady state
â: Deviation of A to the steady state

Parameters			
Beta	0.95	Sigma	2
Alpha	0.33	R	0.05
Delta	0.1		
Sigma_e	0.10		
Rho	0.80		

Coefficents for path of C	
Term	**Coefficent**
$C/_{K}K_t$	0.2895
$C/_{A}A_t$	0.39
C	0.32

Steady state	*Initial*
Capital Stock	3.16
Consumption	1.15
Output	1.46
Investment	0.32
TFP	1

$$E_t\begin{bmatrix}\hat{c}_{t+1}\\ \hat{k}_{t+1}\\ \hat{a}_{t+1}\end{bmatrix} = \begin{bmatrix}1-\frac{\beta(\alpha-1)R}{\sigma}\frac{c}{k} & \frac{(\alpha-1)R}{\sigma} & \frac{\beta R(\rho+(\alpha-1)k^{\alpha-1}}{\sigma}\\ -\frac{c}{k} & -\frac{1}{\beta} & k^{\alpha-1}\\ 0 & 0 & \rho\end{bmatrix}\begin{bmatrix}\hat{c}_t\\ \hat{k}_t\\ \hat{a}_t\end{bmatrix}$$

Eigenvalues	*Initial*
λ_1	1.1106
λ_2	0.9476
λ_3	0.8000

Stability condition	
Modulus $(1+\lambda_1)$	2.1106
Modulus $(1+\lambda_2)$	1.9476
Modulus $(1+\lambda 3)$	1.8000

Coefficient of M Matrix for Eigenvalues	
m11	1.0058
m12	-0.01675
m13	0.011640152
m21	-0.3625
m22	1.0526
m23	0.4625
m31	0.0000
m32	0.0000
m33	0.8000

Figure 2.1: Excel Interface used in solving the Model

Time	A	C	K	Y	ĉ	$\hat{k}$	â	ŷ
0	**1.0000**	**1.15**	**3.16**	**1.46**	**0.00**	**0.00**	**0.00**	**0.00**
1	1.0100	1.1504	3.160860199	1.48	0.0039	0.000	0.010	0.010
2	1.0080	1.1505	3.170968498	1.48	0.0041	0.003	0.008	0.009
3	1.0064	1.1506	3.178528905	1.47	0.0041	0.006	0.006	0.008
4	1.0051	1.1506	3.184074396	1.47	0.0041	0.007	0.005	0.008
5	1.0041	1.1506	3.188032132	1.47	0.0041	0.009	0.004	0.007
6	1.0033	1.1505	3.190743756	1.47	0.004	0.009	0.003	0.006
7	1.0026	1.1504	3.192482003	1.47	0.0039	0.010	0.003	0.006
8	1.0021	1.1502	3.193464203	1.47	0.0038	0.010	0.002	0.005
9	1.0017	1.1501	3.193863228	1.47	0.0037	0.010	0.002	0.005
10	1.0013	1.1499	3.193816324	1.47	0.0035	0.010	0.001	0.005
11	1.0011	1.1498	3.193432234	1.47	0.0034	0.010	0.001	0.004
12	1.0009	1.1496	3.192796921	1.47	0.0032	0.010	0.001	0.004
13	1.0007	1.1494	3.191978157	1.47	0.0031	0.010	0.001	0.004
14	1.0005	1.1493	3.191029212	1.47	0.003	0.009	0.001	0.004
15	1.0004	1.1491	3.189991798	1.47	0.0028	0.009	0.000	0.003
16	1.0004	1.149	3.188898431	1.47	0.0027	0.009	0.000	0.003
17	1.0003	1.1488	3.187774318	1.47	0.0026	0.008	0.000	0.003
18	1.0002	1.1487	3.186638861	1.47	0.0024	0.008	0.000	0.003
19	1.0002	1.1485	3.185506866	1.47	0.0023	0.008	0.000	0.003
20	1.0001	1.1484	3.184389498	1.47	0.0022	0.007	0.000	0.003
21	1.0001	1.1483	3.183295051	1.47	0.0021	0.007	0.000	0.002
22	1.0001	1.1482	3.182229557	1.47	0.002	0.007	0.000	0.002
23	1.0001	1.148	3.181197269	1.47	0.0019	0.006	0.000	0.002
24	1.0001	1.1479	3.180201054	1.46	0.0018	0.006	0.000	0.002
25	1.0000	1.1478	3.179242697	1.46	0.0017	0.006	0.000	0.002
26	1.0000	1.1477	3.178323145	1.46	0.0016	0.005	0.000	0.002
27	1.0000	1.1476	3.177442701	1.46	0.0015	0.005	0.000	0.002
28	1.0000	1.1475	3.176601178	1.46	0.0014	0.005	0.000	0.002
29	1.0000	1.1475	3.175798022	1.46	0.0014	0.005	0.000	0.002
30	1.0000	1.1474	3.175032405	1.46	0.0013	0.004	0.000	0.001

Table 2.2: Path for all endogenous variables

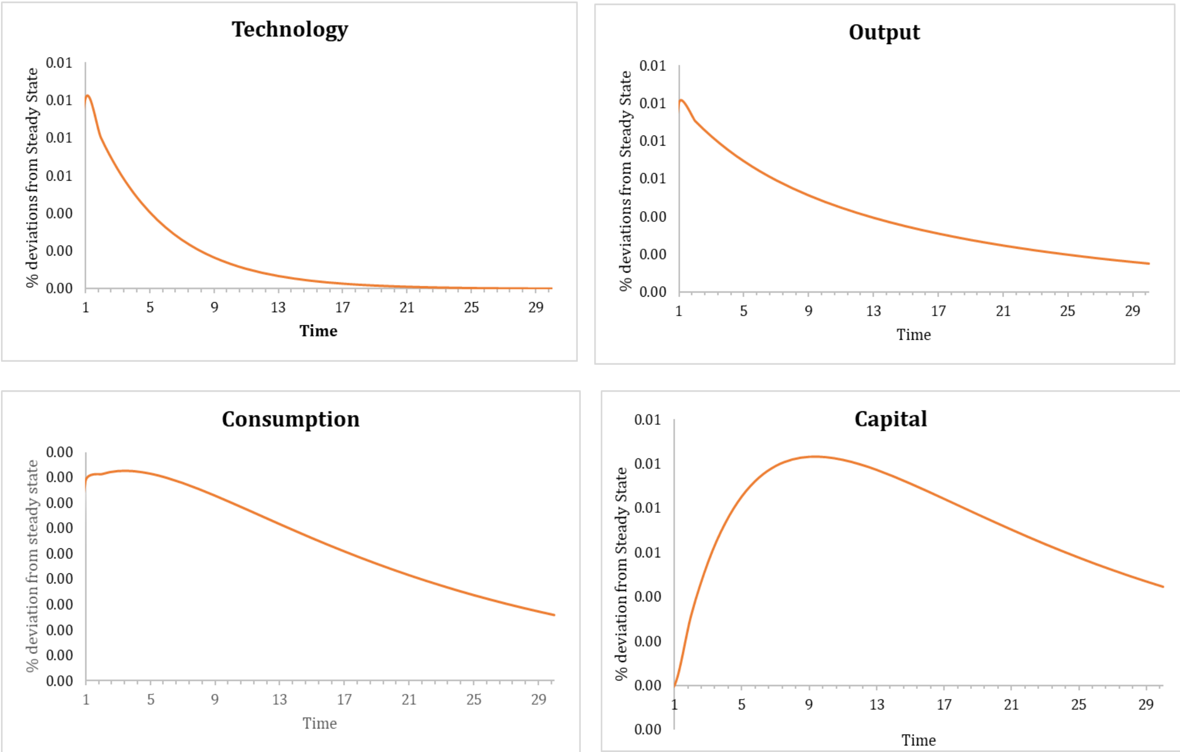


Figure 2.2 Impulse responses following 1% technology shock

The impulse response functions in Figure 2.2 shows that following 1% technology shock output increases (due to increase total factor productivity) and consumption increases. This can be traced from expression 2.3. Capital as it is predetermined, does not increase in the period on which shock hits the economy. However, in subsequent periods, due to increase in marginal productivity of capital because of a positive technology shock firms hire more capital. Impulse responses for capital show a hump shape where it gradually increases till a peak and then starts to decay towards the steady state. Intuitively these movement conforms to theory and the greater attraction of real business cycle core modern economic forecasting through DSGE models are as a result of the tractable framework similar to above used in these models.

The following section will provide an overview on the evolution of real business cycle research paradigm following which I will be exploring in greater details the RBC theory in the context of small and emerging economy literature.

2.3 Evolution of RBC literature

The real business cycle theory was developed in phases. During the initial phase, the study involved documentation of output fluctuation in the United States. Following this, in the 1930s phase began to theorise the properties of the business cycles such as the length and amplitude. Much of these developments however faced several criticisms for its lack of economic underpinning and were seen to be inferior to Keynesian synthesis. Some of the notable work however included Frisch (1933) and Slutzky (1937) whose contribution are among the very few classical business literatures that is embedded in development of modern real business cycle theories. A very detailed summary on various developments that lead to emergence of the modern real business cycle theory can be found in Keyland and Prescott (1990). The Table 2.3 summarises the key developments that lead to emergence of the modern real business cycle theory that is part of this thesis. Due to the nature of this thesis being to study the emerging economy business cycle, I have kept the evolution of RBC theory as brief as possible.

Contributor(s)	Contribution
Burns and Mitchell (1946)	Following the work of Burns and Mitchell (1927), Burns and Mitchell (1946) defined business cycle and its measurement empirically. The central focus of the authors were to identify the turning points in cyclical fluctuations (peaks and throughs) using data and establish the relationship between different macroeconomic aggregates in terms of its co-movement and correlations. The pioneering work by Burns and Mitchell (1946) to this date has defined the background through which business cycle research agenda evolved in the following decades. Their methodology however was widely criticised. The most notable criticism comes from Koopmpans (1947) due lack of theoretical justification on variable selection in their empirical work and missing theorical consideration on how random disturbances generate fluctuation in economic variables which triggers cyclical patterns. Nevertheless, it was subsequently established in the literature the contribution by Burns and Mitchell (1946) provided a framework through business cycle facts are established and subsequently to use these facts to develop economic theories on causes and consequences of business cycle.
Solow (1956, 1957)	In 1956, Robert Solow, influenced by the empirical predictions by Kaldor's (1957)[2] developed a simple growth model which later became neoclassical growth model that laid foundations to develop modern RBC model which steered business cycle modelling away from Burns and Mitchell (1946). The work of Solow introduced neoclassical production function in which output is a function of capital

[2] Kaldor (1957) published stylised facts for US and UK economy which states that in the long run, one observes a fairly constant labour and capital share of national income, capital to output ratio and consumption and investment share of output.

	(K) and labour (L) and given technology (A) and take form of $Y = AF(K, L)$. The production function enables one to incorporate microeconomic foundations into aggregate macroeconomic models the model addressing one of criticism of Koopmpans (1947). In subsequent developments, Cass (1965) and Koopmans (1965), taking Frank Ramsey's seminal contributions from early 1900s extended Solow's model by explicitly modelling of consumer problem and endogenisation of saving. This model become the workhorse model for many macroeconomic applications including RBC and DSGE models.
Adelman and Adelman (1959)	Following the seminal work by Klein and Goldberger (1959) to study the US economy through a system of 25 difference equations, an important contribution on causes of business cycle is introduced by Adelman and Adelman (1959). The authors stressed tested Klein and Goldberger (1959) model by artificially generating macroeconomic series for the US economy and compared the statistical properties obtained from these series to stylised facts reported by Klein and Goldberger (1959). This is one of the earlier attempts made to match moments in business cycle setting. This exercise by Adelman and Adelman (1959) however did not lead to comparable results in terms of matching with stylised facts. Subsequent modification of Klein and Goldberger (1959) system by adding a random shocks uncorrelated shock a la Slutzky(1927) however enabled to generate a model whose statistical properties matched the stylised facts.
Muth (1961)	John Muth introduces rational expectation into agents' expectation. His work on rational expectation although is not novel, he demonstrated how rationality can be introduced to agent's expectation and incorporated into the dynamic models. Rational expectation became an important feature of RBC foundation and modification of rationality by introducing biases and imperfect information later became basis for extending RBC models.
Lucas (1976a)	In an influential article Lucas (1976a) concluded that fixed parameterised macro-econometric models used at the timing of the writing of the paper contradicts theory. While the neoclassical synthesis is based on microeconomic foundation, the dynamics derived for policy making is dictated from data through econometric estimation making theory to be applied loosely in forecasting and policy making. Lucas (1976) questioned this approach by pointing its failures whilst calling for dynamics of the models to be derived from the model itself. Once of the key strengthen of RBC models is that model dynamics are derived from the micro foundations that underpins the model. While data is used to parametrise such models, the validity of these parameterisation can be established by taking the model to data.
Lucas (1976b)	In Lucas (1976), he defined business cycle as 'recurrent fluctuations of output and employment about trend'. The emphasis on cyclical and trend component redirected

	business cycle studies away from Burns and Mitchell (1946) approach based on data. Following Adelman and Adelman (1959) approach, Lucas (1976) calls for development of a dynamic representative economy model in most literal sense which can closely match the behaviour of a benchmark economy in terms of its co-movements observed between different aggregates. The work by Lucas provided a theoretical framework to study business cycle in a general equilibrium setting. However, the work of Lucas (1976) included a number of unexplained issues. For instance, the agents demand function is not derived from representative consumer utility maximisation problem. A further issue that needed to be explored was on defining and operationalising of trend.
Hodrick and Prescott (1980)	Hodrick and Prescott (1980) developed a framework which defined trend and cyclical components for a given time series data to study co-movements of different macroeconomic aggregates.
Sargent (1981)	Prior to Sargent (1981), several important methodological advances such as Muth (1961) followed the tradition of using systems of equations to undertake empirical analysis involving estimation of parameters using data. As a result, empirical investigation and macroeconomic models are perceived to be two different fields which where empirical investigations are capable of deriving parameter values for preferences, technology, information structure and etc. Macroeconomic models on the other hands were able to specify how individual makes choices subject to their constraints without fully taking into account their relationship to observed data. Sargent (1981) proposed frameworks through which macroeconomic models can be parameterised to ensure the statistical properties of the model can replicate the serial correlation and cross-correlation patterns observed in macroeconomic data. This work by Sargent (1981) allowed different empirical knowledge from various branches of economics to be embedded to restrict business cycle models and study more precisely the cyclical disturbances.
Kydland and Prescott (1982)	The seminal work by Kyland and Prescott (1982) developed first RBC model with microeconomic foundations. The model combined neoclassical growth model with the rational expectation in a multi-period setting. In this model business cycle arises due to a transitory shock to technology as demonstrated in section 2.2 which results in a saddle path for all macroeconomic aggregates. The work steered business cycle studies to explain the moments (volatility and co-movement) of selected macroeconomic series. The model also features real variables and allowed deep parameter values derived from the empirical estimation to determine how agents make decisions in the presence of constraints.

Table 2.3: Summary of Key Literature Leading to Development of RBC Theory

Following the development of a tractable framework to account for business cycle, Kyland and Prescott (1990) built on the Lucas (1976) definition of business cycle and explain how various co-movements can be classified. These methodological advanced concluded the development of the core framework that is used to date in RBC theory. While not specified above, the work of Kyland and Prescott (1982) and further subsequent work were based on closed economy framework. Backus and Kehoe (1989) used the first principles from canonical business cycle model to investigate properties of International real business cycle by introducing international financial markets. Further extensions by Backus, Kehoe and Kydland (1992) lead to the developed the international real business cycle research agenda. In this dissertation, the term real business cycle (RBC) will be used to refer any of the above category of the models. The workhorse small open economy real business cycle models fall in to three different groups.

The first group of models are set in the background of complete and frictionless markets which enables for perfect consumption smoothing. These models are also known as stochastic growth model of RBC theory and some of the earliest work includes Brock and Mirman (1972). Under these categories of models', steady state depends on initial level of debt and current account is procyclical unless adjustment costs to investment or capital are introduced. The second group of models are built on stochastic growth models by relaxing complete financial market assumption. In these types of models' assets or bond markets are incomplete and cannot provide full insurance against income fluctuations. Another feature of these types of models are that the net foreign assets are non-state contingent. The most influential work under this category includes Mendoza (1991) and more recently Aguiar and Gopinath (2007). The first two groups of RBC models are subject to extensive criticism due to the dominant role assigned to technology shocks in generating business cycle and the measurement error in Solow 's residuals (See King and Rebelo (2000) for a detailed discussion). A more recent addition since the early 2000s is a third group of RBC models that introduces into incomplete markets framework various forms of market frictions such as risk premium, collateral constraint, default risk and dollarization.

This literature review aims to provide a succinct account of RBC literature on the second and third group of models by focusing its application to study business cycles in emerging and small open economies. In the next section, I will first document different characteristics of business cycle in emerging market economies. Following this, I will outline the modelling techniques and their detailed characteristics from literature to support the theoretical underpinning of the modelling frameworks used in this dissertation.

2.4 Characteristics of Emerging Market Economy Business Cycles

Emerging Market Economies (EMEs) business cycle fundamentals differs from those of developed economies in two main aspects. First, emerging market economies relies heavily on international financial market to meet its external financing requirement. The external finance dependency is complicated by 'original sin[3]' problem which exposes EMEs financial market to fluctuations in external interest rates and real exchange rate. Changes in external interest rate and real exchange rate therefore becomes important drivers of business cycle in these economies through their domestic financial markets. Secondly, EMEs also experience dramatic and infrequent reversals in their current account, commonly referred as 'sudden stops[4]'. Aguiar and Gopinath (2007) accounts sudden stop to be the result of frequent regime and policy changes relating to fiscal, monetary and trade by EME government. Calvo et. al (2004) states that the sudden stop is caused by lack of fiscal discipline by EMEs. The authors further noted that at the heart of 'sudden stop' episodes in EMEs are liability dollarization and large changes in real exchange rate which threatens the non-traded goods sector. The sudden stop phenomenon hence reduces the persistence of EMEs trade balance to output and one would expect behaviour of domestic absorption to significantly depart from what is observed for developed economies.

The two fundamental differences highlighted above between EMEs and developed economies have resulted differences in stylised facts between EMEs and developed

[3] Coined by Eichengreen, Hausmann and Panizza (2007) it is defined as the inability of emerging and small open economies to borrow in international financial market in its own currency.
[4] This term is coined by Dornbusch and Werner (1994) and Calvo (1998).

economies. Table 2.4 reproduces aggregate data reported by Uribe and Schmitt-Grohe (2017) for 120 countries for the period 1965-2010. The authors classified countries into emerging and developed economies based on PPP converted GDP per capita in US$.

Descriptive Statistics	Business Cycle in Emerging & Developed Economies (1965-2010, annual data)	
	Emerging Economies	Developed Economies
Standard Deviation		
σ_y	2.60	1.38
σ_i/σ_y	3.88	3.65
σ_c/σ_y	1.32	0.85
$\sigma_{\frac{TB}{y}}$	1.95	0.64
Correlation with y		
$\rho(c, y)$	0.78	0.78
$\rho(i, y)$	0.77	0.87
$\rho(tb, y)$	-0.56	-0.31
Serial Correlation		
$\rho(y_t, y_{t-1})$	0.80	0.85
$\rho(c_t, c_{t-1})$	0.74	0.76
$\rho(i_t, i_{t-1})$	0.71	0.82
$\rho(tb/y_t, tb/y_{t-1})$	0.70	0.71

Source: Reproduced from Uribe & Schmitt-Grohe (2017, p. 19)

Table 2.4: Business Cycle Stylised facts between EMEs and Developed economies

As shown in Table 2.4, between EMEs and developed economies the data moments for volatility, contemporaneous correlations and persistence differs significantly. These differences can be summarised in three distinct dimensions.

2.4.1 External interest rate is negatively correlated to output

EMEs dependence on international financial market to smooth their consumption exposes agents in these countries to interest rate risks that originates from this market. At the same time, economic instabilities such as episodes of sudden stop increases transection risks to international financial intermediaries. As a result, the financial intermediaries often demand a risk premium to compensate for the additional risk associated with transections. The world interested rate impact combined with risk premium required by international investors therefore plays a major role in EMEs business cycle compared with developed economies. Over a long horizon, the interest rate EMEs face have fluctuated affecting cost of borrowing. Uribe and Yue (2006) states that cost of borrowing EME faces in international financial markets plays a dominant role in generating cyclical fluctuations in these economies. Empirically several studies have established that interest rate is countercyclical and EMEs macroeconomic aggregates respond to both the level and volatility of interest rate (Neumeyer and Perri 2005; Uribe and Yue 2006; Mackowiak (2007); García-Cicco et al. 2010; Chang and Fernández 2013, Horvath (2018); Monacelli et. al, 2018, and Ryes-Heroles and Tenorio 2019).

Table 2.5 reproduces the summary data on volatility and contemporaneous correlation of interest with output for 13 different emerging countries and developed economies report in Table 2 and Table 3 of Horvath (2018).

Descriptive Statistics	Business Cycle in Emerging & Developed Economies 1996Q1–2015Q4	
	Emerging Economies	Developed Economies
Standard Deviation		
σ_r (Sample mean)	3.48	0.62
σ_r (Sample median)	2.30	0.61
σ_r/σ_y (Sample mean)	1.27	0.45
σ_r/σ_y (Sample mean)	0.89	0.47
Correlation with y		
$\rho(r, y)$ for sample mean	-0.35	0.08
$\rho(r, y)$ for sample median	-0.35	0.09

Source: Compiled from Table 2 and Table 3 Data from Horvath (2018)

Table 2.5: Sample average business cycle moments for real interest rate

Table 2.5 demonstrate that real interest rate is highly volatile owing to fluctuation in risk spread for emerging economies compared to developed economies. It further documents the negative correlation between real interest rate with out for emerging economies. The volatility of interest rate appears to fluctuate significantly between emerging economies owing to start differences in country characteristics. For instance countries which have had significant economic turbulence since 2000s such as Argentina, Ecuador and Venezuela has significantly larger volatility of interest rate which contributes to the difference between the mean and median value reported for EMEs.

2.4.2 Moments of trade balance to output ratio

Due to the nature of emerging market economies current account, Garcia et. al (2010) establishes that EME trade balance to output has several distinct properties. First, the autocorrelation function is sharply downward sloping and declines monotonically to zero at 4th or 5th order. Second, EMEs exhibit strong counter cyclicality between trade balance and output compared with developed economies and lag the cycle. For instance, as shown in Table 2.4 the contemporaneous correlation between trade balance and output is -0.56 for EMEs while for developed economies it is -0.31. For the sample of countries included in Table 2.5, Horvath (2018) finds that the mean correlation between the trade balance to output ratio and output is -0.26 in emerging economies and -0.06 in developed countries. The downward sloping autocorrelation function for trade balance to output ratio is accounted for in the literature to the nature of the interest rate faced by EMEs. As described in 2.4.1, international financial intermediaries require a risk premium linked to domestic conditions of EMEs which creates a wedge between the interest rate faced by agents in EMEs and the risk-free rate. The extent to which the risk premium enters to domestic interest rate is governed by an elasticity parameter. In the literature this is often referred as debt elasticity parameter or financial friction parameter. As demonstrated in Uribe and Schmitt-Grohe (2017), without considering the nature of debt elastic risk premium EMEs face, external debt follows a highly persistent process which causes to trade balance to output results to contradict with the data. The risk premium and its associated parameter is therefore responsible for the moments in trade balance to output ratio observed above.

2.4.3 Second Moments of domestic absorption

The consensus in the literature is that while cyclical fluctuations of developed countries have become more stable since World War 2, for EMEs, pre and post war business cycle remains volatile owing to frequent policy and regime changes. Due to this, on average EMEs business cycles are twice as volatile compared to developed economies (Uribe and Schmitt-Grohe, 2017; Garcia et. al 2010; and Aguiar and Gopinath, 2007). In terms of behaviour of individual aggregates for domestic absorption variables - consumption and investment, significant departure is observed in its volatility compared with developed economies.

First, consumption is procyclical and more volatile than output. For over a century of data, Garcia et. al (2010) established that consumption is 2 percentage point more than the output for Argentina. For a sample of 11 EME for a period of 30 years, Uribe and Schmitt-Grohe' (2017) showed that consumption to output ratio is 13% more volatile in EME compared with the 17 developed country included in the sample. A much more striking results were obtained by Aguiar and Gopinath (2007) for a sample of 26 emerging and small developed economies where consumption is 40% more volatile than output. The main source of difference between these studies are due to the length of the period under consideration and the aggregation of countries. While Garcia et. al (2010) used over a century of data, the latter study only accounted data between 1980-2003 for an unbalanced panel. One of the reasons cited in literature for the excessive volatility of consumption in EME is due to its inability to smooth consumption overtime using international financial markets. Some of the reasons for this can be traced from sections above. For the sample of countries described above, Uribe and Schmitt-Grohe' (2017) shows that consumption smoothing increases with per capita income demonstrating that as EMEs develop the business cycle properties exhibit similar characteristics to develop economies.

In the international RBC literature, path of consumption is complex and are governed by labour supply choice and net foreign asset position. Correia et. al (1995) establishes that consumption share of output is dictated by trade-balance to output ratio and higher the net foreign asset position in emerging market, the higher the level of steady state consumption. This therefore makes modelling consumption and matching it to the data tricky as consumption and leisure choice of representative consumers and country's ability to trade in international financial markets significantly differ between EMEs. Therefore, the standard frameworks used in the literature may not be able to mirror the path for consumption as a result.

Second, gross investment is excessively volatile in EMEs. Garcia et. al (2010) shows that for Argentina, gross investment is four times more volatile than output. Stylised facts by Neumeyer and Perri (2005) shows that investment is 18% more volatile than output and for countries which are dollarized or has a history of dollarization such as Argentina, Mexico and Philippines, the overall volatility of investment is much larger than other EMEs. In a standard business cycle model, household consumption smoothing occurs through changes in investment and saving decisions where savings are equal to investment. However, in an open economy saving and investment can be separated with the differences between the two variables financed through current account providing a different path for consumption smoothing than observed in closed economies. As noted above, in emerging economies, consumption is very volatile, implying less consumption smoothing behaviour. For EMEs, Aguiar and Gopinath (2007) demonstrate that consumption approaches a random walk where in response to income shock there are less incentives for consumption smoothing by agents. As a result of this investment become more responsive to changes in income.

This section has outlined the differences observed in small and emerging economies business cycle and outlines causes of these differences based on existing studies. As highlighted above, where empirical results are concerned, there are significant differences in magnitudes owing to differences in models and data used as part of the estimation process. The following section will look at the different forms of methodologies used in literature to study business cycles in EMEs.

2.5 Approaches to modelling EME business cycle

RBC models used to study emerging market economies features an infinitely lived household, a representative firm which uses neoclassical production technology that is subject to exogenous productivity disturbances and a form of adjustment cost relating to either acquisition of capital, or investment. In these models, the representative agents have access to international credit market via a single period non-state contingent bond subject to a no-Ponzi-game condition. A dominant assumption made about international financial market is that while the credit market is perfect, it is incomplete. To ensure equilibrium dynamics are non-explosive and free from initial conditions, further assumption is imposed on either the rate of time preferences by the representative agents, cost of acquiring bonds or ad-hoc interest rate (Schmitt-Grohe and Uribe, 2003; and Arellano and Mendoza, 2002).

In the literature, the approach to model EME business cycle falls into two main strands. The first strand study business cycle solely using the neoclassical model where shock to total factor productivity generate cyclical fluctuations. In this strand of literature, the stochastic growth model by Aguiar and Gopinath (2007) and Kyland and Zarazaga (2007) provides a parsimonious framework for analysis. Both models do succeed in matching volatility of consumption and output but are unable to match the other aggregates moments with data without compromising the moments for consumptions and output.

The second strand of quantitative studies often uses the workhorse small open economy RBC model introduced by Mendoza (1991) to explain business cycle. In this second strand, through the canonical business cycle framework, the focus is placed on country specific frictions, exchange rate-based stabilisation and role of interest rate and its determinants as the driver of business cycle in emerging economies. These strands of literature make significant departure from neoclassical RBC paradigms. I will first briefly explain the former strand following which more detailed summary of second strand will be provided.

2.5.1 RBC models with trend shocks

In one of the most influential papers on EMEs business cycle Aguiar and Gopinath (2007) argued that due to nature of instability emerging and small open economies exhibit, the business cycle is not driven by transitory shocks to technology as proposed by Kyland and Prescott (1982), but rather due to a shock to the trend growth rate of technology. This conjecture is based on the decomposition of trend as measured by Solow residual where the random walk component of trend for EMEs appears to be much larger than EMEs. Furthermore, Aguiar and Gopinath (2007) emphasises that traditional approach to generating business cycle ignores that the representative agent observes the information on nature of the shock and optimises appropriately based on the type of shock country experience. This proposed theory generates interactions between consumption and investment depending on the nature of shock. For instance, a positive shock to trend implies larger increase in consumption compared to output as representative agents observe this shock to be yield larger increase in future output than present period. In the case of transitory shock, the temporary impact on output implies larger increase in investment than consumption. These changes will result in different current account dynamics.

There are several extensions to Aguiar and Gopinath (2007) since its publication. Botz et. al. (2011) extended the above model by introducing a learning problem to the setup through the introduction of a noise into representative agents' expectation. In their model, agents can distinguish between permanent and transitory components of TFP shock and are aware of the distribution of these components. However, as the agents are unable to observe the realisation of each component their expectations are formed based on imperfect information. The imperfect information is modelled through a noise in trend component of TFP. The noisiness of trend growth explains the differences in EME and developed economies business cycle.

Aguiar and Gopinath (2007) is successful in explaining saliant features of Mexican business cycle. The model's mechanism relies on decomposition of Solow's residual using Beveridge and Nelson (1981) approach. As noted by Botz et. al. (2011), this approach makes trend and cycle shock correlated and assign a higher importance to trend shock which drives the results in Aguiar and Gopinath (2007). Using an alternative decomposition which overcomes the issues outlined above, Botz et. al. (2011) were successful replicating the results by Aguiar and Gopinath (2007).

This strand of literature, while shows promise and relies on the formulation of RBC model closer to its original form, as noted in Aguiar and Gopinath (2007), the market imperfections and frictions that we observe in EMEs are not explicitly modelled. Instead, the emphasis of these classes of model are on instability of structural reforms EMEs experience that is linked political instabilities. This implies that market frictions are subsumed in trend shock and fails to demonstrate the interlinkages between markets especially how developments in international financial markets affects EME business cycles. As cited in Rothert (2020) the literature favours the models that relies on role of interest rate as drivers of business cycle than significantly large technology shocks a la Aguiar and Gopinath (2007). The rest of this literature review will therefore look at the role interest rate and financial market frictions plays in generating business in EMEs.

2.5.2 RBC models with Financial friction

Financial systems connect surplus unit (savers) with deficit unit (borrowers). In the context of RBC models, general assumption is that the representative households are the savers and these savings are then funnelled to the representative firms who invest in capital. Financial friction occurs when this transfer of funds between savers and borrowers are interrupted due to some form of complexities that arises within the financial intermediation process. These 'complexities' are referred as frictions. There are multiple approaches taken in the literature to incorporate financial friction into business cycle models. The overall distinction lies with the approach used in departing from neoclassical RBC paradigm. The first approach modifies the RBC to accommodate financial friction while the second approach converts the RBC model into a monetary model. The latter combines real elements with nominal frictions such as sticky prices and monopolistic competition.

In a real model set-up, financial friction can be included either using microeconomic foundations (for instance as shown in Uribe and Yue (2006)) or by modifying real interest rate faced by domestic agents to include a measure of friction in international capital markets (as shown in Horvath (2018)). In models with micro foundation, financial frictions are introduced either to the side of representative agents or to the side of financial intermediaries such as banks. The approach used will determine whether the impact of financial market frictions originates from credit channels (via financial intermediaries) or balance sheet channels (via representative agent's budget constraint). This section outlines theoretical underpinning used to develop microeconomic foundations of balance sheet channels.

The microeconomic foundation behind financial friction is commonly modelled through two main frameworks. The first framework is known as 'costly state verification' introduced by Townsend (1979) and further popularised by and Bernanke, Gertler, and Gilchrist (1999), Carlstrom and Fuerst (1997), and Bernanke and Gertler (1989). The cause of costly state verification is asymmetric information where lenders are unable to verify the credit worthiness of the borrower. The lender must pay a cost to verify the credit worthiness of borrowers resulting an optimal contracting problem. This cost is passed on by lender to borrowers which give rise to an external premium. The external finance premium is likely to increase with the level of debt raised by the representative agent. This therefore makes external financing more expensive, and firms are likely to rely on internal financing via their retained earnings or net worth. However, since the net worth of a firm is subject to fluctuations in asset prices, changes in asset prices will result in fluctuations in investments.

The second approach is known as 'costly enforcement' framework which originated from the work of Hart and Moore (1994) and introduced into macroeconomic models by Kiyotaki and Moore (1997). Under this setup, there is no asymmetric information.

However, there exists uncertainty on future states such as borrower reneging on the debt obligation. Both the lender and borrower will therefore aim to negotiate a contract in their favour resulting in an optimal contracting problem where the initial contract will be collateralised. As lenders are unable to determine the full value they can recover from the sales of collateral in an event on default, a borrowing constraint will be introduced where the borrowers can only borrow up to a fraction of the value of the collateralised asset. In this setting financial market shocks can be introduced by introducing a shock on borrowing constraint or can manifest organically through changes in asset prices. Both of these financial market shocks will impact the borrowing capacity and hence investment decisions by firms.

Between the two approaches, the collateral constraint framework is easier to model due to the financial market friction being reduced to a single constraint. In this thesis therefore I will only use costly enforcement framework to model financial friction. The scope of this literature review therefore will include the forms of financial frictions that are used as part of the thesis.

2.5.2.1 Financial Friction through borrowing constraint

Much of the earlier work on financial friction is based on three agent one good model with nominal rigidities. In terms of a pure real model, some of the most notable costly state verification models are developed by Jermann and Quadrini (2012), Quadrini (2011) and Kiyotaki and Moore (1997). The first tractable framework involving only household and firm was developed by Kiyotaki and Moore (1997) in which the following borrowing constraint was introduced:

$$\xi b_t \leq Q_{t+1} K_t \qquad 2.26$$

In expression (2.26), ξ is a fraction where $0 < \xi \leq 1$, b_t is the value of debt, Q_{t+1} is the price of the asset, and K_t is the size of the asset. $Q_{t+1}K_t$ is referred as net worth or total value of the asset. The implication of the borrowing constraint is that lenders are only willing to lend up to a fraction of the net worth. ξ represent the proportion of loan lender can successfully recover in case of a default by borrower. Such a specification assigns a dual role for durable asset such as capital – a factor of production as well as collateral. Hence, the borrowers credit limit is impacted by the changes in the value of the asset. Therefore, shocks that affect asset prices determines the degree of ease by which firm or household can borrow.

Following, Kiyotaki and Moore (1997) framework several notable RBC models have utilised this approach to study EME business cycle (Mendoza and Roja, 2019, Uribe and Yue, 2006). A notable feature of Kiyotaki and Moore (1997) formulation is as shown above is that the total value of collateral constraint depends on future realised equity price.

Much of the RBC literature associated with costly enforcement focuses on the demand side of the borrowing where either representative firm or consumer is subject to a borrowing constraint. Models that use costly enforcement uses financial accelerator mechanism to study RBC properties of emerging economies. The core transmission mechanism most collateral constrain based model uses is through a financial accelerator process (See Bernanke and Gertler (1989); Carlstrom and Fuerst (1997); Bernanke, Gertler, and Gilchrist (1999); Christiano, Motto, and Rostagno (2014); Carlstrom, Fuerst, and Paustian (2016). The financial accelerator arises due to durable goods such as capital take a dual role as explained above. As a result of this, when price of capital (asset) falls, the net worth of the borrower also falls which tightens the credit constraint that will impact other macroeconomic variables such as investment, employment, capital and output.

The collateral constraint framework used in much of the studies listed above are not necessarily real models due to use of nominal frictions. The real models which use collateral constraint includes Mandoza and Rojas (2020), Jermann and Quadrini (2011), and Uribe and Yue (2006). Jermann and Quadrini (2011) approach to modelling the collateral constraint differs from the above counterparts due to the introduction of a exogenous stochastic disturbances to ξ, referred as a financial shock. Under this formulation ξ follows an Autoregressive of Order one, AR(1) process. .

Various practices are used in the literature to introduce collateral constraint(s). For instance Uribe and Yue (2006) subject the working capital requirement from Neumeyer and Perri (2005) to a collateral constraint. The introduction of working capital itself is a form of friction. By subjecting the working capital firm can raise to a constraint, it drives a wedge between marginal product of labour and wages. Jermann and Quadrini (2011) introduces both working capital and investment capital financing constraint. While the working capital constraint draws a wedge between wages and marginal product of labour distorting equilibrium employment level, the latter shock will impact the equilibrium investment level as a wedge is developed between marginal product of capital and the price of capital. Mandoza and Rojas (2020) imposes the borrowing constraint on household borrowing driving a saving wedge. The quantitative prediction, irrespective of the sector on which constraint are placed remains broadly similar, with financial accelerator originating from the side of representative agent subject to this constraint.

2.5.2.2 Financial Friction through risk premium

A significant number of studies in the literature aims to capture financial friction by introducing a risk premium into the domestic interest rate. A body of early studies have empirically demonstrated that the country spread in emerging and developing countries influence the macroeconomic aggregates (Edwards, 1984; Cline, 1995; and Cline and Barnes,1997). Country spread can be defined as the difference between the interest rate facing the domestic economy and risk-free rate. More formally, this is also known as the risk premium.

In RBC literature, limited attempts were made to establish a microeconomic foundation to endogenies country spread. Fernández and Gulan (2015) developed a novel real business cycle model with financial market frictions where interest rate is fully endogenous. In this model instead rate spread is linked to corporate leverage. The model is able to match the strong counter cyclicality of interest rate by fluctuation in entrepreneurial net worth and the leverage levels. The leverage-net worth nexus can account for the endogenous country risk premium observed in data.

Unlike Fernández and Gulan (2015), most RBC models relies on agency frictions to introduce external risk premium as a proxy for country spread (Rotehrt, 2020; Fernández-Villaverde et. al 2011; Garcia et al 2009; Uribe and Yue (2006); Schmitt-Grohe and Uribe, 2004 and Neumeyer and Perri, 2005). While this is the current norm, earlier studies such as Mendoza (1991) and Schmitt-Grohe and Uribe (2003) introduced risk premium for technical purposes such as overcoming the non-stationarity problem in international RBC models.

In recent years, several studies have turned to develop theories to explain country spread in EMEs. While the use of risk premium as a measure of financial friction allow researchers to keep the model tractable, it does not provide a complete and transparent framework through which propagation mechanism associated with financial disturbances facing EMEs can be established. For this reason, studies in literature that incorporate risk premium into RBC models in recent times tend to include additional financial friction measures involving optimal contracting problem.

The pioneering work by Neumeyer and Perri (2005) introduced financial friction through labour market by introducing a working capital requirement on firms. Under this setup, due to labour market friction, representative firm must set aside total wage bill before starting production. The firm raises this fund through an interest bearing intraperiod loan. Since the interest rate facing domestic form is a function of risk free rate and risk premium, this formulation allows for fluctuation in risk premium to affect employment and output. The question that remains to answer is on the optimal approach to model the domestic interest rate with risk premium.

In the literature, domestic interest rate with risk premium is introduced using two approaches. The first approach introduces risk premium by defining interest rate as a function of risk-free rate and debt elastic risk premium that depends explicitly on country specific conditions. For instance, Schmitt-Grohe and Uribe (2004) specified interest rate as function of international risk-free rate and debt elastic interest rate premium as below.

$$r_t = r^{rf} + \psi\left(\frac{D_t}{Y_t} - \frac{D}{Y}\right) \qquad 2.27$$

In expression (2.27), r^{rf} is exogeneous world interest rate, $\frac{D_t}{Y_t} - \frac{D}{Y}$ is the excess level of debt from steady state debt level and ψ is the debt elasticity parameter which captures the degree of financial friction. This parameter determines the rate at which excessive borrowing risk enters into country interest rate.

The formulation for interest rate in (2.27) is the simplest mechanism through which one can establish a feedback mechanism between external trade balance, level of indebtedness and the risk premium. The debt elasticity parameter in (2.26) can curb the growth rate of domestic absorption which eliminates excessive volatility of trade balance to output ratio. Garcia et al (2010) estimated that when financial friction parameter is high, any fall in trade balance to output ratio below its steady state increases country's external debt which triggers a rise in risk premium leading to an increase in interest rate faced by domestic economy. This will transmit to the real economy by dampening the consumption and investment growth. Curtailing of domestic absorption therefore direct the path of trade balance to its long run trend. Findings by Fernandez-Villaverde et. al (2011) shows that the country spread is counter cyclical and lead the cycle with respect to output and domestic absorption.

The second approach to risk premium formulation does not explicitly model the theory of risk premium. Instead, the risk premium is assumed to follow an exogenous process. Such studies include Fernandez-Villaverde et. al (2011) and Neumeyer and Perri (2005). For instance, Fernandez-Villaverde et. al (2011) for Argentina, Ecuador, Venezuela, and Brazil used a stochastic volatility model to show that interest rate spread can be incorporated into RBC model introduced by Medoza (1991) by specifying an equation for motion for interest rate as follows:

$$r_t = r + \varepsilon_{tb,t} + \varepsilon_{rt} \qquad 2.28$$

In (2.28) the first argument r is the risk-free rate plus the mean of the country spread, $\varepsilon_{tb,t}$ is the deviation of international risk free rate from its long run average, and ε_{rt} is the country spread after deducting its long term average. Uribe and Yue (2006) follow a similar mechanism for interest rate formulation, driven from empirical estimation based on data on US interest rate and country specific interest rate of seven developing countries from 1994Q1 to 2004Q1. In contrast to this approach, Neumeyer and Perri (2005) defines interest rate spread through two exogenous processes involving country specify characteristics and exogenous characteristics but does not establish any correlation between interest rate a country observe with an international interest rate such as the US interest rate. All three strands of literature also incorporate working capital requirement where the former introducers borrowing constraint, but the letter abstain from enforcement friction.

The results from all three papers are similar with varying magnitudes. Neumeyer and Perri (2005) based on dynamic comparative analysis with and without risk premium concluded that inclusion of risk premium in interest rate increases output volatility by 24%. Uribe and Yue (2006) presented a break down of interest rate volatility on business cycle by components of the interest rate. They concluded that 20% of the movement in business cycle in emerging economies are due to variation in international interest rate while 12% of the movement in business cycle comes from risk premium.

Despite the similarities in result, for understanding of business cycle one need to ensure the results are as close to data as possible. According to Uribe and Yue (2006), based on seven countries data, approximately two-thirds of the variation in country spread is attributed to exogenous conditions while the remainder is associated with endogenous changes. They also established that the country spread respond to international interest rate movement with a lag where the initial response is much less than anticipated but soon the response picks up and overshoot (undershoot) the change observed for international interest rate. The dominant exogenous nature of interest rate premium should not be a surprise. This is due to contagion effect of certain international financial market events. For instance, Russia's default 1998 and also East Asian Crisis of 1997 saw countries which are not related to these nations experienced rise in interest rate due to contagion effect.

As outline above, due to the focus of this thesis, literature is scoped to draw evidence from relevant established studies conducted using RBC models. Many studies involving financial friction are done through Dynamic Stochastic General Equilibrium (DSGE) framework that encompass both RBC and New Keynesian theories. Due to the existence of RBC core in DSGE models, one would expect much of the predictions to be similar. For instance, Jermann and Quadrini (2011) extended the RBC model into a simple New Keynesian model and found that both qualitative and quantitative predictions remained the same.

2.5.2.3 Criticisms of collateral constraint models

Real business cycle studies with collateral constraint have concluded that in the presence of collateral constraint, EMEs are subject to self-fulfilling financial crises through overborrowing (Bianchi ,2011; Korinek, 2011; Jeanne and Korinek, 2010). According to Schmitt-Grohe and Uribe (2016) this is associated with a pecuniary externality in open economy models with collateral constraint that comes from two main sources. First, this externality arises due to price of collateral being endogenous to the model such as price of capital but being exogeneous to the agents. As a result of this, representative agents attempt to internalise this externality by overborrowing which put them into a peculiar debt position that triggers financial crises. Second, when the agents overborrow, the collateral constraint relaxes and becomes non-binding which results in multiple equilibria. The main reason for this externality as noted by Schmitt-Grohe and Uribe (2016) and Jeanne and Korinek (2010) is due to the presence of collateral constraint in a two good model where collateral constraint is indexed to traded good output that is assumed to be exogenous. Such issues can be avoided by assigning other forms of endogenous assets as collateral such as capital or use of carefully calibrated parameters for collateral constraint to avoid existence of multiple equilibria.

2.5.3 Financial Friction and Financial Dollarization in emerging economics

As noted earlier, emerging economies are subject to "original sin" – unable to borrow funds in international markets in their own currency. As a result, external financing is carried out in units of foreign currency that are then used to finance domestic expenditure in units of domestic currency. According to Bank for International Settlement (BIS, 2019), foreign currency liability as a percentage of total liability of commercial banks account for 40% in Latin American countries and 15% in Asia, Africa and Middle East. This process of acquiring foreign currency to finance domestic expenditure is referred as financial dollarization. In the last decade, literature on financial dollarization has grown using New Keynesian framework. On the other hand, the RBC literature on EME so far have to a large extent strayed from dollarization phenomenon and assumed all borrowing are carried in units of consumption good. One of the main reasons for this has been due to the need to move significantly away from RBC framework when incorporating dollarization. While the literature acknowledges financial dollarization as a form of capital market friction, the modelling of this phenomenon only started in recent years through RBC models.

Financial dollarization as defined by Basso, Calvo-Gonzalez, and Jurgilas (2007), Castillo, Montoro, and Tuesta (2013), Corrado (2008) and Ize and Parrado (2002), is the use of foreign currency to index assets, liabilities and other financial contracts. Financial dollarization can be further divided into asset and liability dollarization. Asset dollarization can be defined as the use of foreign currency to index deposits and other financial assets. Calvo (2001, p.312) coined the term liability dollarization and defined as "sizable dollar denominated debts". Since then, it has been further subdivided into external liability dollarization and domestic liability dollarization. The former measures the aggregate foreign liabilities of a country against rest of the world while the latter measures the public, banking and private sector domestic debt in foreign currency (Berkman and Cavallo, 2010; Ize and Levy-yayati, 2006). In order to incorporate dollarization into real business cycle model, dollarized assets and liabilities will need to be expressed in real terms. For instance, Notz and Rosenkranz (2021) used real exchange rate to convert the nominal dollarize debt into units of home goods. In addition to conversion of dollarization to real units, as dollarization represents international capital market frictions, it allows the transmission mechanism to be established either through balance sheet effect or credit channel effect.

Much of the EME research that incorporate dollarization focuses on liability dollarization and balance sheet effect for non-financial agents. When the representative agents borrow in units of foreign currency to finance the domestic expenditure, it results in a currency mismatch in their balance sheets. The presence of currency mismatch exposes representative agents to valuation effect. Kitano and Takau (2018) and Notz and Rosenkranz (2021), defines valuation effect as changes in net foreign asset position due to asset price or real exchange rate changes. The empirical work involving dollarization and valuation effect in EME has shown that such a model ameliorates the fit of the quantitative models against the fluctuation observed in data and combined with stochastic trends it can explain the business cycle in emerging market economies (Notz and Rosenkranz, 2021 and Castillo, Montoro, and Tuesta, 2013). In a study involving 28 emerging countries, Catão and Terrones (2016) finds that financial dollarization exhibit "hysteresis" – i.e. dollar denominated asset holdings rises during economic turbulences and fails to fall when the situation reverses. Furthermore, Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) demonstrates that balance sheet effects can provide a better fit for observed cyclicality in data According to Uribe and Schmitt-Grohe (2017) and Mendoza (1995), models which incorporate valuation effect through real exchange rate overcomes the excessive role terms of trade shocks and technology shocks plays in neoclassical models.

Kitano and Takau (2018) states that in the presence of liability dollarization, exchange rate behaviour can be influential in exacerbating the effect on small open economy business cycle. The liability dollarization model by Notz and Rosenkranz (2021) using Bayesian estimation, shows that for a sample of 3 emerging economics, they were able to match the model the moments better and capture the downward sloping autocorrelation function for net export to output ratio as shown by Garc´ıa-Cicco et al. (2010).

As described above, much of the modelling of liability dollarization is carried out through balance sheet channel of financial intermediaries (Kitano and Takau (2017); Choi and Cook, 2004; Gertler and Kiyotaki (2010) and Gertler and Karadi (2011)). A few studies have aimed to capture liability dollarization by private agents (Mendoza and Roja (2019); Schmitt-Grohe and Uribe (2018) and Notz and Rosenkranz (2021). Irrespective of the lens through which liability dollarization is studied, the common basis through which the model integrate effect of liability dollarization on SME is through the movement in real exchange using a dependent economy framework introduced by Salter (1959).

The dependent economy setup literature introduces a tradable and non-tradable sector into the canonical RBC model. In such economies, it allows for purchasing power parity to breakdown as non-traded good would not be able to establish law of one price due to certain factors such as transportation cost or trade barriers. As a corollary, the composite price index between countries would differ based on the non-traded good price differentials. Such a setup closely replicates what one would observe in data for small open economy. According to Mendoza (1995), the consequence of purchasing power parity assumption in RBC models with pure tradable goods is that it results in a near perfect correlation between consumption and output which contradict with empirical observations.

The deviation from parity conditions is exploited in such models by defining real exchange rate as a function of composite price index between home and rest of the world. Empirically, real exchange rate in emerging market has interesting properties. Notz and Rosenkranz (2021) using data for South Africa, Mexico and Turkey demonstrated that real exchange rate in these EME is more volatile compared to the developed countries comprising of Canada, Sweden and Switzerland. Furthermore, these authors also established that there is a strong relationship between net export and trade balance to output ratio for EMEs.

Most of the existing studies cited above uses a DSGE framework to model dollarization. In these models, liability dollarization is used to determine valuation effect or provide stabilisation policy recommendation in terms of exchange rates, capital control and interest rate rules. The focus on policy recommendation requires introduction of nominal rigidities. However, for better policy making one need to understand the causes and consequences of dollarization in real economy. This therefore calls for real models of dollarization to be developed. In terms of pure real models, there are two key papers - Mendoza and Roja (2019) and Schmitt-Grohe and Uribe (2018). The latter formally do not study the impact of liability dollarization while the former is a seminal work that establish a relationship between liability dollarization and sudden stop in EME in the context of non-institutional borrowers.

In addition to liability dollarization, models of this nature also include some form of financial friction. For instance, Mendoza and Roja (2019) introduces a collateral constraint on household debt where household can borrow up to a fraction its net worth expressed in terms of its income from traded and non-traded sector. Notz and Rosenkranz (2021) introduces debt elastic risk premium which alters the interest rate based on household's dollarized debt to output ratio against its steady state value. Schmitt-Grohe and Uribe (2018) follows a similar pursuit as the latter.

The introduction of liability dollarization as described above through real exchange rate channel can also establishes stronger relationship between real exchange rate and interest rate. For instance, when real exchange rate changes, it would affect the burden of repayment of outstanding debt due to either a rise or fall in interest payment because of transitory exchange rate effect. This would therefore have an impact on future borrowing and expectation of future asset prices and generate an endogenous response risk premium due to changes in debt level. These therefore align closely to what is observed in data and representative agents' behaviour.

2.6 Conclusion

This chapter covered the theoretical basis for this thesis concentrating the on the key literature used in real business cycle modelling in emerging market economics. Mendoza (1991) and Schmitt-Grohe and Uribe (2004) are the most commonly used frame works to develop the real business cycle models. Most theoretical and empirical work on EME literature has been trying to match empirical regularities through theoretical and estimated model.

This literature review has shed light on advances real business cycle studies have made in the past two decades to understand the cyclical properties of EMEs. This Chapter has brought together recent advances made in RBC research agenda in the context of EMEs. As evidenced in the literature review, the research direction has shifted to address some of the emerging economies specific characteristics such as financial frictions, sudden stop and liability dollarization.

On the latter two the available RBC literature is sparse. This thesis therefore aims to contribute to this literature by studying existing EME business cycle literature and make a natural progression in theoretical and empirical frame by exploring in the subsequent chapters the role of interest rate, risk premium, financial market frictions and finally, capital market friction through the dollarization phenomenon using a tractable model.

As the end goal of the thesis is determine the extent to which a model of liability dollarization is superior to other forms of frictions used in the RBC literature, the model need to be contextualised to fit to an economy that is dollarized. I have selected the Maldives as the country of choice as it has a highly dollarized economy with a large tourism sector. This therefore allows to fit dependent economy framework into the Maldives to study dollarization.

Chapter 3: Stylised Real Business Cycle Facts of Maldivian Economy

3.1 Introduction

In the seminal work of Kydland and Prescott (1982), one of the key achievements is the RBC model's ability to closely reproduce stylised facts observed in data. This exercise of moment matching looks at how closely theoretical moments of the model can replicate empirical moments obtained from data. In this spirit, a starting point prior to formulation of a business cycle model on the Maldives is to look at empirical moments from the data to establish parameter values for key calibrations and to establish standard moments against which model will be compared to judge the goodness of fit of the model to the Maldivian economy. The key empirical moments of interest for these are: first and second moment of data (mean and standard deviation), contemporaneous correlation of the series with output, and persistence of the series captured by autoregressive features of the aggregates.

The main aim of this chapter is to document key empirical regularities relating to real business cycle properties of the Maldives. The empirical features presented in this chapter will form the basis for calibration, estimation, and model comparison to gauge its goodness-of-fit of every model specification used in this thesis. This task is a novel initiative as no such academic work has been undertaken and published for the Maldivian economy until now. One of the reasons behind the lack of empirical studies on the Maldives is associated with the scarcity of data. While there are some reliable data sources, often the series are incomplete or too short. As part of this Chapter, I will be developing a database using hard copies found in the Maldivian Central Bank Repository[5]. I will also compare how this constructed database performs against data collected by the IMF and Penn World Tables.

The scarcity of empirical work on business cycles is shared by other neighbouring countries to the Maldives in South Asia. As to my knowledge, along with the Maldives

[5] I would like to thank Maldivian Monetary Authority (MMA) for sending me scanned copies of its Annual Reports from 1980s to 2000s which enabled me to extract the data needed to develop relevant series.

limited attempt, these have been done to establish business cycle regularities for many South Asian countries such as Sri Lanka and Bangladesh despite them being rapidly emerging economies. There is a growing literature on Indian economy which documents key characteristics using similar frameworks used in this thesis. Geographically, the closet neighbours of the Maldives are Sri Lanka and India with very strong economic and political ties. For this reason, a second objective of this this chapter is to establish the business cycle properties of some selected South Asian neighbours of the Maldives and compare their cyclical characteristics with the Maldives. To this end, I have selected Sri Lanka and India as countries of choice for the reasons outlined below. Like the Maldives, Sri Lanka, the closest neighbour in terms of proximity, is an island economy with significant economic similarities such as dollarization and a large booming service sector. Therefore, one would expect significant business cycle similarities to exist between these two countries. India is chosen due to the role India plays in the South Asian region as the dominant economy and its economic ties to the Maldives[6]. At the same time globally, India is one of the emerging economic powerhouses and therefore comparing business cycle characteristics between these two countries with the Maldives will provide useful insights into regional business cycle dynamics.

Countries in South Asia have had a major economic transition from the 1990s despite the persistence of large structural instabilities such as an underdeveloped financial sector, corruption, and civil war. For instance, Pandey et. al. (2018) states that the Indian economy experienced a major developmental turn from 1991 when sectoral share of agriculture in GDP declined rapidly to less than a third while services and manufacturing share dramatically increased. In Sri Lanka, following the end of the Civil War in 2009, a major economic transformation agenda led to a large influx of foreign direct investment and exponential growth in the services sector. According to Athukorala et. al. (2017) Sri Lanka's service and manufacturing share of output

[6] One of the largest shares of trade involves medicine imported from India and Sri Lanka where Maldivians travels to these countries to seek medical treatment. Suzana et al. (2018) reports that according to IMF Maldives has in the last 10 years spent $65 million per year on medical imports. This accounts to nearly a per cent of GDP.

remained at 62.2% and 29.2% respectively in 2015 while the agricultural share had drastically fallen from an average of 27.1% in 1980-1999 period to 8.2% in 2015.

Unlike the newly industrialised countries in the 1980s, such as the East Asian "tigers" and Brazil, the economic development model in South Asia has stark differences. According to Nabi (2010), South Asian region workers' remittance is the largest financial flow that has surpassed the investment flow in the region. One of the factors behind the sudden growth in the service sector in these economies is the large remittance flow leading to a boost in consumption. The two key fundamental characteristics of the South Asian economic growth model, which deviates from traditional growth models, comes from the rapid expansion of the service sector and consumption. For instance, India has established itself as a global power in software development with 60% of global software outsourcing (Nabi, 2010). Furthermore, in Sri Lanka, new economic growth is largely attributed to growth in service sectors relating to tourism and software exports (Athukorala et. al. 2017).

Maldives is a natural resource-poor economy, which has the characteristics of an enclaved economy with structural instabilities. Tourism is the largest contributor to the Maldivian economic growth and the main source of foreign currency. Globally, the Maldives is ranked in 71st position in terms of tourism receipt in 2019, and the sector contributed to 32.9% of GDP. The tourism sectors input comprises of leasing of islands to foreign tour operators, imported merchandise goods, and employment of foreign labour, which also subjects the economy to a large outflow through remittances and imports. According to the Maldivian National Bureau of Statistics (2019) total foreign employment in the tourism sector is estimated to be 53% in 2019 compared with 59% during the 2014 National Census. The latter survey's result, although looks optimistic, the response rate is less comprehensive compared with the National Census Survey.

One of the consequences of a lack of natural resources in the Maldives is over-reliance on the rest of the world for consumption and production. Together with the dominance of the tourism sector, this has made the Maldivian economy to be reliant on the US dollar as a medium for transactions with the rest of the world. The use of the US dollar as a main source of revenue and spending makes the Maldives heavily dollarized and susceptible to global economic shocks surrounding US economy and US dollar exchange rates. Within the South Asian region, along with the Maldives, Sri Lanka too is subject to heavy dollarization. Therefore, one can expect some degree of similarities between stylised facts reported on Maldives and Sri Lanka. To further explore the extent to which dollarized economies stylised business cycle properties are similar, I will also look at data on Peru. Peru, like the Maldives and Sri Lanka exhibit a very high degree of dollarization. Therefore, these economies may have similar business cycle characteristics compared with India. The objective of this exercises to compare similar countries. Indian economy may be an outlier in this sample due to its dominant position in the region and global economic landscape. Therefore, to draw some meaningful conclusions in the context of dollarized economies, Peru is included in the representative sample of economies focused in this chapter.

This chapter's contribution falls into three strands. The first strand involves collection and development of reliable databases for the Maldives on relevant macroeconomic series for the purpose of studying business cycle facts of the Maldives from 1977-2014. Within the national archives of the Maldives, there does not exist a long enough database due to different government Ministries being responsible for collection and production of economic data in different time periods. To fill this gap, I will be collating available data from different archives and the Central Bank of the Maldives to develop a single database. In order test the quality and reliability of this compiled database, I will look at data held by other secondary sources - International Monetary Fund and Penn World Table. Within the second strand, firstly, in this chapter I will document Maldivian business cycle characteristics, and secondly, I will compare business cycle properties of the Maldives with two key South Asian neighbours, to provide evidence of business cycle similarities between the countries in South Asia. The intra-country comparison exercise will be extended by comparing Maldivian stylised facts with Peru and Sri Lanka to gather an overview on the business cycle among dollarized economies. The third and final strand relates to the data filtration technique. Traditionally, business cycle studies have used the Hodrick–Prescott (HP)[7] filter to separate cycle and trend from time series data to compute the cyclical moment. While the HP filter is subject to several criticisms as shown in Section 3.2. In this chapter, along with HP filer, I will also an alternative filter proposed by Hamilton (2019), more commonly referred as Hamilton Filter. The purpose of using both the filter is due to increasing empirical recognition of this filter to be a superior filter for time series data in simple time series models. Hence, both filter will be used to look at the magnitude differences in their results.

The contributions marked above fill a gap in business cycle studies in South Asia to various degrees. First, in terms of availability of studies on the countries featured in this study, as of my knowledge, no empirical work has been done specifically to establish the business cycle characteristics of the Maldivian Economy. A growing, but limited number of studies, attempted to determine business cycle regularities for India such as Pandey et. al. (2018), Ghate at. al (2013) and Gabriel et. al (2012). For Sri Lanka, panel business cycle studies such as Michael et. al. (2011) provides insights into the business cycle attributes of key variables such as GDP. However, their scope does not cover the wider aggregates important to document business cycles in emerging economies such as trade balance. A growing body of literature on business cycles for Peru exists and therefore does not form part of my contribution to literature. Second, in studying regional business cycles, as of my knowledge, no empirical studies have attempt compare cyclical moments between South Asian countries. A few studies such as Michael et. al. (2011) and Pallage et. al (2001) has combined India and Sri Lanka with Southeast Asian countries to study business cycle similarities in different contexts. This chapter, therefore, aims document the extent to which south Asian economies share similar business cycle characteristics.

The remainder of this chapter is organised as follows: Section 3.2 looks at the data sources and treatments applied to the relevant data to prepare them for empirical work featured in this thesis. Section 3.3 reports business cycle moments for the Maldives for each data set using both HP filter and Hamilton filter and comments on the differences

[7] Alternative filters include BK filter developed by Baxter and King (1999)

observed in results due to filtration techniques used. The results are benchmarked against the stylised facts reported by Schmitt-Grohe and Uribe (2017) for small and emerging economies. Section 3.4 compares Maldivian business cycle moments with India, Sri Lanka, and Peru to establish the degree to which cyclical properties among these economies are similar.

3.2 Data Sets and their sources

In the literature, lack of quality data on emerging economies are widely recognised. For the Maldives, there are a few publicly available databases which provides data on macroeconomic aggregates. Three main databases were identified to provide series of reasonable length that can overcome empirical inaccuracies associated with short data series. These are: Penn World Tables[8] (PWT) published by the American Economic Review, International Financial Statistics (IFS) published by the International Monetary Fund, and Annual and Quarterly Economic Reports published by the Maldives Monetary Authority (MMA)[9]. It is worth noting that quarterly data is more frequently featured in real business cycle studies but due to limited years and series for which quarterly data are available[10], the business cycle properties and associated calibrations are performed using annual data. In terms of business cycle dynamics, the results are independent of the data frequency used.

The data sources identified above are subject two limitations. The first limitation is the inability to acquire all relevant data series of interest from a single database. As a result, data from two different databases need to be merged to form a single usable dataset. I will refer the data that comes from another source the "borrowed series" in the dataset. As explained in page 9 of this thesis, there are differences in how data are extrapolated by different databases, therefore "borrowed series" may not fit well with the existing data and hence may not provide the full information on how the series move with the existing series.

[8] PWT is developed and maintained by scholars at the University of California, Davis and the Groningen Growth Development Centre of the University of Groningen

[9] From 1980-2007 these reports were on hard copy format only.

[10] Where quarterly data is available it is from 2006 Q4 onwards. For some of the aggregates such as external balances no quarterly data exist.

Using the three available databases, I have developed three datasets titled as Dataset 1, Dataset 2 and Dataset 3. In each data set the substantives data series comes from one of the above sources and the missing data series are "borrowed" from another source to complete the set. The decision to use all three available datasets are for two reasons. First, I wanted to demonstrate variability in stylised business cycle facts due to database differences. Secondly, as I have collated all available national data from archives to develop a full database on Maldives, I wanted to establish how this dataset fares in comparison to more established databases widely used in literature to study business cycle. Details of each data set is as follows.

- **Dataset 1** combines data from the Maldives Monetary Authority with the Penn World Table. The latter source is used to "borrow" data on consumption and investment[11] only. This dataset forms my contribution to understanding the Maldivian economy, since (except for consumption and investment) all series are built by collating data held in the Maldives Central Bank and Planning Ministry[12];
- **Dataset 2** is compiled from the Penn World Table 9.0 and International Financial Statistics. The latter source is used "borrow" data on export, import, trade balance and current account balances; and
- **Dataset 3** is compiled purely from International Financial Statistics data.

The second limitation of data lies with irregularities and inconsistencies one can observe in the way data are reported and treated by these data sources. For instance, except the Penn World Tables, all other sources do not express data using a common currency. For some series, data are reported in Maldivian national currency while other series are reported in US dollar. As a result, nominal or Purchasing Power Parity adjusted exchange rates needs to be used to express all data series in a uniform currency before detrending the data. This treatment, however, causes exchange rate movement to influence data series and hence the cycle and trend in data. In the case of the Maldives, nominal exchange rate has remained fixed for numbers of years due to

[11] These data are not collected or forecasted by the Maldivian Statistical agencies.
[12] All data available are compared using relevant collection method to check for comparability before being merged into a single series. Only data that are collected using the same method are merged.

pegged exchange rate regimes which addresses the concern raised above[13]. However, as volatility of inflation affects the purchasing power of the currency, the latter year's exchange rate does not mitigate the issue. Another inconsistency lies with the way data are expressed in real terms. In conversion to real aggregates, nominal data is deflated using their respective deflators. Whenever the relevant deflator is unavailable, Consumer Price Index is used. Final notable inconsistency is that with the Penn World Table data. Unlike the other two sources, PWT real data for the main macroeconomic aggregates, except for export import and current accounts. The missing trade data in US dollar are taken from International Financial Statistics and are converted to a constant price by applying relevant constant price Purchasing Power Parity factor published by the Penn World Tables and the Federal Reserve St. Louis.

Appendix 3.1 describes these three datasets by reporting the definition for each series, construction methodology, and frequency. Figure 1.1 plots data reported by these three sources on key macroeconomic aggregates following relevant treatments as described above. As show in Figure 1.1 and explained in page 9 there are notable differences in these data sets in terms of magnitude and behaviours owing to the issues discussed above.

The data used are not adjusted for seasonality as these are annual data. Since the time series data features an underlying trend, all data are de-trended to separate trend and cycle. Prior to the application of the de-trending filter, all data except trade balance, current account and their associated per capita values are transformed by taking natural logs. The latter mentioned series remains at their levels. The most widely adopted de-trending method in the literature is the HP filter proposed by Hodrick and Prescott (1981, 1997) that decomposes the data into trend and cycle. Despite its popular use in social science research, the limitation of the HP filter is widely acknowledged by researchers.

[13] Maldives adopted a hard peg in October 1994 and since then there were two episodes of devaluation in July 2001 and April 2011. The latter was due to introduction of a managed floating exchange rate is ± 20%. Since the introduction of management floating, the exchange rate has been standing at its limit of +20% to-date.

There are three notable criticisms of the HP filter. Firstly, the HP filter, as noted by Nelson and Kang (1981) and Hamilton (2018), it can result in spurious cycles due to the filter ignoring the process of data generation for respective series. The HP filter "predict" future from the past values and hence do not consider underlying process for data generation. Secondly, the exact science behind the smoothing parameter λ is unknown except for the two-sided HP filter. However, the two-sided HP filter is not purely backward looking[14] making it irrelevant to DSGE estimation. Third, as noted by Söderlind (1994) as sample sizes are of finite lengths, the filter applied cannot be uniform for all observation in the context of RBC models as it often results in a significant phase shift that is either derived from the start or end values of the sample[15].

In an attempt to overcome the issues associated with the HP filter, Hamilton (2017, p.841) proposed an alternative filter, referred to here as the "Hamilton Filter" which 'preserves the underlying dynamic relations' of a series and can consistently estimate the cyclical properties which can cater for a broad range data generation process. The procedure used by the Hamilton Filter to separate data into cycle and trend is through either using a simple OLS process to derive a linear projection of the population of y_{t+h}[16] on a constant and four more recent values of y_t, or applying a random walk procedure of $y_t = y_{t-1} + \varepsilon_t$. As emerging and small open economies, excluding the developed countries, experience significant regime changes and relative importance of a random walk component in generating business cycles as documented by Aguiar and Gopinath (2007), we extracted the cyclical components through the Hamilton procedure involving a random walk. The difference in the two procedures is that often a random walk procedure gives higher variations compared with the OLS procedure. The Hamilton Filter, like the HP filter, suggests using a two-year horizon in obtaining business cycle properties.

The choice of lagged period, p and horizon h is then set based on number of data

[14] The model solution for RBC and DSGE model are based on a backward-looking structure where the solution today depends on current and past shocks. A two-sided HP filter uses unfiltered data from past and future to forecast the current state of the filtered data. See Pfeifer (2017, p. 33) for more formal explanations.
[15] This reference is related to difference in weight in their growth components of data points at either end of the series, which if treated equally as the HP filter does can distort the cyclical component of the data.
[16] h related to the number of periods ahead Hamilton filter regresses over.

observations in a year where p and h is multiplied by the number of observations in a year. This implies, for a two-year horizon, quarterly data would have $p = 4$ (number of lagged period) and h=8 (horizon under consideration). As this study looks at annual data, we set $p = 1$ and h=2.

In the last two years several studies have attempted to validate the claims made by Hamilton (2017). In an extensive study, Schüler (2018) concludes that the Hamilton filter is not subject to the same drawbacks as the HP filter and therefore produces more robust estimates for the business cycle. However, Schüler (2018) also acknowledges limitations associated with the Hamilton filter in terms of muting some short-term fluctuations. In another extensive study involving multiple filters, Hodrick (2020, p.25) concludes that Hamilton's filter is robust with simple time series models or 'ARIMA(2,1,2) model with constant parameters and 289 observations'. Furthermore, Hodrick (2020) concludes that the HP filter is more relevant for those economic series which has a slow growth component like population growth. Considering this finding, one can conclude that for emerging economies, the Hamilton filter may provide a more robust estimate. In this chapter I will be reporting both Hamilton and HP filter estimates for the Maldives dataset to establish the differences. However, going forward, as most of emerging economy stylised facts are reported using the HP filter, for convenience I will use the HP filter estimates for comparison of theoretical moments with empirical moments.

3.3 Business Cycle Properties

Following decomposition of data into cycle and trend, business cycle properties are extracted by looking at the relevant statistical second moments of cyclical for each variable. In particular, the following second moments form the stylised facts: measure of volatility (standard deviation), measure of cyclicality with respect to GDP (contemporaneous cross-correlation), measure of persistence (first order autocorrelation) and phase shift (cross correlations at different lead and lag periods).

As described in Section 3.2, there are three possible data sets I can use to establish business cycles estimates for the Maldives that can then feed into empirical work in this thesis. Results from the Hamilton filter and HP filter will be reported for each of these data sets to which will aid in document business cycle properties and establish differences in result due to the choice filter used. I would choose the most appropriate dataset to use in future chapters based on relative similarities of the results with results reported by Schmitt-Grohe and Uribe (2017) and general fit with those observed in EME literature.

Table 3.1, **Table 3.2** and **Table 3.3** report the key second moments that describes the cyclical properties of expenditure components of output: relative standard deviations, contemporaneous cross-correlations with output and first order autocorrelations of each series. The standard deviation looks at volatility of each component. The cross-correlation coefficient indicates the nature of cyclicality of each indicator with respect to output. A positive value indicates the series is procyclical, a negative series indicates the series is counter cyclical and a figure close to zero indicates that the series does not affect the cycle. The autocorrelation measures the persistence of each series where it informs the extent to which previous period value of the series $(t-1)$ affects the current period value t.

Results in Table 3.1 show that the use of the HP filter on data set appears to produce volatilities consistent with the benchmark results for most variables. Between the HP filter and Hamilton filter, it shows that the HP filter and Hamilton filter differs significantly in volatility of output and imports only. The results show that in terms of domestic absorption, consumption is more volatile than output and investment is more volatile than consumption and output. This result therefore is consistent with the prediction from literature documented in Chapter 2. However, the magnitude of investment to output ratio and import to output ratio are much smaller than values suggested in the literature. In dataset 1, consumption and investment are estimated from the relevant shares reported by the Penn World Table which has significant variation between years. The relevant shares are multiplied by the GDP reported by Maldivian authorities who approximate GDP based on value added in each sector compared to the expenditure approximation method used in the Penn World Table. As these shares vary each year as noted by Hodrick (2020), the Hamilton filter performs poorly over the HP filter when a non-constant parametrisation appears to drive the data.

Descriptive Statistics	Data Results 1977-2014, annual data		Benchmark Results (Uribe & Schmitt-Grohe, 2017)	
	Hamilton filter	HP filter	Emerging Economies	Poor Economies
Standard Deviations				
σ_y	12.57	8.76	3.98	4.12
${}^{\sigma_i}/_{\sigma_y}$	1.91	1.93	3.79	3.80
${}^{\sigma_c}/_{\sigma_y}$	1.24	1.18	1.23	1.09
${}^{\sigma_x}/_{\sigma_y}$	2.15	2.52	3.67	3.47
${}^{\sigma_m}/_{\sigma_y}$	1.70	0.28	3.52	3.70
$\sigma_{\frac{CA}{y}}$	3.54	2.46	2.63	1.71
$\sigma_{\frac{TB}{y}}$	2.06	2.53	2.92	1.64
Correlation of each variable with y				
$\rho(y,y)$	1	1	1	1
$\rho(c,y)$	0.56	0.49	0.68	0.53
$\rho(i,y)$	0.56	0.66	0.71	0.65
$\rho(x,y)$	0.29	0.53	0.13	0.18
$\rho(m,y)$	-0.08	0.08	0.46	0.23
$\rho(tb,y)$	0.25	0.28	-0.34	-0.08
$\rho(ca,y)$	0.06	0.08	-0.39	-0.29
First order autocorrelation				
$\rho(y_t,y_{t-1})$	0.50	0.34	0.60	0.39
$\rho(c_t,c_{t-1})$	0.35	0.26	0.44	0.29
$\rho(i_t,i_{t-1})$	0.43	0.04	0.45	0.27
$\rho(x_t,x_{t-1})$	0.48	0.48	0.44	0.47
$\rho(m_t,m_{t-1})$	0.27	0.30	0.44	0.43
$\rho(tb/y_t, tb/y_{t-1})$	0.23	0.31	0.42	0.36
$\rho(ca/y_t, ca/y_{t-1})$	0.36	0.30	0.39	0.36

Table 3.1: Cyclical properties of Maldivian economy using Dataset 1

The results on contemporaneous correlation with output show that both filters fare significantly well with respect to the benchmark data except for external balances. The correlation of consumption with output appears to be at the lower end of benchmark results. This can be attributed to the fact that the share of government consumption is higher in the Maldives compared with private consumption hence consumption is much less correlated with the output. For instance, the IMF (2017) reports that the Maldivian government expenditure share is 38.7% of GDP in 2016. The result shows that the trade related variables result differs significantly from the benchmark data. There are several justifications as to why this may be the case. Firstly, the fundamental nature of the Maldives is that it lacks natural resources causing a large proportion of imports, and therefore, one would expect imports to be less correlated with GDP due to its dependency. Where exports are concerned, as tourism accounts for the largest export share and source of income, one would expect a larger correlation with output. In terms of respective shares for imports and exports, in 2015, imports contributed to Maldivian GDP by -70.1% (IMF, 2017) while export share of GDP is 12.9%. This accounts for one of the reasons why the results for the Maldives may have deviated significantly from the benchmark results in terms of magnitude and direction. The first order autocorrelation results show that the Hamilton filter, in general, generates a stronger persistence although differing in magnitude with the benchmark results. Consistent with emerging economy data, output has a stronger persistence than other indicators.

The results reported in Table 3.2 covers additional two variables: hours worked, and capital reported in the Penn World Table. The volatility of output is higher in Hamilton factor representing the random walk. However, when ratios are concerned, except for external balances, both filters are able to generate consistent results with benchmarked data. In terms of volatility, both filters applied appears to match the benchmark result although the Hamilton filter does a better job than the HP filter in terms of meeting stylised facts for emerging economies in relation to order of volatility, direction of correction and persistence and are closer to what is observed for benchmark data. It can also be seen that compared with Table 3.1, results in Table 3.2 shows that consumption magnitude of consumption volatility is smaller in dataset 2. As shown in Figure 1.1, consumption in PWT has a smoother line compared with a much more volatile line in dataset 1 representing a higher volatility of consumption in dataset 1. One of the reasons for a smoother consumption in dataset 2 is due to inclusion of government consumption[17], which tends to be much more stable than private consumption- hence smaller volatility. As expected for emerging economies, investment has the highest volatility, and the values are within the expected range for emerging economies. Contemporaneous correlation shows that the Hamilton filter can match the benchmark results better when compared to the HP filter. It can be seen from those results that exports have a stronger correlation with the output. This can be explained by the fact that roughly 30% of the Maldives output are contributed from Tourism industry and 6% from fishing which are the main of exports for the Maldives. The dataset 2 is also able to reproduce the negative correlation of external balances (trade balance and current account) observed in small open economies. The result of persistence shows that consumption, investment, exports, imports, current account, and capita has a strong persistence and closely resemble what we observe for small open economies.

[17] Penn World Table 'ccon' reports real consumption of household and government. While it reports separately the share of household consumption for each year, I have decided against extracting from 'ccon' household consumption due to lack of knowledge on how this variable is constructed.

Descriptive Statistics	Data Results 1976-2014, annual data		Benchmark Results (Uribe & Schmitt-Grohe, 2017)	
	Hamilton filter	HP filter	Emerging Economies	Poor Economies
Standard Deviations				
σ_y	8.40	4.28	3.98	4.12
σ_i/σ_y	3.63	4.08	3.79	3.80
σ_{cc}/σ_y	1.16	1.31	1.23	1.09
σ_k/σ_y	0.96	1.26	NA	NA
σ_h/σ_y	0.84	0.98	0.89*	NA
σ_x/σ_y	4.15	4.87	3.67	3.47
σ_m/σ_y	3.33	0.14	3.52	3.70
$\sigma_{\frac{CA}{y}}$	0.86	0.61	2.63	1.71
$\sigma_{\frac{TB}{y}}$	0.94	0.64	2.92	1.64
Correlation of each variable with y				
$\rho(y,y)$	1	1	1	1
$\rho(c,y)$	0.53	0.35	0.68	0.53
$\rho(i,y)$	0.57	0.36	0.71	0.65
$\rho(k,y)$	0.14	0.23	NA	NA
$\rho(h,y)$	0.18	0.06	0.65*	NA
$\rho(x,y)$	0.55	0.39	0.13	0.18
$\rho(m,y)$	0.35	0.04	0.46	0.23
$\rho(tb/y\,,y)$	-0.24	-0.08	-0.34	-0.08
$\rho(ca/y\,,y)$	-0.07	-0.04	-0.39	-0.29
First order autocorrelation				
$\rho(y_t,y_{t-1})$	0.32	0.12	0.60	0.39
$\rho(c_t,c_{t-1})$	0.69	0.59	0.44	0.29
$\rho(i_t,i_{t-1})$	0.55	0.47	0.45	0.27
$\rho(x_t,x_{t-1})$	0.58	0.53	0.44	0.47

$\rho(m_t, m_{t-1})$	0.59	0.55	0.44	0.43
$\rho(tb/y_t, tb/y_{t-1})$	0.39	0.45	0.42	0.36
$\rho(ca/y_t, ca/y_{t-1})$	0.53	0.55	0.39	0.36
$\rho(k_t, k_{t-1})$	0.74	0.69	NA	NA
$\rho(h_t, h_{t-1})$	0.46	0.34	NA	NA

* results reported by Neumeyer and Perri (2005) for emerging economies.

Table 3.2: Cyclical properties of Maldivian economy using dataset 2

The results from dataset 3 are reported in Table 3.3. The results indicates that volatilities reported in the HP filter are similar to results in Table 3.1. This can be evident from Figure 1.1, where the time series plot for output in dataset 1 and dataset 3 has similar curvatures which is less smooth than dataset 2 plot. At the same time, volatility of external balances is higher in dataset 3 and dataset 2 compared to dataset 1. The timeseries plot shows that current account to output ratio again share similar patterns between these two datasets and is less smooth than dataset 2. On overall volatilities, this dataset can replicate to the expected order of volatility for investment, consumption, and output for emerging economies.

Contemporaneous correlations with output show that the two-filtering technique presents significantly different results both in direction and magnitude for most variables except for external balances. We can explain the difference by looking at the data approximation method used by the International Financial Statistics database for investment. The investigation into the data collection methodology reveals that investment is approximated using a constant share of GDP for different periods. These shares, which varies usually from every five years, are multiplied with output to get the data series. As the Hamilton filter extracts the random walk component in the data to extract the cyclical properties of the series, one can expect the results to feature an unusual coefficient similar to our results, as the trend component of the data is fixed and vary in steps. The first order autocorrelation results reported also features significant differences in results for most variables. At the same time, with the exception of investment, autocorrelation appears to be low. Therefore, it is reasonable to assume that the investment autocorrelation coefficient is higher because the series has been constructed from a constant share across time showing an artificially induced persistence in the data.

Descriptive Statistics	Data Results 1980-2016, annual data		Benchmark Results (Uribe & Schmitt-Grohe, 2017)	
	Hamilton filter	HP filter	Emerging Economies	Poor Economies
Standard Deviations				
σ_y	10.31	7.06	3.98	4.12
σ_i/σ_y	2.64	2.98	3.79	3.80
σ_c/σ_y	2.27	1.83	1.23	1.09
σ_x/σ_y	3.90	3.01	3.67	3.47
σ_m/σ_y	2.66	0.94	3.52	3.70
$\sigma_{\frac{CA}{y}}$	8.22	6.64	2.63	1.71
$\sigma_{\frac{TB}{y}}$	5.25	5.70	2.92	1.64
Correlation of each variable with y				
$\rho(y, y)$	1	1	1	1
$\rho(c, y)$	0.08	-0.12	0.68	0.53
$\rho(i, y)$	-0.05	0.43	0.71	0.65
$\rho(x, y)$	0.61	0.05	0.13	0.18
$\rho(m, y)$	0.32	0.43	0.46	0.23
$\rho(tb/y, y)$	0.21	0.51	-0.34	-0.08
$\rho(ca/y, y)$	0.42	0.43	-0.39	-0.29
First order autocorrelation				
$\rho(y_t, y_{t-1})$	0.24	0.25	0.60	0.39
$\rho(c_t, c_{t-1})$	0.34	0.13	0.44	0.29
$\rho(i_t, i_{t-1})$	0.51	0.56	0.45	0.27
$\rho(x_t, x_{t-1})$	0.38	0.26	0.44	0.47
$\rho(m_t, m_{t-1})$	0.29	0.40	0.44	0.43
$\rho(tb/y_t, tb/y_{t-1})$	0.40	0.16	0.42	0.36
$\rho(ca/y_t, ca/y_{t-1})$	0.14	0.40	0.39	0.36

Table 3.3: Cyclical properties of Maldivian economy using dataset 3

Based on the results reported using all three datasets, the standard deviation of investment in all three cases, despite the differences in magnitudes, is the most volatile macroeconomic aggregate in the Maldives, followed by consumption and output. We can therefore conclude that for the Maldives both consumption and investment volatility are higher than output volatility. This conclusion conforms to the prediction from EME literature as as described in Chapter 2. For instance, Neumeyer and Perri (2005) show that output is volatile, but consumption is much more volatile than output, which appears to be different to what we observe for developed countries.

The measure of persistence (autocorrelations) appears on average under three databases to be higher using the Hamilton filter compared with the HP filter. It can be established that all datasets report a significantly smaller value for persistence of output that benchmark results. While the results on persistence, on hindsight appears to be low compared with emerging markets, one must point that these results at individual country level are extremely diverse. This would therefore be an open research question to determine whether the persistence of Maldivian macroeconomic indicators follows a random walk that is outside the scope of this thesis. The data for the Maldives appears to fall within the range for some of the emerging markets studied in the past such as those countries as reported in Chapter 2 and other influential papers Aguiar and Gopinath (2007).

One of the defining characteristics of emerging markets and small open economies is the observed volatility of current account and trade balance and the inverse relationship between these aggregates with output. Datasets 2 values reported in Table 3.2 appear to document a weak negative correlation of current account and trade balance with output and the persistence of these two variables are broadly in line with the benchmark results reported in many small open economies. Given dataset 2 has followed a more established framework in collecting and extrapolating the data compared with dataset 1 and 2 as explain in Chapter 1, one would therefore leans towards dataset 2 to provide less biased and meaningful results.

For the purpose of this paper, I will be selecting the benchmark results and data to use in rest of the thesis through the following criteria: These criteria relate to data collection and approximation methods used by different data sources cited herein, availability of multiple series under one main source and periods of coverage, and ability to match stylised facts for small and emerging economies in terms of moments. Based on this, the most reliable data set appears to be from the Penn World Table data as this dataset and its results meet the above criteria to the highest standard. Between the HP filtering and Hamilton filtering procedure, I have decided to use the results reported by the HP filter due to two reasons. First, computer programmes such as MATLAB and Dynare does not support Hamilton filter hence I am unable to get comparable estimates following simulation and estimation. Secondly, most RBC studies currently report results based on HP filter hence for benchmarking purposes, I would need to use HP filter. Therefore, the data series to be used in the rest of the Chapter and thesis will be HP filtered data from Data Set 2. Schmitt-Grohe and Uribe (2017, p.15) average estimates for macroeconomic aggregates will be used as a basis to compare the finding of this Chapter with emerging and small open economy. The rationale for selecting Schmitt-Grohe and Uribe (2017) to benchmark my results for small and emerging market economies in this chapter is due to the alignment of data frequency and the reporting mechanism to the data used in this thesis. Firstly, the authors used annual data for a period of 35-45 years reflecting comparability of years in this thesis. Secondly, the classification of countries into poor, emerging, and developed are further subdivided into small, medium, and large countries for each group.

3.4 Business Cycle moments compared with India, Sri Lanka and Peru

In this section, I will first compare the Maldives business cycle with the two most economically and culturally close economies in South Asia – India and Sri Lanka - to determine level of business cycle synchronisation in the region. As described at the beginning of this Chapter, Peru is introduced into this comparison exercise to determine the extent to which other dollarized economies share similar business cycle characteristics to the Maldives. Data on India, Sri Lanka and Peru are gathered through the Penn World Tables and IFS and compared with the benchmark results obtained for the Maldives in Table 3.2. Penn World Tables and IFS data sources are used for these countries to ensure the data collection method is consistent, and variation in data collection and aggregation does not influence the results. All the data are treated using the same approach as above and the Hamilton filter is used to separate trend and cycle. Results for all three economies are reported in Table 3.4. In Table 3.4, I will also be reporting stylised facts computed for Peru using the same method and data sources to determine the extent to which dollarized economies business cycle match with each other.

The results for the Asian countries as reported in Table 3.4 shows that standard deviations of key economic variables, while they are similar in magnitude for Sri Lanka and India, it is significantly different for the Maldives. Key indicators that conform with the pattern one would expect for emerging economies, except for except external balance indicators. All the other standard deviations are more volatile for the Maldives. This result is not surprising as studies done on Asian business cycle synchronisation show that these economies have not achieved similarities in the behaviour of their macroeconomic aggregates. For instance, in a study by He and Liao (2012) involving Southeast Asian countries, India and G8 countries shows that business cycle synchronisation does not appear to persist among Asian countries. Instead in the sample, there will be a regional economy that shares similar characteristics with other regional economies, but the level of synchronisation depends on the level of regional trade between economies and their link to major global economies. As shown in the Table 3.4, India and Sri Lanka appear to share similar volatilities while the Maldives appears to be significantly more volatile in all of its aggregate than these countries. The similarity between India and Sri Lanka is due to a larger trade relationship that exists between these countries. For instance, according to the Indian High Commission (2021)[18,] India is Sri Lanka's largest trading partner and between South Asian countries, Sri Lanka stands as India's largest trading partner. Michael et. al (2011) also shows that across time, India and Sri Lanka have a similar volatility in output since 1880, establishing the possibility that in South Asia these two countries have a regional level synchronisation. The study also concluded that global idiosyncratic shocks diverge business cycles in each region except for the advanced developed countries.

[1818] https://www.hcicolombo.gov.in/Economic_Trade_Engagement

Business Cycle Moments	Maldives (1980-2016)	(1980-2018, annual data)			Emerging Economies (Uribe & Schmitt-Grohe, 2017)
		Sri Lanka	India	Peru	
Standard Deviation					
σ_y	8.40	2.98	2.65	9.19	8.71
σ_i/σ_y	3.63	5.31	6.69	3.34	2.79
σ_c/σ_y	1.17	1.13	0.98	1.07	0.98
σ_k	0.96	1.87	0.95	0.48	NA
$\sigma_{\frac{CA}{y}}$	0.86	0.21	4.63	1.12	3.08
$\sigma_{\frac{TB}{y}}$	0.94	3.46	1.24	0.07	3.80
Correlation of each variable with y					
$\rho(y, y)$	1	1	1	1	1
$\rho(c, y)$	0.53	0.47	0.77	0.96	0.75
$\rho(i, y)$	0.57	0.78	0.59	0.79	0.77
$\rho(k, y)$	0.14	0.63	0.38	0.52	-0.38*
$\rho(tb/y, y)$	-0.24	-0.45	0.01	-0.21	-0.21
$\rho(ca/y, y)$	-0.07	-0.13	0.22	-0.35	-0.24
First order auto correlations					
$\rho(y_t, y_{t-1})$	0.32	0.63	0.51	0.66	0.87
$\rho(c_t, c_{t-1})$	0.69	0.26	0.72	0.63	0.74
$\rho(i_t, i_{t-1})$	0.55	0.59	0.40	0.56	0.72
$\rho(k_t, k_{t-1})$	0.74	0.90	0.93	0.85	0.65
$\rho(tb/y_t, tb/y_{t-1})$	0.39	0.16	0.62	0.27	0.62
$\rho(ca/y_t, ca/y_{t-1})$	0.53	0.19	0.45	0.40	0.52

Table 3.4: Business Cycle Moments for Selected Economies and the Maldives

One of the reasons for the larger standard deviations for the Maldives is its lack of self-reliance which, together with dollarization, makes the Maldivian economy more vulnerable to foreign shocks. This can be further evidenced by comparing the Maldives business cycle standard deviation with Peru. As shown in Table 3.4, Maldives and Peru shares relatively similar standard deviations except for capital. As both economies are heavily dollarized, the results support the hypothesis that these countries business cycle moments are significantly influenced by changes in global markets.

The contemporaneous correlation shows that the Maldives and Sri Lanka share greater similarities in correlation for consumption, capital, and external balances. India, on the other hand, shows significant differences. Peru and Sri Lanka also share significant similarities. In terms of persistence, a varied level of persistence is recorded between the countries in South Asia. However, the Maldives and Peru share similar persistence for all variables except output. A notable similarity in all the four economies is a relatively low persistence in output compared to emerging economies. This result is widely acknowledged for South Asian economies due to its reliance on the service sector external remittance (Ghate et. al, 2013).

Overall, it can be seen in the context of South Asian economies, while there are similarities in business cycle indicators, there exist significant differences between countries. However, where Peru and the Maldives are concerned, there are greater levels of similarities in business cycle indicators, which might stem from the dollarized nature of these two economies.

3.5 Conclusions

This chapter illustrates the main business cycle facts for the Maldives based on available datasets, and establishes the most appropriate data to be used in calibration and estimation of different business cycle models for the Maldives. The results of business cycle indicators show that, on average, the Maldives share similar business cycle characteristics as emerging market economies where investment is more volatile than consumption, and volatility of domestic absorption is higher than volatility of output. It also shows that Maldivian trade balance and current account is weakly countercyclical.

The results establish the unique characteristics of dollarized economies and also South Asian economies. Firstly, the persistence of output among South Asian countries is very low. Secondly, India's economic growth is driven by consumption as shown by large contemporaneous correlation between consumption and output and persistence of consumption. This is a common feature of India's growth model documented in literature, where India has experienced a large consumption boom due to increase in remittance flow by residents in other countries, and the growth in the service sector. These two factors have contributed to increase in demand for consumption. Sri Lanka's post-civil war mega infrastructure developmental projects have made investment to be most correlated with output. Similarly, the accelerated tourism development of the Maldives since the1980s shows that investment is one of the strongest drivers of economic growth in the Maldives as shown by the correlation coefficient.

The high volatility of Maldivian aggregates shows the level of economic fragility in the Maldives. This is also a characteristic shared by Peru, giving rise to the conclusion that overall countries which are heavily reliant on dollarization, report structural instabilities and are more vulnerable to global shocks.

Appendix 3.1: Description of Data Sets

Data Set 1: Penn World Table and Maldivian Monetary Authority (MMA) Data

Series	Definition	Treatment	Frequency
Y	Real gross domestic product: Gross domestic product (GDP) reported in millions of national currency by MMA deflated using GDP deflator. Units: in millions (2010=1)	GDP in millions of Maldivian currency divided by GDP deflator.	Yearly, 1979-2014
C	Real household consumption expenditure: household consumption expenditure including expenditure estimated using relevant consumption share in national currency deflated using GDP deflator. Units: in millions (2010=1)	Household consumption expenditure is estimated by multiplying relevant consumption share of GDP calculated by Penn World Table for each year with corresponding nominal GDP in Maldivian currency reported by MMA and deflated using GDP deflator.	Yearly, 1979-2014
I	Real gross fixed capital formation: gross fixed capital formation estimated using relevant investment share in national currency deflated using GDP	Gross fixed capital formation reported in Maldivian currency is estimated by multiplying relevant investment share of GDP calculated by Penn World Table for	Yearly, 1979-2014

	deflator.	each year with corresponding nominal GDP in Maldivian currency reported by MMA and deflated using GDP deflator.	
X	Real exports: exports reported in national currency by MMA deflated using GDP deflator.	Exports in Maldivian currency divided by GDP deflator.	Yearly, 1979-2014
M	Real imports: exports reported in national currency deflated using GDP deflator.	Imports in Maldivian currency divided by GDP deflator.	Yearly, 1979-2014
CA	Real current account balance: Current account balance reported in USD converted to domestic currency and deflated using GDP deflator.	Current account balance in US Dollar multiplied by end of the year exchange rate reported by MMA and divided by GDP deflator.	Yearly, 1979-2014
CA/Y	Current account per capita.	CA divided by Y	Yearly, 1979-2014
TB	Real trade balance .	X – M	Yearly, 1979-2014
TB/Y	Trade balance per capita.	TB divided by Y.	Yearly, 1979-2014

Data Set 2: Penn World Table 9.0 and International Financial Statistics

Series	Definition	Treatment	Frequency
Y	Real Gross Domestic Product (GDP) at constant prices. Units: in mil. 2011US$ Source: Penn World Tables	Taken as reported by database.	Yearly, 1976-2014
CC	Real household and government consumption at constant prices. Units: in mil. 2011US$	Taken as reported by database.	Yearly, 1976-2014
I	Real investment in constant prices. Units: in mil. 2011US$ Source: Penn World Tables	Computed by subtracting real consumption from real domestic absorption. Units: in mil. 2011US$	Yearly, 1976-2014
X	Real exports of goods at constant prices using Purchasing Power Parity Rates Units: in mil. 2011US$ Source: International Financial Statistics and Penn World Tables.	Export in current US$ reported in International Financial Statistics are deflated using Purchasing Power Parity (PPP) Exchange Rate. Sources: Penn World Table	Yearly, 1976-2014
M	Real imports of goods at constant prices using Purchasing Power Parity	Imports in current US$ reported in International Financial Statistics are	Yearly, 1976-2014

	Rates Units: in mil. 2011US$ Source: International Financial Statistics and Penn World Tables.	deflated using Purchasing Power Parity (PPP) Exchange Rate obtained from method above.	
CA	Real current account balance in constant prices using constant price factor. Units: in mil. 2011US$ Source: International Financial Statistics and Penn World Tables.	Current account balance in current US Dollar reported by International Financial Statistics are deflated using Purchasing Power Parity (PPP) Exchange Rate obtained from method above	Yearly, 1976-2014
CA/Y	Current account per capita. Units: in mil. 2011US$	CA divided by Y	Yearly, 1976-2014
TB	Trade balance in constant prices using Purchasing power parity rate. Units: in mil. 2011US$	X – M	Yearly, 1976-2014
TB/Y	Trade balance per capita. Units: in mil. 2011US$	TB divided by Y.	Yearly, 1976-2014
K	Real capital stock at constant national based on investment and prices of structures and equipment Units: in mil. 2011US$		Yearly, 1976-2014

L	Labour force calculated based on number of persons engaged in population. Units: in mil.		Yearly, 1976-2014
H	Hours worked: yearly hours worked by employed population approximated using average hours worked at each census period.	Employment data is multiplied by annual average hours worked from data reported in every 5-year census report of the Maldives. Average annual hours are calculated by multiplying average weekly hours with 48 weeks (deducting the 4 weeks mandatory annual leave by law). Average weekly hours are calculated by multiplying average daily hours worked with 5 days.	Yearly, 1976-2014

Data Set 3: International Financial Statistics Data

Series	Definition	Treatment	Frequency
Y	Real gross domestic product: Gross domestic product (GDP) reported in millions of national currency deflated using GDP deflator. Units: in millions (2010=1)	GDP in millions of Maldivian currency divided by GDP deflator.	Yearly, 1980-2016
C	Real household consumption expenditure: household consumption expenditure including expenditure of Non-profit institutions serving households reported in national currency deflated using GDP deflator. Units: in millions (2010=1)	Household consumption expenditure including expenditure of Non-profit institutions serving households in Maldivian currency divided by GDP deflator.	Yearly, 1980-2016
I	Real gross fixed capital formation plus changes in inventories: gross fixed capital formation reported in national currency deflated using GDP deflator.	Gross fixed capital formation plus changes in inventories reported in Maldivian currency divided by GDP deflator.	Yearly, 1980-2016

X	Real exports: exports reported in national currency deflated using GDP deflator.	Exports in Maldivian currency divided by GDP deflator.	Yearly, 1980-2016
M	Real imports: imports reported in national currency deflated using GDP deflator.	Imports in Maldivian currency divided by GDP deflator.	Yearly, 1980-2016
CA	Real current account balance: Current account balance reported in USD converted to domestic currency and deflated using GDP deflator.	Current account balance in US Dollar multiplied by end of the year exchange rate reported by international financial statistics and divided by GDP deflator.	Yearly, 1980-2016
CA/Y	Current account per capita.	CA divided by Y	Yearly, 1980-2016
TB	Real trade balance .	X – M	Yearly, 1980-2016
TB/Y	Trade balance per capita.	TB divided by Y.	Yearly, 1980-2016

Chapter 4: An Estimated Real Business Cycle for the Maldivian Economy

4.1 Introduction

Real Business Cycle research agenda has taken several dimensions over the last three decades as documented in Chapter 2. The 'real models' uses a standard business cycle formulation in its entirety to study propagation and amplification mechanisms following a technology shock. The Dynamic Stochastic General Equilibrium Models use a real business cycle core and incorporate nominal frictions through sticky wages, prices, etc to study the propagation and amplification of various types of shocks. A key objective of these real business cycle-based studies is to match stylised facts drawn from data.

In this chapter I develop a standard RBC model to fit to the Maldivian economy. Following informal calibration of the model, I will then empirically estimate the model using Bayesian analysis. The purpose of this model is to develop a standard framework that can capture stylised facts of the Maldives. In subsequent chapters I will embed structurally important characteristics of small and emerging economies, with a strong emphasis on features that are applicable to the Maldives. The model in question is the simplest RBC model with one country, two shocks. Due to the small, scaled nature of this model, the numbers of parameters estimated through Bayesian will be limited. A fuller model will be estimated in Chapter 6.

The contribution from this paper falls under three broad themes. First, the standard model developed in this paper incorporates real interest rate shock which directly competes with technology shocks as a source of fluctuation. Therefore, through this, one can determine the role of interest rate shock in affecting business cycle moments. Ireland and Schuh (2008) notes that one of the reasons for standard business cycle models being stylised, is the role one shock plays in generating a business cycle which makes business cycle models stochastically singular. Second, this model is calibrated and simulated to fit to the Maldivian economy. As of my knowledge, an RBC model has not been developed to fit the Maldivian economy, and therefore, I aim to contribute to Maldivian policy makers toolkit through this model. Finally, unlike most RBC models, this model does not only rely on economic theory to determine the extent to which it can explain stylised facts. Instead, I will be taking the model to the data and re-estimate the model, using the Bayesian method, for the Maldivian economy to establish the extent to which the model is able to replicate moments from data.

The model developed in this paper follows from Schmitt-Grohe and Uribe (2003). In the literature two most influential models to form the RBC core comes from Mendoza (1991) and Schmitt-Grohe and Uribe (2003). I follow the latter due to simplification of a stationary inducing setup. Mendoza (1991) uses an internal discount factor approach to induce stationarity by linking a subjective discount factor to aggregate consumption and hours worked. Schmitt-Grohe and Uribe (2003) uses both external discount factor approach and internal discount factor approach. The internal discount factor approach makes a subjective discount factor depend on individual consumption and hours worked, while the external discount factor implies the subject discount factor is a function of cross-sectional average per capita consumption and hours worked[19].

Due to small and emerging economies reliance on international financial markets, an open economy setup with trade balance and current account would be more realistic. A current account allows representative agents to smooth their consumption over time through purchase or sales of interest-bearing bonds. The model described in the next section will feature two representative agents – household and firm. This is a rational expectation model which follows the work of Muth (1961) where agents' decisions depend on the information they have now and from past experiences. I abstain from introducing government into the model as our primary objective is to study households, firms, and current account dynamics for the Maldivian economy.

[19] As shown in Uribe and Schmitt-Grohe (2017) both set up has identical results. External discount factor approach simplifies the optimisation setup.

The model developed assumes the household owns all factors of production and lends it to the firm for production who then returns all the profits to the household. The household is also assumed to be able to borrow or lend at a risk-free rate through sale or purchase of one period foreign bond. In traditional real business cycle models, households discount the future by selecting a subjective discount factor θ_t where $\theta_t < 1$. This discount factor translates into cash flow (in terms of goods) the household receives from investment into current utils.

The discount factor shows the representative household's time preference in consumption – how they value today's consumption over future consumption. It shows the value households place to consume their income today by forgoing some of the current income by saving, so that in the future the household can consume more. The stochastic discount factor, which is found by multiplying first order condition of utility with respect to consumption $\frac{\partial U}{\partial C_t}$ with the discount factor; θ_t governs the rate at which the representative household is willing to substitute consumption between two time periods. As the household has access to international risk-free bond markets whose interest rate is determined exogenously, the use of this stochastic constant discount factor is not without problems in the real business cycle models. Schmitt-Grohe and Uribe (2003) shows that a constant subjective discount factor results in a steady state of the model being determined by the initial conditions, (namely the initial level of debt, capital, and technology) which implies that there will not be a unique steady state.

There are several ways to overcome this initial value problem. Schmitt-Grohe and Uribe (2003) summarises the key approaches from literature. These include use of an endogenous or exogenous discount factor, debt elastic interest rate premium where domestic interest rate is an increasing function of country's foreign indebtedness compared to its long run foreign debt and convex debt adjustment cost. All these methods to introduce stationarity results in identical results. Based on the above approaches outlined by Schmitt-Grohe and Uribe (2003), I have chosen to replace the stochastic discount factor with an endogenous discount factor to emphasise household intertemporal saving behaviour one observes in EMEs. As explained below, unless the discount factor is controlled, the household asset accumulation behaviour will be subject to counterfactual results. Firstly, from an empirical point of view, since the Obstfeld (1982) application of endogenous discount factor to the Uzawa specification, there is consensus in the literature that the use of an endogenous discount factor provides a better fit to what is observed in data between consumption and terms of trade. Secondly, the data reveals that changes in agents' budget constraints makes their saving rate evolve over time. The weights a representative household places on consumption would fluctuate based on the evolution of saving. This makes the saving rate an important determinant of consumption and thus terms of trade of a country. Finally, as summarised by Obstfeld and Rogoff (1996, p. 116-120), to ensure wealth or capital does not accumulate forever, or de-accumulate to an implausibly low level, the rate of time preference measured by the discount factor should not be less than or above the world interest rate. This establishes at a strict equality between the interest rate and the discount factor. Since the world interest rate is exogenous and variable for small open economies, use of a fixed discount factor is not intuitively appealing even when one combines other stationary inducing techniques to resolve the steady state being dependent on initial values.

When an endogenous discount factor is used, the household's optimal consumption decision in each period leads to changes in marginal utility and a subjective change in the individual preference for future consumption, commonly referred as 'impatience effect'. The household's consumption and leisure choice in each period will, therefore, feature this relative impatience effect, as the value the household places on future period's consumptions relative current consumption will change. By construction, the discount factor shows that an increase in current consumption decreases the weights the household assigns to all future utilities, thus becoming more impatient. As the representative agent's impatience rises, current consumption increases, net foreign asset falls, and trade balance represented by the difference between output gross domestic absorption deteriorates.

The model in addition to endogenous discount factor also features endogenous labour supply and demand, investment adjustment costs, capital depreciation and technology and interest rate shocks. We assume international financial markets are incomplete. A key departure from the Schmitt-Grohe and Uribe (2003) specification is to introduce investment adjustment costs instead of capital adjustment costs, and the inclusion of interest rate shocks. Interest rate shocks are introduced due to the recent empirical support at firm and aggregate level estimation on its ability to explain business cycles. The use of interest rate shock marks a clear departure from classical real business cycle models. For instance, Christiano, Motto and Rostagno (2014) found that interest rate shocks propagated by changes in risk premium account for about 60% of fluctuations in United Stated output since mid-1980s. Furthermore, this thesis aims to establish the role technology, interest rate, and dollarization plays in explaining the real business cycle in the Maldives. For this purpose, I start my canonical RBC model with technology and interest rate shock to gather evidence on the role of interest rate shock in generating the business cycle.

In international real business cycle literature, it is widely accepted that inclusion of only productivity shocks may produce biased results as the direction of effect on portfolio valuation may be incorrect in such models. Küçük and Sutherland (2015) states that when the only source of shock is a productivity shock, then valuation effect on portfolio may have incorrect dynamics as opposed to models with risk premium shocks and government shocks. Uribe and Yue (2006) using the RBC framework with financial friction, demonstrated that 20% of changes in macroeconomic variables in emerging economies can be accounted for by changes in US interest rate. Neumeyer and Perri (2005) produces similar results where interest rate shock can account for volatilities in macroeconomic aggregates. The latter two papers aim to establish the role of interest rate in an economy subject to friction in financial markets. In this chapter I attempt to understand whether interest rate can generate volatilities in real economy in a frictionless economy.

The main conclusion from this chapter is that when interest rate directly competes with technology shock, one can see that it plays a role in generating the business cycle in small and emerging open economies. Both formal and informal estimation validates this role of interest rate. This should come as no surprise due to small and emerging and open economies reliance on international financial markets for its borrowing and lending. Furthermore, a simple RBC model can mimic some of the stylised cyclical properties of the Maldivian economy. The result of this paper is not as strong as Uribe and Yue (2006) since I have assumed interest rate is exogenous to the country to simplify the model.

This paper is organised as follows: The next section outlines the theoretical model; and this is followed by calibration and estimation of the model using calibrated values. The model's impulse responses are discussed to elaborate on the transmission and propagation mechanism. This section then compares theoretical moments with data to evaluate the fit. The final section of the paper estimates the model using the Bayesian estimation and compares the estimated moments with the data, following which an overall conclusion is drawn.

4.2 The Model

The simple RBC model is a representative agent model with a household and a firm. The household aims to maximise their utility function by subject to a budget constraint. They own all factors of production hence make investment decisions which is subject to a quadratic adjustment cost and participate in international financial market by buying or selling of bonds at exogenously set world interest rate. The firm produce output Y_t. The representative firm aims to maximise profit by optimally choosing capital and labour. Figure 4.1 provides a flow chart summarising the model.

As shown in Figure 4.1, household supplies labour to firm though labour market and receives wages and other incomes from the firm. The household participate in the good market by spending on goods and services through its consumption and investment decision. The economy is subject to two shocks – technology shock and world interest rate shock. The former shock affects production and latter affects cost of bonds. A full summary of each representative agent involvement in the economy with relevant expressions describing model equations are in the following sections.

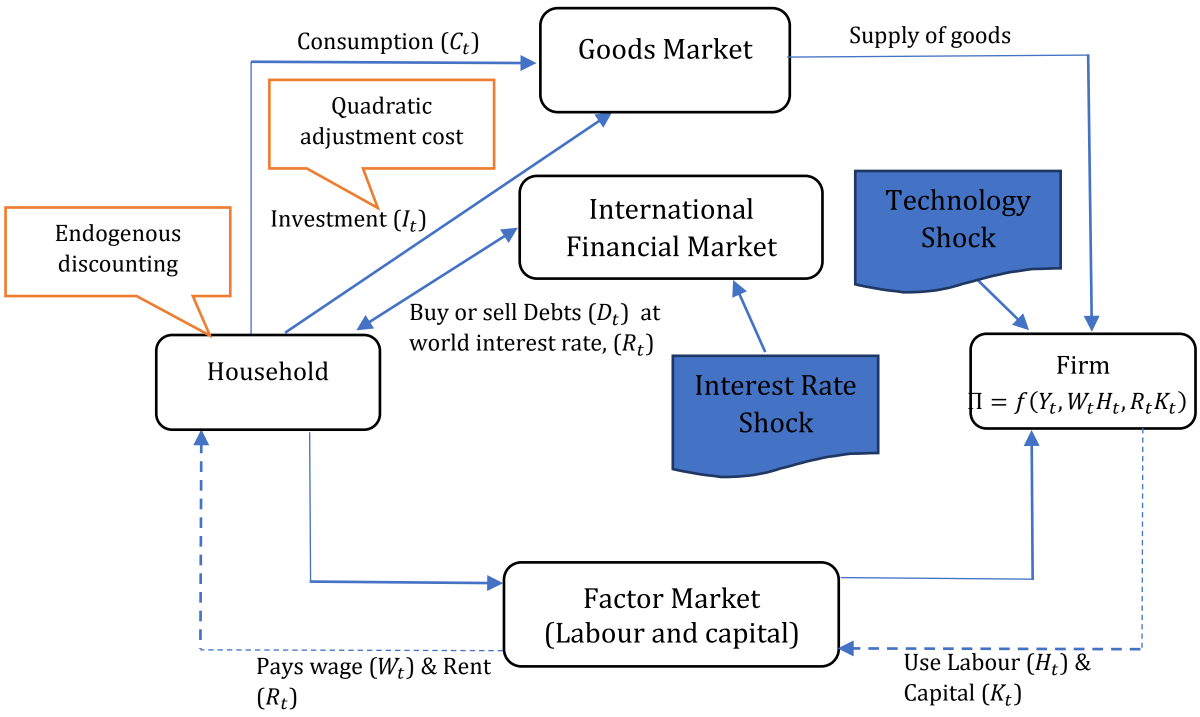


Figure 4.1: Flowchart showing representative agent RBC model

4.2.1 The Household

The household supplies labour H_t and consumes goods C_t at each time period t. The household derives their utility from consumption and leisure, L_t. The total time endowment of the household is normalised to 1 making hours available to leisure equals to $L_t = 1 - H_t$. The household holds debts D_t which carries interest R_t. The interest is exogenously set in world market. The household saving is the difference between the holding of debt between two periods $D_{t+1} - D_t$.

The properties of the household utility function and its resource constraints are described below.

4.2.1.1 *Utility function and budget constraint*

Utility of the agents features Constant Relative Risk Aversion (CRRA). Constant relative risk aversion implies that the utility function features constant intertemporal elasticity of substitution, (inverse of risk aversion parameter), and consumption and hours worked are homogenous of degree one such that its values can only alter when the relative prices change. As documented by Mendoza (1991), changes in the household risk aversion parameter in a small open economy does not change the variability of output. The representative household maximizes expected utility over the infinite sequence of consumption $\{C_t\}_{t=1}^{\infty}$ and leisure $\{H_t = (1 - L_t\}_{t=1}^{\infty}$.

Uzawa (1968) preferences uses an endogenously determined rate of time preferences based on consumption and leisure and combines the Greenwood et al (1988) style representation of utility, commonly referred as GHH preferences, where there is non-separability between consumption and hours worked. This style of utility representation eliminates the wealth effect on labour supply that enables amplification and propagation effects of shocks to hours worked in theoretical models consistent with data. In addition, Mendoza (1991) noted that this form of preference specification ensures that the model directs its focus solely on the dynamics of foreign assets and investments as vehicles for saving, which is a more relevant representation of choices available for representative agents in small open economies. Furthermore, Neumeyer and Perri (2005, p. 363) states that the use of this style of preferences has become norm in real business cycle literature, as the inclusion of GHH preferences improves models' ability to explain business cycle facts.

$$U_t = U(C_t, H_t) = E_0 \sum_{t=0}^{\infty} \frac{\theta_t (C_t - \chi \frac{H_t^{\omega}}{\omega})^{1-\sigma} - 1}{1-\sigma} \qquad 4.1$$

The utility function in (4.1), σ is the relative risk aversion parameter, which is also elasticity of intertemporal substitution where $\sigma \geq 1.01$. The parameter ω controls the Frisch elasticity of labour supply parameter which measures the responsiveness of hours worked to wage changes assuming constant marginal utility of consumption. This implies that the labour supply curve has a wage elasticity of $1/(1 - \omega)$. χ is a constant used to ensure steady-state hours worked is equal to the targeted 0.33. The E_0 is the rational expectation operator conditional on information available at period 0. This utility function also displays Constant Relative Risk Aversion in the first argument, $(C_t - \chi \frac{H_t^{\omega}}{\omega})^{1-\sigma}$. The functional form imposed on the utility makes this setup inconsistent with a balanced growth path as consumption and real wage would not be growing at the same rate in a steady state while hours are fixed. The intertemporal labour supply would be $W_t = \chi H_t^{\omega-1}$ enabling hours worked to be determined independent of the wealth effect. This formulation preserves the procyclical nature of employment as technological progress will not lead to decline in employment. One can ensure the balanced growth path in the model are consistent with the data by fixing parameters of the utility function and production function consistent with the long run growth averages.

The discount factor associated with the utility function, θ_t is endogenous and optimally determined by the choice of consumption, C_t and hours worked, H_t. It can also be seen in (4.1) that marginal rate of substitution depends on disutility associated with hours worked and hours worked is independent of any dynamics in consumption.

The law of motion of endogenous discount factor, θ_t follows:

$$\theta_0 = 1 \qquad 4.2$$

$$\theta_{t+1} = \beta(C_{t,}H_t)\theta_t \qquad \text{for } \forall\, t \geq 0 \qquad 4.3$$

$$\beta(C_{t,}H_t) = \left(1 + C_t - \chi \frac{H_t^{\omega}}{\omega}\right)^{-\Psi} \qquad 4.4$$

where $0 < \beta(C_{t,}H_t) < 1$, $\beta_C < 0$ and $\beta_H > 0$.

As demonstrated by Schmitt-Grohe' and Uribe (2003) the signs of the first derivative of the discount factor with respect to consumption and hours, make the model stationary where the non-stochastic steady state is independent of initial conditions relating to wealth, capital stock and technology. The discount factor depends on individual level of consumption and labour input in the previous periods and elasticity of discount factor Ψ. This representation implies that each household's periods choice of consumption and leisure would be determined based on their valuation of future period utilities.

The parameter Ψ plays an important role in stationarity and speed of convergence of the model. A positive and larger value of Ψ implies that the household becomes more impatient as the discount factor rises. In the subsequent sections, we can see the importance of this deep structural parameter in ensuring convergence and stationarity of the model.

The consumers face the following budget constraint in time period, t

$$D_{t+1} = D_t(1 + R_t) - Y_t + C_t + I_t + \frac{\emptyset_X}{2}(I_t - I_{t-1})^2 \qquad 4.5$$

where D_{t+1} is purchase (sale) of debt when $D_{t+1} > 0$ ($D_{t+1} < 0$) in time period $t + 1$, R_t is the gross interest rate paid on debt held at the beginning of period t and is determined exogenously in international capital market, and I_t is the gross investment. Investment is subject to a quadratic adjustment cost, $\emptyset_X$ which shows that there is a cost $\emptyset_X$ associated with accumulation of investment between periods. The functional form investment adjustment cost takes satisfy the following conditions: $\emptyset_X(0) = \emptyset'_X(0) = 0$. These restrictions imposed on adjustment costs are to ensure zero investment adjustment costs at a steady state and relative price of investment in terms of consumption goods is unity. The measurement used is the units of investment goods expressed in terms of final goods. Given these properties, instead of specifying a functional form, parameterising the adjustment cost based on data would still preserve the integrity of the conditions specified above. Y_t is the income the household receives following the distribution of periodic profit from the firm.

Investment adjustment costs have been introduced in the literature as an alternative to capital adjustment costs. Use of adjustment costs have become a standard specification property for small open economy models. According to Uribe and Schmitt-Grohe' (2017, p. 106), capital adjustment costs are typically introduced in small open economy models to mute 'excessive volatility of investment' in response to changes in productivity of domestic capital or foreign interest rate. Therefore, the use of any form of adjustment costs give rise to a 'hump-shaped' impulse response curve for investment and output. In this chapter, I use investment adjustment costs following Christiano, Eichenbaum, and Evans (2005) as it can match observed autocorrelation between investment and output in data, unlike capital adjustment costs.

4.2.2 The Firm

Output is produced by combining capital and labour as inputs using a Cobb–Douglas production function which satisfies the Inada conditions $\lim_{k\to 0} F_K(.) = \infty$ and $\lim_{k\to\infty} F_K(.) = 0$ for $\forall L > 0$ and $\lim_{L\to 0} F_L(.) = \infty$ and $\lim_{L\to\infty} F_L(.) = 0$ for $\forall K > 0$. Inada conditions are restrictions placed on the shapes of the production function. By satisfying Inada conditions, it guarantees existence of a stable path, which converges to an interior equilibrium.

$$Y_t = F(K_t, H_t) = A_t K_t^{\alpha} H_t^{1-\alpha} \quad 0 \leq \alpha \leq 1 \qquad 4.6$$

where Y_t is output, A_t is an exogenous productivity shock, K_t is beginning-of-period capital stock and H_t is labour hours.

The stock of capital evolves according to

$$K_{t+1} = (1-\delta)K_t + I_t \qquad 4.7$$

4.2.3 Closing the model

The economy is subject to two one period shocks – productivity and interest rate shock. The productivity and interest rate shock follows an AR(1) process with its law of motion given by:

$$\text{In}A_{t+1} = \rho_A \text{In}A_t + \epsilon_{t+1}^A; \qquad \epsilon_{t+1}^A \sim NIID\ (0, \sigma_\epsilon^2); t \geq 0 \qquad 4.8$$

$$\text{In}R_{t+1} - \bar{R} = \rho_R(\text{In}R_t - \bar{R}) + \epsilon_{t+1}^R; \qquad \epsilon_{t+1}^R \sim NIID\ (0, \sigma_R^2); t \geq 0 \qquad 4.9$$

The parameter ρ_A and $\rho_R \in (0, 1)$ are the persistence of technology shocks and interest rate respectively and σ_ϵ^2 and σ_R^2 captures the standard deviation of innovation to productivity shocks and innovation to interest rate.

The household chose sequence $\{C_{t,}H_{t_t}, B_t, , I_t, K_t, \theta_{t+1}, A_t, R_t\ \}_{t=0}^{\infty}$ so as to maximize the utility function (4.1) subject law of motion of discount factor (4.4), sequential budget constraint (4.5), production technology (4.6), equation of motion of capital (4.7) and a non-Ponzi constraint of the form

$$\lim_{j\to\infty} E_t \frac{B_{t+j}}{\prod_{s=0}^{j}(1+r_s)} \leq 0. \qquad 4.10$$

3.2.4 Non-stochastic Equilibrium

Taking$\theta_t\lambda_t^1$, $\theta_t\lambda_t^2$ and $\theta_t\mu_t$ as the Lagrange multiplier associated with the household budget constraint, endogenous discount factor, and shadow price of capital, the representative agent's maximisation problem can be written as:

$$\mathcal{L} = E_t \sum_{t=0}^{\infty} \theta_t \left[\left(\frac{\left(C_t - \chi\frac{H_t^\omega}{\omega}\right)^{1-\sigma}}{1-\sigma}\right.\right.$$
$$+ \lambda_t^1\left(B_t(1+R_t) + A_tK_t^\alpha H_t^{1-\alpha} - C_t - I_t - \frac{\emptyset_X}{2}(I_t - I_{t-1})^2 - B_{t+1}\right)$$
$$\left.\left.+ \mu_t\big((1-\delta)K_t + I_t - K_{t+1}\big) + \lambda_t^2\left(\left[1 + C_t - \chi\frac{H_t^\omega}{\omega}\right]^{-\Psi} - \frac{\theta_{t+1}}{\theta_t}\right)\right)\right]$$

The first order conditions associated with the maximization problem can be pinned down as described in (4.11)-(4.15).

$$\frac{\partial \mathcal{L}}{\partial C_t}:\ \lambda_t^1 = \left(C_t - \chi\frac{H_t^{\omega}}{\omega}\right)^{-\sigma} + \lambda_t^2\,\Psi\left(1 + C_t - \chi\,\frac{H_t^{\omega}}{\omega}\right)^{-\Psi-1} \qquad 4.11$$

$$\frac{\partial \mathcal{L}}{\partial H_t}:\ \lambda_t^1(1-\alpha)A_tK_t^{\alpha}H_t^{-\alpha} = H_t^{\omega-1}\left(C_t - \chi\frac{H_t^{\omega}}{\omega}\right)^{-\sigma} - \lambda_t^2\,\Psi\chi H_t^{\omega-1}\left(1 + C_t - \chi\frac{H_t^{\omega}}{\omega}\right)^{-\Psi-1} \qquad 4.12$$

$$\frac{\partial \mathcal{L}}{\partial K_{t+1}}:\ \theta_t\mu_t = E_t\theta_{t+1}[\lambda_{t+1}^1\alpha A_tK_t^{\alpha-1}H_t^{1-\alpha} + \mu_{t+1}(1-\delta)] \qquad 4.13$$

$$\frac{\partial \mathcal{L}}{\partial I_t}:\ \theta_t\lambda_t^1\big(1 + \emptyset_X(I_t - I_{t-1})\big) = \theta_t\mu_t + E_t\theta_{t+1}\lambda_{t+1}^1\big(\emptyset_X(I_{t+1} - I_t)\big) \qquad 4.14$$

Expression (4.11) and (4.12) are first order conditions with respect to consumption and hours worked and (4.13) and (4.14) are first order conditions with respect to K_{t+1} and I_t. (4.11) and (4.12) implies that the marginal rate of substitution between leisure and consumption depends only on hours worked.

The first order conditions with respect to bonds following substitution for $\beta(C_{t,}H_t)$ in (4.4) and the first order conditions for endogenous discount factor are expressed below in (4.15) and (4.16)

$$\frac{\partial \mathcal{L}}{\partial D_{t+1}}:\ \lambda_t^1 = \left[1 + C_t - \chi\frac{H_t^{\omega}}{\omega}\right]^{-\Psi}(1+R_t)E_t\lambda_{t+1}^1 \qquad 4.15$$

$$\frac{\partial \mathcal{L}}{\partial \theta_{t+1}}:\ \lambda_t^2 = -E_t\left(\frac{C_{t+1} - \chi\frac{H_{t+1}^{\omega}}{\omega}}{1-\sigma}\right)^{1-\sigma} + E_t\lambda_{t+1}^2\left[1 + C_{t+1} - \chi\frac{H_{t+1}^{\omega}}{\omega}\right]^{-\Psi} \qquad 4.16$$

The representative firm aims to maximise profit $(\max_{\Pi} E_t\sum_{t=0}^{\infty}\theta_t(Y_t - W_tH_t - r_t^KK_t)$ subject to (4.6) and (4.7). The first order conditions with respect to hours and capital associated with the firm problem is as follows:

$$(1-\alpha)A_tK_t^{\alpha}H_t^{-\alpha} = W_t \qquad 4.17$$

$$\alpha A_t K_t^{\alpha-1} H_t^{1-\alpha} = r_t^K \qquad 4.18$$

To derive the model moments, I start by combining (4.11) with (4.12) and substituting W_t with expression in (4.17) to arrive

$$(1-\alpha) A_t K_t^{\alpha} H_t^{-\alpha} = \chi H_t^{\omega-1} \qquad 4.19$$

Substitution of (4.19) back into (4.17) leads to the following expression.

$$W_t = \chi H_t^{\omega-1} \qquad 4.20$$

By defining $Q_t = \frac{\mu_t}{\lambda_t^1}$ where $\mu_t$the marginal utility from extra capital is installed and λ_t^1 is the marginal utility from additional consumption, I combine (4.13) and (4.14) to form

$(1 + \emptyset_X(I_t - I_{t-1}) =$

$$E_t\left[\theta \frac{\lambda_{t+1}^1}{\lambda_t^1}\left(\emptyset_X(I_{t+1} - I_t) + \alpha A_{t+1} K_{t+1}^{\alpha-1} H_{t+1}^{1-\alpha} + Q_{t+1}(1-\delta)\right)\right] \qquad 4.21$$

In the above expression $\theta = \frac{\theta_{t+1}}{\theta_t}$ which based on (4.2)-(4.4) reduces to $\beta\big(C_{t,}H_t\big)$.

Combining expression (4.11) with (4.15) provides the Euler equation where for convenience I define Λ_{t+1} as stochastic endogenous discount factor:

$$\Lambda_{t+1} = \beta\big(C_{t,}H_t\big) \; \frac{\lambda_{t+1}^1}{\lambda_t^1} \qquad 4.22$$

which translate in its long form as

$$\Lambda_{t+1} = \beta\big(C_{t,}H_t\big)\, E_t\left[\frac{U_{c,t+1}\big(C_{t+1,}H_{t+1} - \lambda_{t+1}^2\, \beta_{c,t+1}(C_{t+1,}H_{t+1})\big)}{U_{c,t}(C_{t,}H_t) - \lambda_t^2\, \beta_{c,t}\big(C_{t,}H_t\big)}\right] \qquad 4.23$$

I can write the Euler equation in compact form using the stochastic discount factor as $1 = (1 + R_t)E_t\Lambda_{t+1}$. The interpretation of the Euler equation is that at the margin, the household is indifferent between consuming a unit of good today or save it now for future consumption in the next period with interest payment.

Finally, taking first order conditions with respect to investment, (4.14) can be written as follows by defining $Q_t = \frac{\mu_t}{\lambda_t^1}$ where $\mu_t$the marginal utility from extra capital is installed and λ_t^1 is the marginal utility from additional consumption.

$$(1 + \emptyset_X(I_t - I_{t-1}) = E_t\left[\beta\left(C_{t,}L_t\right) \frac{\lambda_{t+1}^1}{\lambda_t^1}\left(\emptyset_X(I_{t+1} - I_t) + \alpha A_{t+1}K_{t+1}^{\alpha-1}H_{t+1}^{1-\alpha} + Q_{t+1}(1-\delta)\right)\right] \quad 4.24$$

In (4.24), Q_t is the standard Tobin's q which shows the amount of consumption goods that needs to be forgone to have an additional unit of future capital goods. If $\emptyset_X = 0$, then $\mu_t = \lambda_t^1$ making Q_t = 1. It is important to elaborate on the derivation of Q_t since at steady state, the efficiency condition must imply that two Euler equations (that is with respect to bonds and capital) are the same.

The first order condition with respect to capital in (4.13) after re-arranging and substituting Tobin's Q would imply

$$Q_t = E_t\left[\beta\left(C_{t,}L_t\right) \frac{\lambda_{t+1}^1}{\lambda_t^1}\left(\alpha A_{t+1}K_{t+1}^{\alpha-1}H_{t+1}^{1-\alpha} + Q_{t+1}(1-\delta)\right)\right] \quad 4.25$$

Using (4.18), we can define $Q_t$in (4.25) to be the present discounted value of the rental rate on capital (that is price of installed capital). In other words, Q_t is the shadow value, in consumption units, of a unit of K_{t+1} as of the time that the household makes its period t investment and capital utilization decisions. The function above is also the Euler equation for investment. In the steady state, the Euler equation for investment must be equal to the Euler equation for bonds (4.15). Using first order conditions with respect to capital reported in (4.13), we can prove that in the steady state these two Euler equations are indeed equal where it takes the form $\beta(C, H) = \frac{1}{1+r}$.

A point of caution with regard to the rental rate needs to be made here. The household receives rental income for the loaned capital which is determined as $r_t^K = \alpha A_{t+1} K_{t+1}^{\alpha-1} H_{t+1}^{1-\alpha} - \delta$. However, with an endogenous discount factor and investment adjustment costs, gross interet rate R_t would be a composite function of the rental rate r_t^K and Q_t as implied by equation (4.25). Using this, we arrive to gross return on capital as follows:

$$R_t = \frac{r_t^K + Q_{t+1}(1-\delta)}{Q_t} \qquad 4.26$$

In my model, the interest rate R_t evolves as a function of exogenous world interest rate and faced by domestic agents in the world financial market and the AR(1) shock process in (4.9).

A competitive equilibrium is a set of processes $\{D_t, C_t, H_t, I_t, Y_t, K_{t+1}, \lambda_t^1, \lambda_t^2, \ \mu_t\}$ following first order conditions (4.10)-(4.15), all holding with equality and given (4.8), (4.9), (4.10) and (4.22) and initial values pertaining to technology, capital and bonds. Using these and additional first order conditions from the firm's maximization problem we solve the model for its steady state as a function of its parameters. Upon which, the first order conditions of the model and steady state expressions are written in logarithms in MATLAB using Dynare. The rationale for writing in logs is to allow Dynare to solve the log-linearized model and report the moments in percentage deviations from its steady state for each variable. The codes used for estimation are provided in Appendix 4.1.

4.2.4 Deterministic Steady State

To solve the analytical steady state of the model, we take the steady state relationships for all variables in the manner consistent with the usual state where for instance $\lambda_{t-1} = \lambda_t = \lambda_{t+1} = \lambda$

The first order condition (4.14) using definition Q_t given in the previous section can be written as:

$$\theta_t\big(1 + \emptyset_X(I_t - I_{t-1})\big) = \theta_t Q_t + E_t\theta_{t+1}\frac{\lambda_{t+1}^1}{\lambda_{t+1}^1}\big(\emptyset_X(I_{t+1} - I_t)\big) \qquad 4.27$$

This expression can be used in steady state to pin down the value of Tobin's Q at steady state to be $Q = 1$. I have also normalised the technology at steady state to $A = 1$.

The Euler equation for bonds (4.15) at steady state becomes

$$1 = \left[1 + C - \chi\frac{H^\omega}{\omega}\right]^{-\Psi}(1 + R) \qquad 4.28$$

Using the definitions used elsewhere in the chapter for endogenous discount factor at steady state become $\theta = \left(1 + C - \chi\frac{H^\rho}{\rho}\right)^{-\Psi}$. By substituting this expression in (4.28) one can pin down the steady-state interest rate as

$$R = \frac{1}{\theta} - 1 \qquad 4.29$$

I can now determine stead state capita to labour ratio by evaluating (4.25) at the steady state which equals to $\alpha K^{\alpha-1}H^{1-\alpha} = {}^{1}/_{\theta} - (1 - \delta)$. Substituting in this expression (4.29) can be used to pin down steady state capital to hours ratio as follows.

$$\alpha K^{\alpha-1}H^{1-\alpha} = R + \delta$$

$$\left(\frac{K}{H}\right)^{\alpha-1} = \frac{R + \delta}{\alpha}$$

$$\frac{K}{H} = \left(\frac{R + \delta}{\alpha}\right)^{\frac{1}{\alpha-1}} \qquad 4.30$$

To work out hours worked at the steady state, I have used (4.19) to solve for H as follows.

$$(1 - \alpha)K^\alpha H^{-\alpha} = \chi H^{\omega-1}$$

$$H = \left[\frac{1}{\chi}(1 - \alpha)\left(\frac{K}{H}\right)^\alpha\right]^{\frac{1}{\omega-1}}$$

Using the definition og steady state $\frac{K}{H}$ in (4.30), one can re-write the above steady state hours expression as:

$$H = \left[\frac{1}{\chi}(1-\alpha)\left(\frac{R+\delta}{\alpha}\right)^{\frac{\alpha}{\alpha-1}}\right]^{\frac{1}{\omega-1}} \quad 4.31$$

The target steady state hours in this model is 0.33. To ensure this target is maintained at steady state, as shown in (4.31), one will need to solve for χ, given all the deep structural parameters of the model.

Consumption at the steady state can be pinned down from the household budget constraint where consumption is equal to

$$C = Y - I - RD \quad 4.32$$

In expression (4.32) R and D are parameters for steady state interest rate and debt level. Steady state level of investment can be derived directly from the equation for motion of capital $K = K - (1-\delta)K$. This expression at steady becomes

$$I = \delta K \quad 4.33$$

Steady state level of output is directly arrived using production function at steady state level as follows.

$$Y = K^{\alpha} H^{1-\alpha} \quad 4.34$$

Finally, trade balance to output ratio at the steady state is arrived using the national income identity as given below.

$$\frac{TB}{Y} = 1 - \frac{C-I}{Y} \quad 4.35$$

4.3 Dynamic Analysis

4.3.1 Calibration

The model features 10 parameters indicating there are 10 calibration targets. For the purpose of calibrating the model, the parameters are chosen such that the values of parameters ensure the model aggregates are able to match some of the empirical regularities observed for the Maldives. The values for calibration targets come from two main sources: microeconomic evidence and long run growth facts. For the latter, I have used the data showcased in Chapter 3 where relevant first and second moments to each respective parameter is assigned. Due to lack of availability of data and scarcity of microeconomic studies on the Maldives, some of the parameters are also directly taken from small open economy literature or are calculated according to steady state equations of the model.

In calibration of risk aversion, σ and the Frisch-elasticity, ω parameter, researchers use microeconomic evidence. Coefficent of relative risk aversion is calculated either through empirical studies of consumption (See Hall (1978) and Dynan (1993) or using consumer expenditure survey. Mehra and Prescott (1985), concludes that the coefficient of relative risk aversion is positive but not larger than 10. In small open economy literature, often a value of 2 is assigned to this parameter, but in emerging markets and developed markets, the parameter value most frequently used is 1. Therefore, to check the performance of the model, both 1.01[20] and 2.00 would be assigned to the relative risk aversion parameter due to lack of data and microeconomic studies for the Maldives.

Frisch intertemporal elasticity demonstrates the willingness to work in response to changes in wage rate, and in the literature the parameter value assigned ranges between 1 to 2. The main method of determining the inverse of the Frisch elasticity parameter, ω, is to calculate the percentage variability in hours worked. Smets and Wouters (2003) states that if the hours worked data are unavailable, which is the common case for most emerging and some of developed countries, one could get a reliable estimate from employment. For the Maldives, I have fixed 1.744 based on variance of employment.

For calibration of the depreciation rate (δ) and the world interest rate ($\bar{R}$) long run averages of relevant data has been used. Depreciation rate is calculated by taking the average depreciation from the data published by the Penn World Table, and world interest rate is calibrated by taking the average Federal Reserve fund rate from data. There is no consensus in the literature on how investment adjustment costs ($\emptyset_X$) is

[20] The utility function (1) requires $\sigma \neq 1$. When $\sigma \rightarrow 1$ the utility function collapses to $\log C_t - \omega \log H_t - \log \omega$ making it a 'log-log' preference specification. It also causes utility to be not bounded

measured. Many empirical studies measure investment adjustment costs by using aggregate investment data. For instance, Christiano et al (2005) estimates this parameter value to be between 0.5 to 3.24. However, Groth and Khan (2010) using evidence at firm level, shows that the parameter value for investment adjustment cost is positive but relatively small. Their studies estimate this value to lie between 0.0004 to 0.001. As the sole purpose of adjustment cost is to generate empirically consistent results and produce curvature in the relevant impulse response function; in this paper, I calibrate investment adjustment to match standard deviation of investment and set at 0.160. At the same time, for comparison purposes, an investment adjustment cost parameter value of 0.05 is set to match the counter cyclicality observed between output and external balances.

Hours worked data is calibrated using the average hours worked reported in the Census Report for the Maldives during 1985 to 2014. As the sum of hours worked and leisure are normalised to 1, we used the average hours worked per day reported in this census, to derive the fraction of hours worked in a day by an average worker. The parameter we calculated is consistent with the hours used in many empirical works featuring small and emerging economies.

In the steady state, as shown by Schmitt-Grohe and Uribe (2003), capital, investment, and output are independent of the elasticity discount factor (Ψ) with respect to composite of the utility function $C_t - \chi \frac{H_t^{\omega}}{\omega}$. At the same time from resource constraint (5), we can derive that in steady state, trade balance to GDP the ratio will be:

$$\frac{TB}{y} = 1 - \frac{c+i}{y}. \qquad 4.36$$

Based on the steady state equations, it implies that the value elasticity of the discount factor is influenced by trade-balance to GDP ratio. Therefore, the parameter Ψ, will be calibrated to match the steady state trade-balance to GDP ratio and would take the functional form of

$$\Psi = -\log\left(\frac{\frac{1}{1+\bar{R}}}{1+c-\chi\frac{H^{\omega}}{\omega}}\right) \qquad 4.37$$

The set of parameters to be calibrated and their relevant values are summarized in Table 3. The parameters featured in preferences, technology and resource constraints are referred as “deep parameters” which determines the dynamics of the model.

Parameter	Title	Source	Calibrated Value
α	Capital share of income	ratio of labour income to net national income at factor prices	0.33
R_bar	world interest rate	extracted from literature usually indexed to real interest rate of US economy	0.05
σ	Coefficient of risk aversion parameter	Fixed based on real business cycle literature.	and 2.00
ω	Frisch-elasticity parameter (Inverse labour supply elasticity)	Calibrated based on Heckman and MaCurdy (1980) and MaCurdy (1991). This figure must correspond to percentage of variability in hours	1.455 and 2.00
Ψ	elasticity discount factor w.r.t. to arguments of utility function	Calibrated to match trade-balance-to-GDP ratio at steady state.	various
χ	Labour hours parameters to control the hours worked at steady state	Calibrated to match steady state hours to 0.33	1.25
H	Steady-state hours worked	Calibrated using average daily hours worked for the Maldives normalised as a fraction in 24 hours	0.33

$\emptyset_X$	investment adjustment cost parameter	Calibrated to match standard deviation of investment or counter cyclicality of external balances	0.160 and 0.05
D	Steady state debt ratio	Derived from Schmitt-Grohe and Uribe (2003)	0.7442
δ	depreciation rate	Calibrated by taking long run average for depreciation reported in Penn World Data	0.10
ρ_A	autocorrelation of TFP	Using data on the Maldives for real GDP, Capital and Labour hours worked, A_t computed similar to Aguiar and Gopinath (2004) and coefficient for ρ_A is computed by running a first order autoregressive model of A_t in MATLAB.	0.52
ρ_R	autocorrelation of interest rate	Autocorrelation of Hamilton fileted Fed Rate data with Hamilton filtered real GDP.	0.30
ϵ^R	Standard deviation of TFP	Derived from Neumeyer & Perri (2004)	2.59%
ϵ^A	Standard deviation of interest rate	Derived from Neumeyer & Perri (2004)	1.89%

Table 4.1: Parameters values and sources

4.3.2 Estimation

The model is calibrated using the parameter values in Table 4.1, and business cycle properties of the model are reported for different parameter values in Table 4.2. The results of each series are detrended using the HP filter with the smoothing parameter of 100. The model moments, autocorrelation and cross correlation are reported along with its corresponding values estimated using the actual Maldives data reported in Chapter 3.

I decided to run the model for different parameter values suggested by literature, for utility and investment adjustment, to look at sensitivity of parameters and to determine the performance and fit of the model. In this regard, our benchmark model, which from here on referred as Model 1, is parameterised with $\sigma = 2, \emptyset_X = 0.050\ and\ \omega = 1.455$. Alternative parameterisations are featured in models 2, 3 and 4. For model 2, we vary the risk aversion by reducing it to σ =1.01 to make utility logarithmic. Model 3 re-parameterises model 1 by fixing the Frisch-elasticity parameter to $\omega = 2$ as frequently featured in emerging market literatures. Model 4 reparametrises model 1 by fixing investment adjustment cost to $\emptyset_X = 0.160$ to match standard deviation of investment as shown in the data. For the following section, we will first present the results of our benchmark model and then compare the results of the benchmark model with model 2-4.

The key differences between different models can be summarised by looking at the role of each parameter that is varied in the respective model. The relative risk aversion parameter, σ, governs consumption smoothing behaviour of household. A larger value for σ implies desirability of household to smooth consumption meanwhile a lower value of σ implies household do not have a strong desire to smooth its consumption overtime. Therefore, consumption path will be decreasing in volatility for larger σ. Therefore, the key difference between model 1 and model 2 is on household consumption smoothing behaviour which will impact external balances. They key difference between benchmark model and model 3 is on inverse Frisch elasticity parameter ω where in model 3 labour supply elasticity is much more inelastic compared with model 1. As a result, one would expect a much more sluggish hours response in model 3 compared to model 1 which will feed to output and external balances. Model 4 differs from benchmark model in terms of investment adjustment cost, $\emptyset_X$. Intuitively, the larger the investment adjustment cost, the smaller the investment and capital accumulation. This would imply that in response to a positive shock which increases output, consumption will have a larger jump and volatility when $\emptyset_X$ is larger (model 4) compared with model 1.

4.3.3 Transmission Dynamics

Based on first order conditions and steady state relationships, we can summarise the dynamics of our model through the principles in subsequent paragraphs. the first paragraph outlines basics for dynamics we expect to see in hours, consumption, capital and investment, while the second paragraph summarises the dynamics for trade balance and current account.

Holding fixed level of labour input, wealth determines the level of consumption. Given this, steady state expression (4.32) implies that consumption growth is determined by real interest rate. As consumption is invariant to wealth effect, any positive wealth shock, such as the TFP shock, would leave the labour supply schedule unchanged. Labour demands by the firm depends positively on the level of investment and productivity and wages is the only determinant of labour supply. A positive productivity shock will therefore increase the labour demand and hours worked which will increase the output. Given the substitution between hours worked and leisure, it is important to note that the Frisch-elasticity parameter value plays a key role in transmission, especially when it comes to technological shock. A larger Frisch-elasticity parameter makes the labour supply curve flatter by creating a more responsive effect on quantity of labour employed for any change in labour demand associated with shocks. Such a setup would therefore amplify the effect of shocks on labour hours worked in transmission dynamics.

The household aims to smooth consumption overtime and uses borrowing (saving) and investment as vehicles for achieving this goal. However, due to the presence of investment adjustment costs, the rate of investment growth is expected to be slow and therefore consumption would respond more to shocks. In an incomplete financial market setting, changes to domestic absorption defined by the sum of consumption and investment relative to output growth, will determine the directional effect of the trade balance and current account. For instance, if there is a rise in consumption relative to real GDP, a deterioration of the current account would imply that the agents are selling bonds to finance the consumption; hence the rise in bonds and the deterioration of the current account and trade balance as there would be a rise in imports.

4.3.4 Impulse Response functions

The behaviour of the aggregate economy in response to a shock can be summarised using impulse response functions. As noted earlier, the calibration of model 1 stands as a benchmark model and I have varied a parameter from the benchmark model to determine the extent to which the model results differ from benchmark model. Figure 4.2 reports the impulse response of technology shocks (1%) for the benchmark model where the key deep parameters take upon the values of $\gamma = 2$; $\emptyset_X = 0.05$ and $\omega = 1.455$.

The vertical axis of impulse responses shows the percentage deviation from the steady state following a shock, and the horizontal axis features the number of time periods under consideration. Period 0 is also known as the 'jump period' where in response to a shock, the variable jumps from its steady-state growth rate. The periods following this jump shows the convergence path in years to steady state.

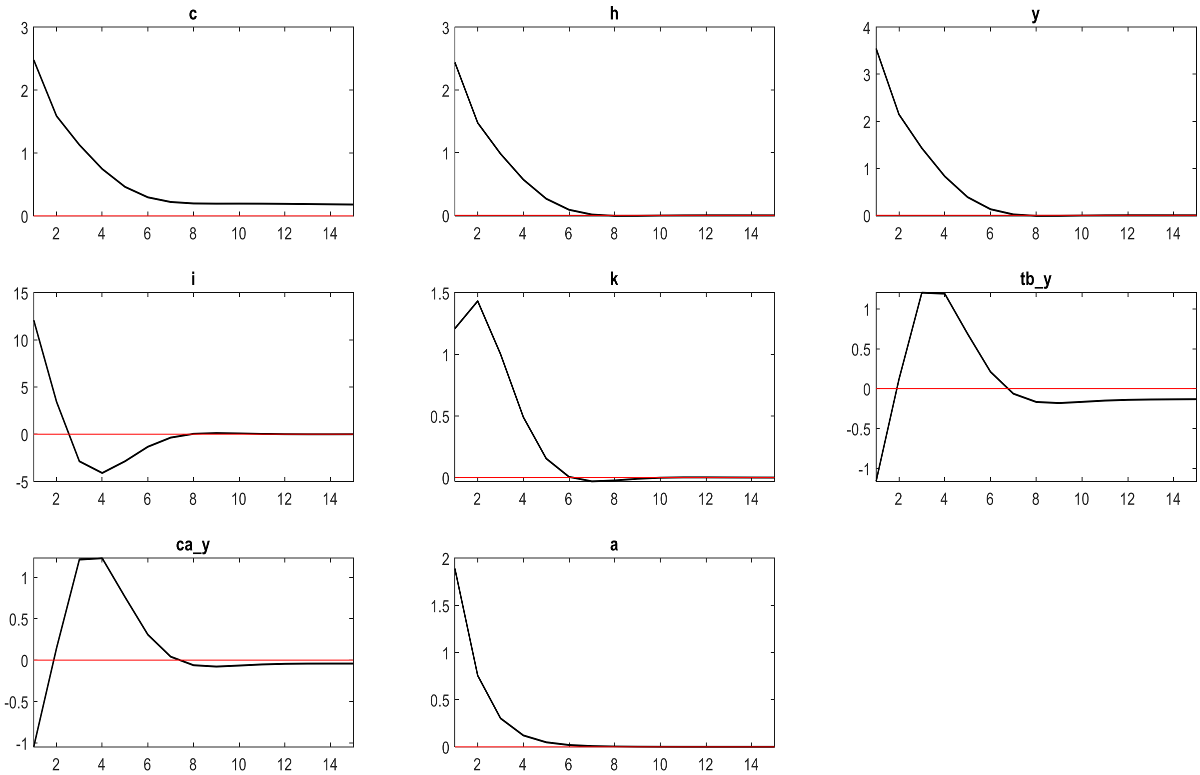
A technological shock alters the output, consumption, investment, hours worked, output per labour-hour, real wages, external balances, and the real interest rate through principles in the previous section. As shown in Figure 4.2, a technological shock causes consumption, hours worked, output, investment, and capital to increase while current account and trade balance deteriorate. There are two are two main propagation mechanism which contributes to these paths in real variables.

Firstly, due to a positive technology shock, firms accumulate capital as such a shock result in increase in the marginal product of capital and labour. As real interest paid on capital and wages paid to labour are both indexed to their respective marginal productivities, this would result in a rise in the household income which contributes to a rise in consumption and output. At the same time, investment by the firms would increase along with capital stock, due to rise in output and marginal productivities in the next period. Secondly, due to changes in the marginal productivity of labour, there would be intra-temporal substitution between hours worked and leisure. As the higher marginal product increases demand for labour hours, the household would substitute more hours for leisure.

The combined effects on aggregates as shown in Figure 4.2 is consumption, output, hours worked, capital and investment has increased against its steady state rate. Looking at the figure, one can see that investment jumps the most (that is by 12.50%) due to technology shock. This is partly associated with higher elasticity of investment with respect to shadow price of capital, as we parameterised $\emptyset_X$to be 0.05. At the same time, the rise in consumption (3.28%) is less than the rise in output (4.69%) indicating that not all income is consumed. This is due to the consumer's need to smooth consumption over time which results in saving by the representative household for the future. The preference specification indicates that due to technological shock, labour hours worked would increase from steady state (initial jump is 3.23%) as the firm's demand for more labour and the representative household substitute hours for leisure.

In response to technology shock, the impulse responses relating to external balances – current account to output ratio and trade balance to output ratio - both decreases by 0.63% and 0.71% respectively. The strong counter cyclicality of the current account and trade balance with output is a specific feature of small and emerging economies. This new transitional dynamic is the result of bonds accumulation by the representative household following the technology shock. The household saves or borrows in this model through purchase or sales of foreign bond. This implies that model economy's trade balance will be the difference in income and gross domestic absorption ($TB_t = Y_t - C_t - I_t$) and expressed as ($CA_t = D_t - D_{t-1}$). If the rise in income measured by output is greater than domestic absorption as measured by the sum of consumption and investment, then the trade balance of the country will improve as the household acquires less foreign bonds. Otherwise, trade balance will deteriorate as the household finances part of the current absorption by borrowing from the rest of the world. Therefore, as explained in the previous paragraph, since rise in output is less than domestic absorption (4.69% < (3.28% + 12.5%), both current account and trade balances will deteriorate following the impact of the shock.

Figure 4.2 also shows that investment overshoots from its steady state on impact compared with the capital stock. This is because capital stock grows at its fastest on impact, and growth rate slows, causing larger growth investment. An important note from the impulse response functions is that the behaviour of investment is a mirror image of changes in external balances. This implies that investment is responsible for generating the countercyclical initial responses in trade balance. The effect of technology shock lasts for 8 period for most variables. Another important point to note is that, in the theoretical model, the growth rate in investment as a result the shock is closely correlated with the output as shown in the relevant impulse responses. This is a major improvement to the real business cycle models as a result of using investment adjustment costs, which the conventional business cycles cannot replicate despite being evident from data. As the presence of investment adjustment costs causes the growth rate of investment to be sluggish in response to technology shocks; causing consumption to grow at a higher rate than investment, as evident from the impulse responses, consumption growth rate gradually surpasses the investment growth rate.



Legends of impulse responses are as follows:
(c: consumption; h: hours, y : output, i: investment, k: capital, tb_y: trade balance to output, ca_y: current account to output, a: TFP)

Figure 4.2: impulse response functions following a 1% positive technology shock ($\sigma = 2$; $\emptyset_X = 0.05$ $\omega = 1.455$)

In Appendix 4.1, Figure 4.1.1 documents the impulse response functions under alternative parameterisation which forms model 2, 3, and 4 along with model 1. In model 3 ω is increased to 2 making labour elasticity more inelastic. Given the large shift in the labour demand curve to the left because of positive productivity shock, hours fluctuate less compared to Figure 4.2 (3.23% against 1.89%) at impact. The increase in output in model 2 as result is smaller which results in lower increase in consumption, investment and capital accumulation compared to model 1. As the rate of output increase and domestic absorption increase is much weaker than model 1, much smaller effects on the current account and trade balance are observed in model 3. Therefore, we can conclude that the larger Frisch-elasticity parameter reduces the magnitudes of dynamics, and reduces amplification, as standard deviation of output, hours and consumption falls.

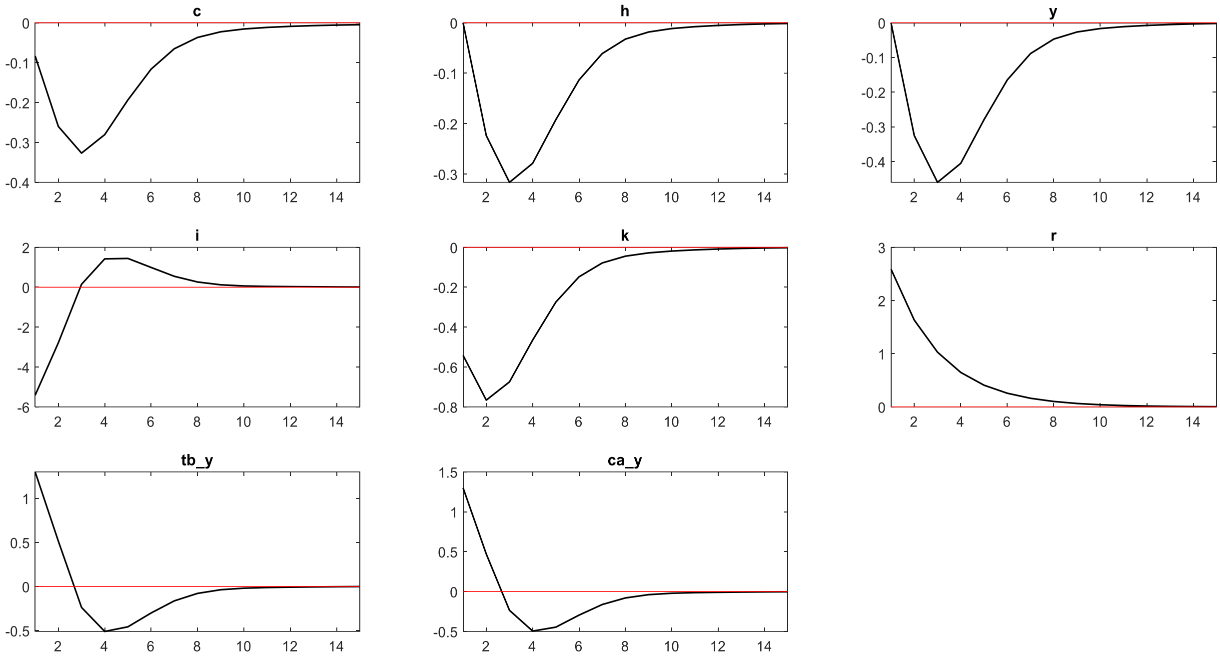
Figure 4.3 presents impulse response functions following a shock to international interest rates for model 1 (rise in interest rate). The propagation mechanism of world interest rate shocks affects all aggregate variables in subsequent periods. As the interest rate directly enters consumption, investment, capital and external balances, the shock is initially felt in these real variables. Hours and output react after the jump period in response to changes in the above variables. The main channel of transmission for interest rate shocks comes from a combination of the capital accumulation effect and the intertemporal substitution effect. The latter has a lagged response compared with the capital accumulation effect. As predicted by theory, in response to world interest rate shocks, the cost of borrowing rises leading to lower investment, which then translates into lower capital accumulation. As current period capital is financed using previous period interest rates, there is no immediate effect on hours worked. However, in the following period, hours worked falls due to decrease in demand for labour as both investment and capital has fallen. Consumption reduces in the jump period in response to a rise in the opportunity cost of consumption associated with higher interest rate. Since hours worked and capital in this period are both determined by the previous period interest rate, output at the jump period remains unresponsive to the shock. Reduction in consumption and investment implies trade balance, and current account improves as domestic residents save through international markets.

In response to interest rate shock, at the jump period, hours do not change. This is due to the marginal product of labour being constant, thus no effect on the labour demand curve. On the following period $t + 1$, hours fall by 0.50 per cent. The output follows the same path of employment where output falls in $t + 1$ period by 0.45 per cent. Following the shock, consumption, investment, capital, and foreign bonds fall at the jump period.

The path for consumption can be traced from the first order condition for bonds (4.15) and the steady state expression of consumption (4.32). The log-linearized steady state expression for consumption shows that relative deviation in consumption is a result of the product of two terms: the product of percentage deviation in interest rate from its steady state rate with elasticity of endogenous discount factor, and percentage deviation in hours with the Frisch-elasticity parameter as the following:

$$\frac{C_t - C}{C} = -\Psi \frac{R_t - R}{R} - \omega \frac{H_t - H}{H}$$

In the above expression, C and H without time subscript, indicates steady state values for each respective variable. This expression implies that a jump period, since change in hours are zero, effect on consumption would come from the product of elasticity of discount factor, and percentage deviation of interest rate from its steady state values. Since the shock to interest rate is magnitude 1 percent, the change in consumption at the jump period is relatively small at -0.0006 per cent. However, at t+1 as hours fall by 0.31 per cent, the consumption fall is much larger, equal to 0.003 per cent. The largest jump in response to interest rate shock lies with investment and bonds, as one would expect, due to changes to the cost of borrowing and yields. Due to the shock, saving increases and investment decreases, which creates current account and trade balance surpluses, as predicted in standard neoclassical models.



Legends of impulse responses are as follows:
(c: consumption; h: hours, y : output, i: investment, k: capital, tb_y: trade balance to output, ca_y: current account to output, r: real interest rate)

Figure 4.3: impulse response functions following 1% increase in world interest rate ($\sigma = 2;\ \emptyset_X = 0.05\ \omega = 1.455$)

In Appendix 4.1, Figure 4.1.2, the impulse responses following interest rate shock under different parametrisations are presented. The impulse responses show similar patterns, and all parameterisation is able to match the observed counter cyclicality of trade balance and current account with real GDP. It also shows that in response to a technology shock, the initial jump in consumption is the same for all models, except model 3, where changes in the Frisch-elasticity parameter lowers the consumption jump period 0. It also shows that model 1 and model 2 have similar dynamics in response to technology shocks, indicating that changes in degree of risk aversion has a very limited effect on transmission dynamics as hours worked which subsequently will affect the capital, investment and output is not affected by changes in risk aversion.

It can be seen from Figure 4.1.2, that both model 1 and model 2 show similar dynamics indicating changes in degree of risk aversion does not produce significantly different transmission dynamics. However, as evident from Figure 4, changes in the Frisch elasticity parameter and the investment adjustment cost parameter, produces different dynamics in response to technology shocks compared with the benchmark model and each other.

4.4 Model moments with data

The business cycle properties of the theoretical model are summarised by its unconditional second moments. Table 4.2 presents the unconditional second moments of theoretical models along with the empirical results obtained for the Maldivian economy using data set 2. All choices of parameterisation were able to match some of the theoretical moments with those of empirical moments. Model 1 is the baseline model which uses parameter values in Table 4.1. The model economy simulated using baseline parameters of $\sigma = 2$ using $\emptyset_X = 0.05$ and $\omega = 1.455$ was able to match most unconditional theoretical moments with the data. Model 1 is able to match the standard deviation of output, investment, to a close degree with the data while consumption and capital were underreported. It is also able to replicate the contemporaneous correlation coefficient of investment to output ratio while observing the inverse relationship between external balances with output. At the same time, the model can match the persistence of external balances, consumption and capital closely. Compared with the baseline model, Model 2's risk aversion parameter was changed from $\sigma = 2$ to $\sigma = 1.01$, the results are broadly similar for most aggregates. The autocorrelation and persistence appear to have increased for some aggregates. The external balance persistence however has fallen compared with model 1 as household relies less on current account for consumption smoothing. The similarity in result is due to the relative risk aversion not be a factor affecting the model's steady-state equations except for the utility and shadow price of the household resource constraint, which results in minor changes compared to what is observed in model 1.

x = variable	Maldivian Data			Model 1 $\sigma = 2;\ \emptyset_X = 0.05;$ $\omega = 1.455$			Model 2 $\sigma = 1.01;\ \emptyset_X = 0.05;$ $\omega = 1.455$		
	σ_x	$\rho_{xt,GDP,t}$	$\rho_{x,t}, \rho_{x,t-1}$	σ_x	$\rho_{xt,GDP,t}$	$\rho_{x,t}, \rho_{x,t-1}$	σ_x	$\rho_{xt,GDP,t}$	$\rho_{x,t}, \rho_{x,t-1}$
GDP	4.28	1	0.12	4.55	1	0.61	4.55	1	0.62
Consumption	1.31	0.35	0.59	0.77	0.95	0.69	0.78	0.96	0.69
Hours	0.98	0.06	0.46	0.69	1.00	0.61	0.69	1.00	0.62
Investment	4.08	0.36	0.47	3.37	0.58	0.33	3.76	0.59	0.33
Capital	1.26	0.23	0.70	0.55	0.88	0.80	0.56	0.88	0.80
Current account to output	0.61	-0.04	0.55	2.72	-0.01	0.51	2.72	-0.02	0.49
Trade balance to output	0.64	-0.08	0.45	2.83	-0.04	0.52	2.81	-0.07	0.49

x = variable	Maldivian Data			Model 3 $\sigma = 2;\ \emptyset_X = 0.05;$ $\omega = 2.00$			Model 4 $\sigma = 2;\ \emptyset_X = 0.160;$ $\omega = 1.455$		
	σ_x	$\rho_{xt,GDP,t}$	$\rho_{x,t}, \rho_{x,t-1}$	σ_x	$\rho_{xt,GDP,t}$	$\rho_{x,t}, \rho_{x,t-1}$	σ_x	$\rho_{xt,GDP,t}$	$\rho_{x,t}, \rho_{x,t-1}$
GDP	4.28	1	0.12	3.44	1	0.54	4.26	1	0.55
Consumption	1.31	0.35	0.59	0.66	0.85	0.72	0.78	0.93	0.65
Hours	0.98	0.06	0.46	0.50	1	0.54	0.68	1.00	0.55
Investment	4.08	0.36	0.47	2.91	0.61	0.35	2.08	0.68	0.54
Capital	1.26	0.23	0.70	0.49	0.80	0.81	0.43	0.74	0.87
Current account to output	0.61	-0.04	0.55	1.83	0.31	0.64	1.52	0.38	0.70
Trade balance to output	0.64	-0.08	0.45	1.95	0.24	0.67	1.62	0.26	0.74

(Note: all standard deviations are expressed relative to GDP.)

Table 4.2: Business cycle properties of simulated model and actual data

Model 3 changes baseline model's parameter for inverse of Frisch elasticity from 1.455 to 2.00. Such a change would make labour supply elasticity relatively inelastic, indicating it would become less responsive compared to before, to wage changes. As we can see from theoretical results, the changes in the Frisch elasticity parameter reduces standard deviation of hours and decreases persistence of hours. In terms of matching model moments with data, re-parameterisation is unable to match most of the moments including reversal of correlation between trade balance and GDP. Model 4 re-parameterises baseline model's investment adjustment cost from 0.05 to 0.160, as unlike the rest of the models, its fit with the data worsens compared with all the other models.

A point to note from the theoretical model is that, while I am able to generate standard deviation of investment to be higher than consumption, I am unable to match the common order of volatility where consumption is more volatile than output, as demonstrated in data and literature of EME business cycle. One of the reasons for this could be due to the fact that by construction of utility function, hours worked do not impact on consumption. It can also be seen from comparison of Model 1 and Model 4, higher adjustment makes investment and output fluctuate less with increase in persistence for investment, while the correlation between output and investment worsens. A higher investment adjustment cost makes investment less responsive to changes in its shadow price. In the standard real business cycle models with capital adjustment costs, it is generally unable to match this relationship between output and investment.

García-Cicco et. al (2010) offers a more robust explanation on why RBC models are unable to observe a higher relative volatility of consumption than output. As shown in Figure 4.2, in response to a positive productivity shock output increases on impact but then it gradually falls to its pre-shock level. This implies that household, to smooth their consumption would start to save rather than borrow which will result in consumption to gradually fall. The impulse responses also shows that the magnitude of increase in consumption initially and the eventual fall, is less than the path of the output making consumption to be less volatile than output.

In open economy business cycle models, investments are more volatile compared with closed economies since the difference between investment and saving is financed from international capital markets compared with closed economies where saving is equal to investment. At the same time, as noted by Mendoza (1991), a classic feature of small open economies is the separation of saving from investment where, in response to technology shocks, intertemporal smoothing or substitution of consumption is irrelevant for investment decisions; as representative agents would always achieve optimal saving through the current account while interest rate is exogenous and fixed, making consumption and investment separate. The results in Table 4.2 appear to support this feature of small open economies as we vary the relative risk aversion parameter.

Overall, the baseline model matches with the data on Maldives to some degree. While I am able to match standard deviation of output and investment, contemporaneous correlation with output only matches weakly to external balance. Persistence of consumption, capital and external balances are closely matched with data. As described above, some the model moments do not correspond to the stylised facts due to limitation of RBC model itself such as inability to match consumption volatility and underreporting of hours. When accounted for simple nature of this model which omit persistent rigidities in markets, structure of economy and data issues outlined in the previous chapter, one can conclude that the benchmark model does a reasonable job in replicating some of the saliant features of the Maldivian economy. The results also report some anomalies with stylised facts such as extremely large cross-correlation between consumption and output regardless of assumed parameterisation for relative risk aversion.

4.5 Variance decomposition

The variance decomposition explains the contribution of each shock to the relevant macroeconomic variable in our model. The variance decomposition for the baseline model is presented in Table 4.3.

		Percentage contribution by each shock on each variable						
Parameters	Shock Type	C	H	Y	I	K	TB/Y	CA/Y
$\gamma = 2;\quad \emptyset_X = 0.05$	Technology	97%	97%	97%	82%	74%	67%	66%
	Interest Rate	3%	3%	3%	18%	26%	33%	34%

Table 4.3: Variance Decomposition

Variance decomposition shows that the predominant driver of the business cycle is technology shock. However, it also shows that contrary to common assumption of RBC models, when interest rate shock competes with technology shock, part of the changes in real variables are driven by interest rate shock. Interest rate shock plays a bigger role in external balances, investment, and capital.

4.6 Empirical Strategy

This section aims to evaluate the empirical fit of the RBC model developed in this chapter, both by establishing whether if informally calibrated parameters and moment matching when replaced with formal systems estimation, can support the simple RBC model. The estimation would allow me to understand whether the cyclical fluctuation documented in the previous sections can be supported from data.

In the literature, formal estimation of these models is done using various approaches. Some of the more established methods used in estimation in the literature includes Maximum Likelihood (ML), General Method of Moments (GMM) and Bayesian estimation. An and Schorfheide (2007), Kydland and Prescott (1996), Hansen and Heckman (1996), and Sims and Zha (1998) provide a succinct explanation on merits and issues with these frameworks.

For the purpose of this thesis, I will where appropriate, be using the Bayesian estimation. As discussed in An and Schorfheide (2007), the Bayesian estimation offers three distinct advantages over the established methods. Firstly, the Bayesian estimation uses general equilibrium setup to impose cross-equation restrictions, taking into account all model features, making this method more efficient compared with those partial equilibrium approaches. Secondly, the combination of priors which captures one's belief about parameters is more robust in determining the model parameters rather than relying purely on maximum likelihood estimation. As noted by Del Negro and Schorfheide (2011) the Bayesian framework allow for information from multiple sources to be combined to arrive robust results. Finally, the estimation of the model is based on the likelihood functions that are derived from the theoretical model. Similar to any estimation technique, the effectiveness of the Bayesian estimation lies with appropriate specification of the model and quality of data that can provide adequate information on parameters of interest.

The estimated model in this section will be done by combining estimated parameters with the calibration parameters due to the small size of the model presented. An additional reason for doing this is due to the nature of data being fed into the model not being rich enough to identify the vast number of parameters used in this model. As this model features only two shocks, I can only provide two data series. For this purpose, I have selected to provide data relating to real interest rate and output. All series are in logarithms. Born & Pfeifer (2014), Jiang (2016) states that all data used in estimation should be filtered using one-sided HP filter. While I have established in Chapter 3 Hamilton filter is a superior choice, as there is lack of empirical evidence on use of Hamilton filter in estimation, I have decided to avoid any controversy by using one-sided HP filter for the two series used in this estimation. Table 4.4 identifies the parameters estimated from those calibrated parameters used in Table 4.1 in the previous section.

Parameter		Calibrated Vs estimated
α	Capital share of income	0.33
R_bar	world interest rate	0.04
σ	Coefficient of risk aversion parameter	2.00
ω	Frisch-elasticity parameter	1.455
Ψ	elasticity discount factor w.r.t. to arguments of utility function	various
H	Steady-state hours worked	0.33
$\emptyset_X$	investment adjustment cost parameter	0.05
δ	depreciation rate	0.10
ρ_A	autocorrelation of TFP	Estimated
ρ_R	autocorrelation of interest rate	Estimated
ϵ^A	Standard deviation of TFP	Estimated
ϵ^R	Standard deviation of interest rate	Estimated

Table 4.4: Estimated Vs Calibrated Matrix

4.6.1 Bayesian Estimation

The parameters identified in Table 4.4 are estimated using the Bayesian Estimation. An and Schorfheide (2007) provide a detailed account of the Bayesian estimation in the

DSGE models. The process of Bayesian estimation starts with assignment of priors on estimated parameters. Priors communicates one's assumptions about distribution of parameters. Taking the model as given, Kalman filter is used to compute the likelihood functions from the data. The priors assumed in Table 4.4 acts as weights on the likelihood function. For each estimated parameters posterior kernel is computed by combining likelihood function with priors. The posterior kernel for each estimated parameters needs to be maximised where for a parameter to be identified appropriately the log-posterior kernel should not be flat. The maximisation of posterior kernel then computes an approximation for prior mode for each respective parameters. The posterior mode is then used to compute posterior mean for each estimated parameter. The estimation process uses a sampling technique known as Metropolis-Hastings (MH) algorithm (commonly used in Dynare as Monte Carlo Markov Chain (MCMC) to obtain the relevant posterior distribution for each estimated parameter. The numerical method used in MH algorithm can be found in An and Shorfheide (2007), Fernandez-Villaverde (2010), Guerrón-Quintana and Nason (2012) and Del Negro and Schorfheide (2011, 2013). Under the assumption of normal distribution, MH simulates the posterior kernel and combine with the posterior mode simulation. During this process, from each posterior density function, samples are drawn which is unknown at the outset. After each draw estimated parameters are updated. When sufficient draws are obtained in each parallel MH chain, the posterior density, mean and variance for each parameter distribution is obtained.

The parameters to be estimated, for notional convenience is contained in a vector Θ. This parameter vector, Θ is estimated conditional on data, $X^T = \{x_1, \dots, x_T\}$ using Bayes theorem as

$$p(\Theta|X^T) = \frac{L(\Theta|X^T)p(\Theta)}{\int L(\Theta|X^T)p(\Theta)\mathrm{d}\Theta}$$

where $p(\Theta)$denotes the prior distribution of the parameter vector Θ, $(\Theta|X^T)$ is the likelihood of parameters given data $X^T$with T observations (evaluated using Kalman filter), and $\int L(\Theta|X^T)p(\Theta)$ is the marginal likelihood. As one could not obtain a closed form solution for the posterior, it must be simulated.

The use of prior is to specify the knowledge one has about an estimated parameter. As stated by Del Negro and Schorfheide (2008, p.1) prior distributions either reflect subjective opinions or summarize information derived from data sets not included in the estimation sample'. In the Bayesian estimation exercise of this chapter, the choice of priors for the estimated parameters are informed from literature. For instance, An and Schorfheide (2007), Del Negro and Schorfheide (2008) and Lubik and Schorfheide (2006) uses beta distribution (B) and inverse gamma distribution (IG) to specify the prior distribution for autocorrelation and standard deviation of shock respectively. As noted by Castillo et al. (2006), inverse gamma distributions are used for parameters that are strictly positive, beta distribution is used for probabilities and normal distribution is used when more information on the parameter is needed. The standard deviation of shocks therefore follows an inverse gamma distribution. The choice of prior distribution will determine the prior domain. For instance, domain of a beta distribution is $[0,1)$ while for an inverse gamma distribution, the domain of the prior is $\mathbb{R}^+$. The domain of the prior distribution function will influence the prior standard deviation.

The uncertainty of information about a parameter is captured through standard deviation of a prior. A smaller prior standard deviation indicates that we are almost certain that the value of the prior is centred around a specific data point. Given the uncertainty surrounding the nature of the parameters estimated for the Maldives, I have set prior standard deviations as large as possible based on the domain of prior function. The choice of prior, their mean and standard deviation for each parameter is listed in in column III and IV in Table 4.5.

Parameter (I)	Description (II)	Prior Distribution & Prior mean (III & IV)		Posterior	
				(V)	(VI) 90% HPD interval
ρ_A	Autocorrelation of technology shocks, A	B [0.8 0.25]	0.80	0.18	[0.0205 0.3332]
ρ_R	Autocorrelation of interest rate shocks,	B [0.8 0.15]	0.80	0.98	[0.7978 1.000]
σ_ϵ^2	Standard Dev ϵ_{t+1}^A	IG [0.01 2.00]	0.50	1.01	[0.8211 1.2060]
σ_R^2	Standard Dev ϵ_{t+1}^R	IG [0.01 2.00]	0.40	0.162	[0.1323 0.1951]
Log-data density (Laplace approximation)					-129.092332
Convergence Diagnostics		Block 1	Block 2		Block 3
Acceptance Ratio		31.8487%	31.85475%		31.8878%
MCMC inefficiency factor, ρ_A		18.184	17.867		19.197
MCMC inefficiency factor, ρ_R		21.653	19.438		20.994
MCMC inefficiency factor, σ_ϵ^2		19.313	19.573		18.876
MCMC inefficiency factor, σ_R^2		19.052	17.974		19.197

B = Beta Distribution, N = Normal distribution and IG = Inverse Gamma Distribution

Table 4.5: Prior and Posterior

4.6.2 Model Identification

Model identification is carried out using the Fisher information matrix. This identification analysis was first suggested by Rothenberg (1971). As Rothenberg points out, the information matrix "is a measure of the amount of information about the unknown parameters available in the sample." The sensitivity component shows each estimated parameters effect on the model behaviour.

Figure 4.4 shows the Identification is done using the Fisher information matrix introduced by Rothenberg (1971). The upper panel shows the identification strength at prior mean. This identification provides an indication on the level of information contained in the dataset on the parameter being estimated. The parameters are presented in the order of their strength of the identification relative to the value. The lower panel shows the sensitivity of each parameter. The sensitivity component of identification shows how each parameter effects the model behaviour. As shown by this side of the panel, all the parameters have non-negligible impact on the moments in the model. This, therefore, confirms that both the necessary and sufficient conditions for identification as discussed in Iskrev (2010) are met.

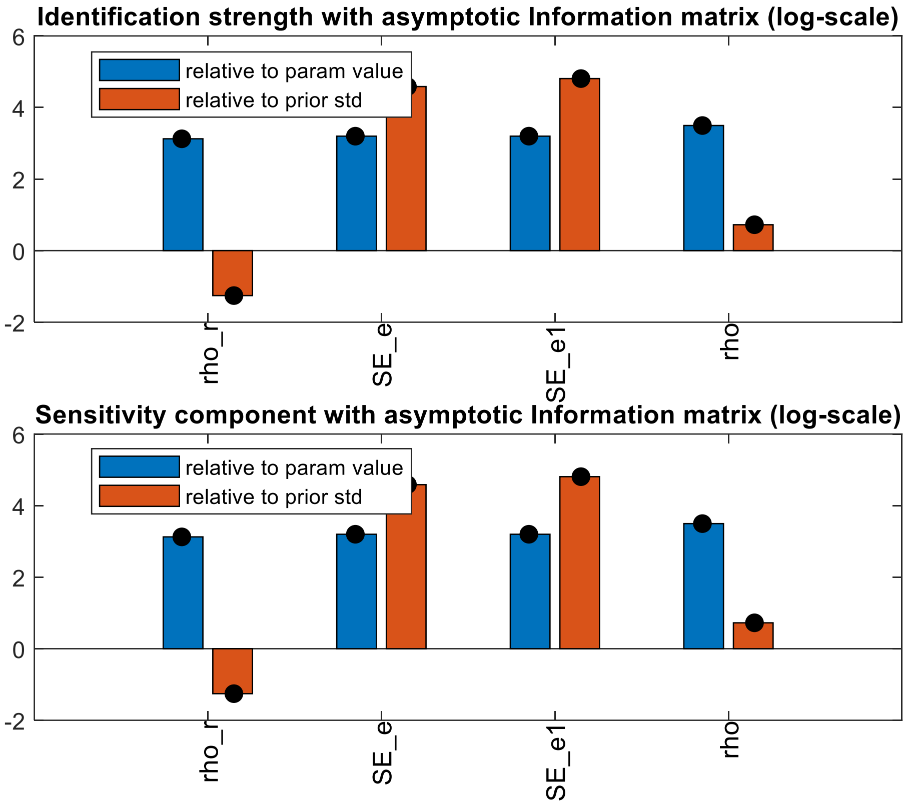


Figure 4.4: Model Identification Analysis

4.6.3 Posterior Distribution

The posterior modes are generated using Dynare's Monte-Carlo optimization routine. Metropolis-Hastings (MH) algorithm is used to obtain a sample from the posterior distribution. The covariance matrix is adjusted using scale parameter in the jump distribution in order to obtain an acceptance ratio of 25%-35%. For MH three parallel Markov chains of 1,000,000 draws are run from the posterior kernel.

Appendix 4.2 reports the mode check plots for all parameters estimated in this model. Mode check plot computes the log of the posterior kernel and of the log likelihood as a function of each respective parameter, keeping the other parameters constant. This plot, therefore, allows one to understand the informativeness of priors; where if there are differences in shape between the likelihood kernel and the posterior likelihood, it indicates the prior is informative and is able to influence the curvature of the likelihood function. Ideally, the estimated mode should be around the maximum of the posterior likelihood function. As shown in Appendix 4.2, all the estimated parameters mode plot check conforms to the criteria stipulated above.

As part of the estimation, Brooks and Gelman (1998) convergence diagnostics are produced, which is based on the comparison between pooled and within the chain variation, which MC draws through interval statistics around mean, second (m2) and third (m3) moments in Appendix 4.3. While the univariate convergence diagnostic follows Brooks and Gelman (1998), the multivariate convergence diagnostic applies these principles to the range of the posterior likelihood function. The multivariate convergence diagnostics are reported in Figure 4.3.2 in Appendix 4.3. To achieve convergence, the two lines – red and blue must be close to each other and stabilise horizontally. As shown in Appendix 4.3, this convergence criteria is achieved both for univariate and multivariate convergence.

One of the key criticism of Brooks and Gelman (1998) graphics presented in Appendix 4.3 is that this exercise becomes an eyeballing task which could lead to disagreement on convergence. More robust approach will be to look at convergence diagnostics using statistical testing. Table 4.5 and Table 4.6 reports convergence diagnostics using methods proposed by Geweke (1992) and Raftery and Lewis (1992).

Geweke (1992) proposed a convergence diagnostic for a MCMC chain to establish whether the first half of the chain has the same mean as the second half of the chain. As the two samples comes from same chain, if they achieve convergence, the means will be the same and, hence achieving convergence. The Geweke (1992) test in Table 4.6 is done for 200,000 draws after the burn-in to form first part of the chain and 592,000 draws from the last part of the chain. A one sample t-test is undertaken to validate the null hypothesis that they come from the same distribution. Given both samples come from the same distribution, there will be high level of autocorrelation hence the standard errors are corrected using Newey and West (1987) method. The tapering shows this correction. As show in the last column of Table 4.6, one cannot reject null hypothesis at 5% significance level that they come from the same distribution. Therefore, we can conclude based on Geweke (1992) convergence is achieved.

Geweke (1992) Convergence Tests, based on means of draws 200000 to 352000 vs 592000 to 1000000.
(p-values are for Chi2-test for equality of means)

Parameter	Post. Mean	Post. Std	p-val No Taper	p-val 4% Taper	p-val 7% Taper	p-val 15% Taper
σ_R^2	0.164	0.021	0.00	0.131	0.114	0.117
σ_A^2	1.086	0.139	0.00	0.07	0.079	0.060
ρ_r	0.981	0.013	0.387	0.859	0.859	0.858
ρ_A	0.322	0.096	0.767	0.94	0.942	0.936

Table 4.6: Geweke (1992) Convergence Tests

Raftery and Lewis (1992) provides data on number of draws that needs to be taken to achieve a given level of precision in quantile of the posterior sample. The objective of the test is to understand how many draws are needed to achieve 95% of Highest Posterior Density Interval (HPDI) to achieve actual posterior probability between 92.5% an 97.5%. Which means the error tolerance is 5%. Table 4.7 shows the outcome of the Raftery and Lewis (1992). The result shows we need to have a maximum burn-in of 69 observation and a total number of draws of 18,780. As these draws and burn-ins are within 1,000,000 draws with 20% burn-ins means we achieve the necessary condition to achieve convergence.

Parameters	M (burn-in)	N (req. draws)	N+M (total draws)	k (thinning)
σ_R^2	35	9928	9963	8
σ_A^2	33	9424	9457	8
ρ_r	69	18780	18849	15
ρ_A	31	8708	8739	7
Maximum	69	18780	18849	15

(test is based on quantile q=0.025 with precision r=0.010 with probability s=0.950)

Table 4.7: Raftery and Lewis (1992) Convergence Diagnostics

4.6.4 Results

Table 4.5, column V and VI, shows the results of the posterior estimation through posterior mean and 90% HPD interval respectively. The bottom section of Table 4.5 provides MCMC convergence diagnostic statistics. As shown in Table 4.5, the acceptance ratio is as set 33%. For the MCMC inefficacy factor, the convention is a smaller value is preferred over a larger one. As shown in Table 4.5, these values appear to be small.

For the auto correlation of shock parameters and standard deviation of shocks, it appears it assumes prior distribution; and the result of the posterior following estimation comes from the same distribution, due to the proximity of parameter values in both the distributions. The parameter values for the shocks are in line with the standard values used in the literature.

The autocorrelation of technology and interest rate shocks are highly persistent. The values still confine to the expected level in the literature. In the context of the Maldives, given its dependence on the external sector, therefore, can explain the persistence of shock parameters. The standard deviation of technology shocks is slightly overestimated. Among the two standard deviations, output appears to be the most volatile when compared to the world interest rate shock.

Table 4.8 demonstrates posterior means of several second moments for some aggregates ratio, as well as their data counterparts for comparison. As shown in Table 4.8, the model is able to match the volatility output but overestimates the volatility of external balances volatility compare with the data and results based on calibration. This is due to the significantly larger estimated autocorrelation parameter for interest rate shock and higher standard deviation of technology shock. However, the volatility of hours and are not far off the data. The estimated model is also able to match the persistence data for consumption, hours and investment. The success of the model's ability to meet volatility, as shown in the data, is also able to preserve the observed order of volatility for the aggregates in emerging and small open economies except for consumption; that is, investment being more volatile than output. In terms of contemporaneous correlation, the model is not able to match the data for investment.

The standard observation of inverse relationship between trade balance with output, and current account with output, is not observed by the model. The positive correlation may be due to the quality of data being supplied as not being rich enough to get more consistent estimates. Appendix 4.4 shows the Bayesian impulse responses which appear to be consistent with Model 1 impulse responses.

Macroeconomic aggregates	Data			Estimated Moments		
	σ_x	$\rho_{xt,GDP,t}$	$\rho_{x,t}, \rho_{x,t-1}$	σ_x	$\rho_{xt,GDP,t}$	$\rho_{x,t}, \rho_{x,t-1}$
GDP	4.28	1	0.12	3.88	1	0.32
Consumption	1.31	0.35	0.59	0.74	0.94	0.45
Hours	0.98	0.06	0.46	0.69	1.00	0.32
Investment	4.08	0.36	0.47	1.62	0.80	0.30
Capital	1.26	0.23	0.70	0.42	0.59	0.92
Current account to output	0.61	-0.04	0.55	1.12	0.52	0.70
Trade balance to output	0.64	-0.08	0.45	1.21	0.63	0.79

Table 4.8: Empirical moments compared with data

% variation cause by	C	Y	I	K	TB/Y	CA/Y
Technology Shock	95%	95%	86%	23%	73%	80%
Interest Rate shock	5%	5%	13%	77%	27%	20%

Table 4.9: post-estimation variance decomposition

Table 4.9 shows the post estimation variance decomposition. The results show that for a canonical business cycle model, the most important shock is technology shock. The variance decomposition is similar to the values reported in Section 4.5. Interest rate shock has a smaller impact on output and consumption (5%), while 13% of investment is affected by interest rate shock. The results also shows that the capital accumulation is most affected by interest rate shock. The result to some degree supports conclusions from Uribe and Schmitt-Grohe (2017) where interest rate shock explains approximately 20% change output, investment and external balances.

4.7 Conclusion

The investigation in the Maldivian economy's aggregates shows that the theoretical results obtained from data closely follows the results of small open economies literature for the most aggregated. Based on calibration, Model 1 is the better suited model when compared with all others. Therefore, standard calibration parameters and assumptions from the literature establishes a reasonable match with the data. When the model is re-estimated and re-calibrated following Bayesian estimation, I can obtain a stronger fit with the data for volatility and persistence than the calibrated model. The autocorrelation is not as closely matched in the estimated model. The estimated and calibrated model can explain stylised facts of investment.

The application of the real business cycle theory into the Maldivian economy has brought some interesting highlights. The benchmark model can match the standard deviation of hours, and investment with data. At the same time the model can mimic the persistence for consumption, current account to output ratio, trade balance to output ratio, to the data. As the countercyclical current account is one of the defining features of emerging and small open economies, the benchmark model is able to match this with the data; although the estimated model is not able to replicate the observation from the data. Two possible reasons can be put forward for this. First, being the limited data fed into model – in this case output and interest rate. Second, the standard RBC model, without other forms of real rigidities, can provide too stylised results that are not observed.

The results further established that the interest rate has a role in generating the business cycle for small open economies – especially on the variables relating to external balances, investment, and capital - as opposed to conventional assumptions in standard RBC models. This, therefore, warrants further inquiry using a more in-depth framework.

The main limitation of this study is the dataset used for calibration and estimation being unable to cover a longer time period. Similar to many small economies, the Maldivian economy collected limited amount of data on macroeconomic aggregates prior to the 1980s. The frequency of the data was also an issue, as quarterly data would be able to capture richer dynamics than annual data. Despite the data issue, it appears the RBC model developed in this chapter signals that there may be an important role which interest rate plays in business cycles. In a subsequent chapter, I will be exploring this by making necessary amendments to the simple model presented in this chapter, by introducing financial friction and dollarization to closely represent structural characteristics of the Maldives and other small emerging economies.

It is my belief, that if the model had been modified to incorporate the high dependency of the Maldivian economy to rest of the world markets - both as a source of income, expenditure, and capital - it would be able to match the data much more closely. Nevertheless, this first attempt in literature, to our knowledge, to construct a real business cycle model for the Maldives lays groundwork for future extensions. In the following chapter, I will be introducing financial friction to establish the role of interest rate shock, by modifying this simple model to determine the extent to which interest rate and financial market frictions can explain the business cycle.

Appendix 4.1: Impulse responses under different parameterisation

Figure 4.1.1: Impulse responses under different parameterization following a technology shock

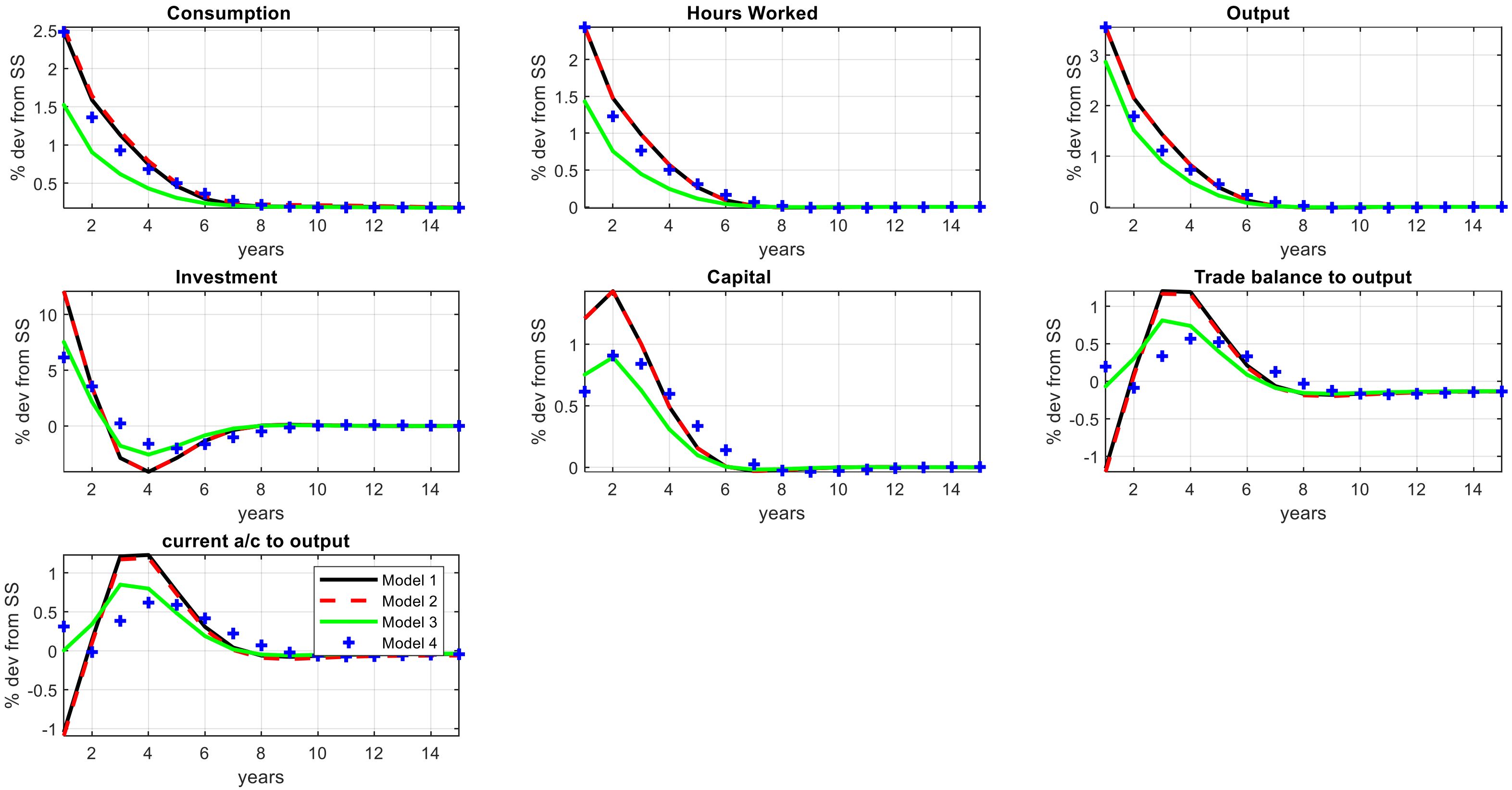
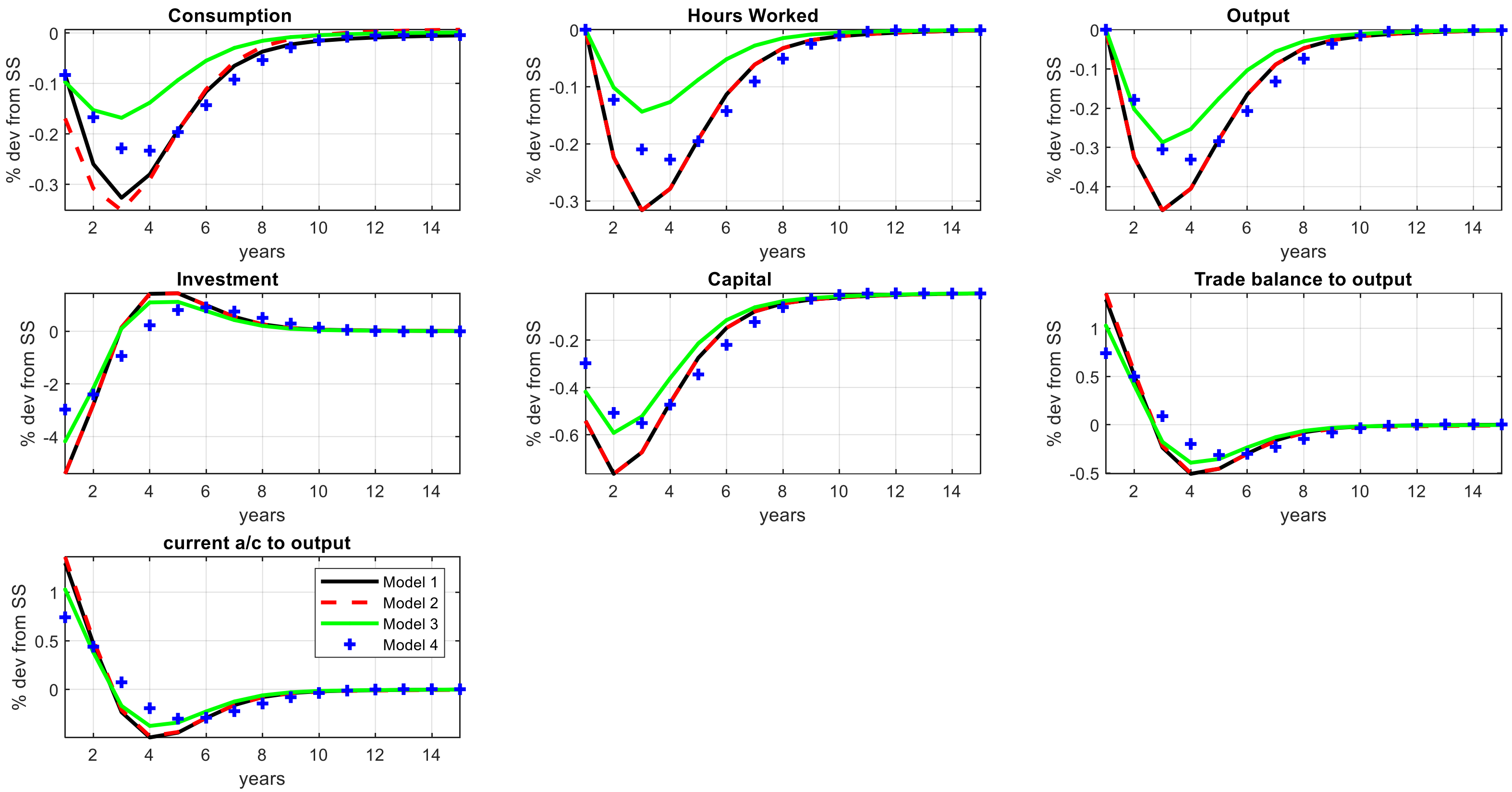
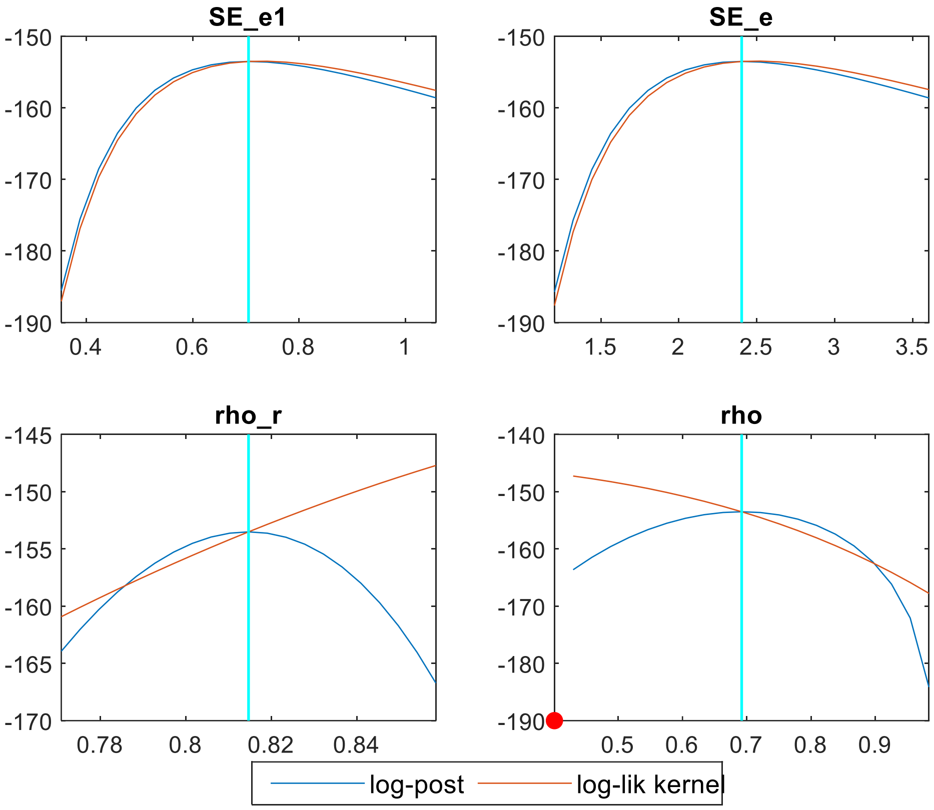


Figure 4.1.2: Impulse responses under different parameterization following a positive interest rate shock



Appendix 4.2: Posterior mode plot



Appendix 4.3: Convergence Diagnostic

Figure 4.3.1: Brooks and Gelman (1998) univariate convergence diagnostics

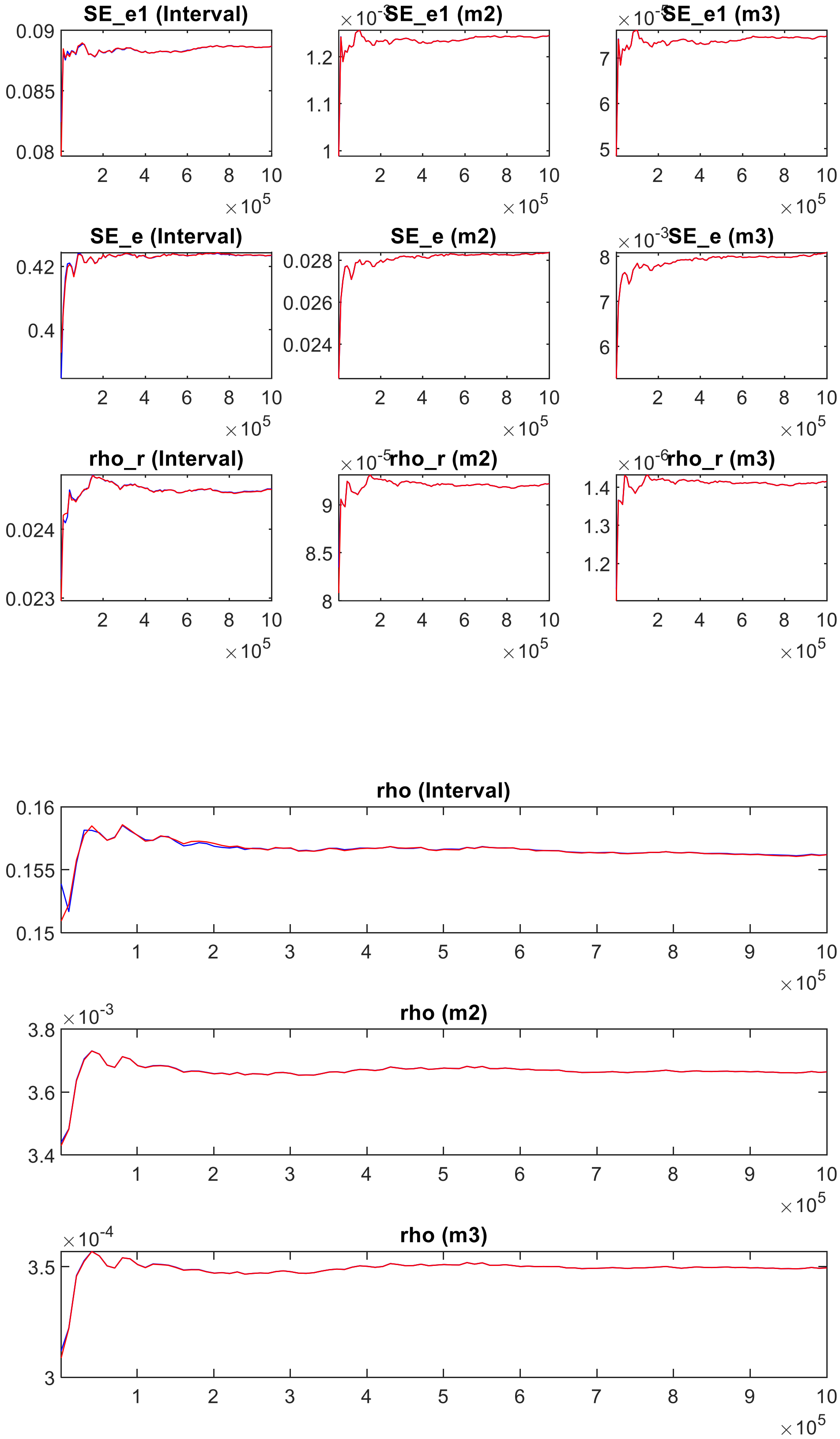
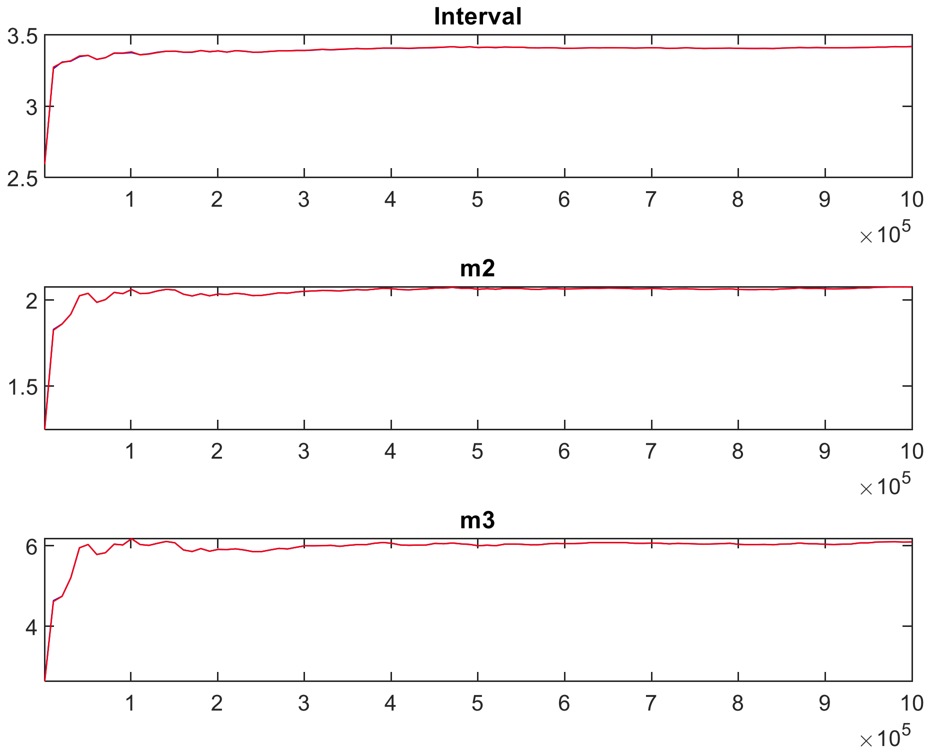


Figure 4.3.2: Brooks and Gelman (1998) multivariate convergence diagnostics



Appendix 4.4: Bayesian Impulse Responses

Figure 4.4.1: Impulse with 95% error bands responses following a technology shock

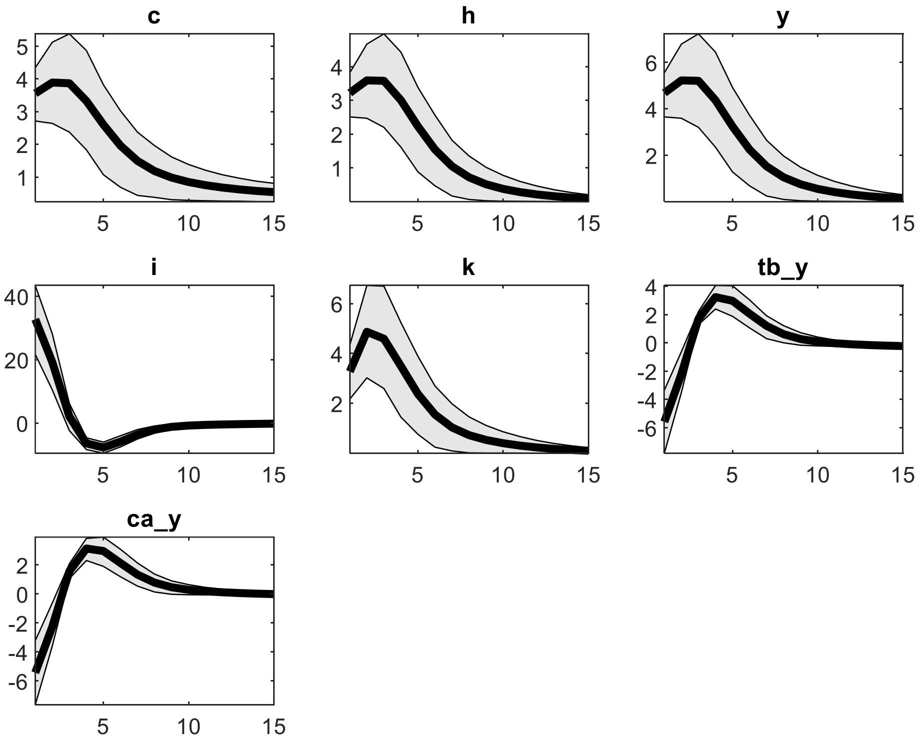
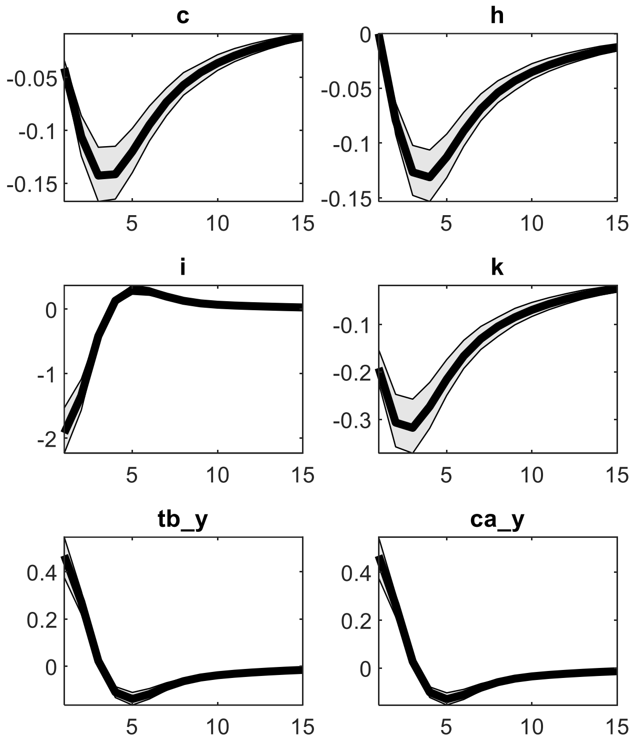


Figure 4.4.2: Impulse with 95% error bands responses following a interest rate shock



Appendix 4.5: Dynare Codes

```
var  c h y i k a lambda util b tb_y, ca_y, r beta_fun, eta Q;

varexo e e1;


parameters  gamma

        omega

        rho

        rho_r

        chi

        delta

        psi_1

        alpha

        phi

        r_bar

        sigma

        sigma_r

        b_bar;


gamma  = 2.00; %risk aversion

omega  = 1.455; %Frisch-elasticity parameter

psi_1  = 0; %set in steady state %elasticity discount factor w.r.t. to arguments of utility
function

alpha  = 0.32; %labor share

phi    = 0.05; %investment adjustment cost parameter
```

```
r_bar    = 0.04; %world interest rate

delta  = 0.1; %depreciation rate

rho    = 0.40; %autocorrelation TFP

sigma =1.89; %standard deviation TFP

rho_r    = 0.63; %autocorrelation TFP

sigma_r = 2.59; %standard deviation TFP

chi = 1.25;

b_bar  = 0.7442;



model;

   //1. Eq. (5), Evolution of debt

   b = (1+exp(r(-1)))*b(-1)- exp(y)+exp(c)+exp(i)+(phi/2)*(exp(i)-exp(i(-1)))^2;


   //2. Eq. (6), Production function

   exp(y) = exp(a)*(exp(k(-1))^alpha)*(exp(h)^(1-alpha));


   //3. Eq. (7), Law of motion for capital

   exp(k) = exp(i)+(1-delta)*exp(k(-1));


   //4. Eq. (15), Euler equation

   exp(lambda)= beta_fun*(1+exp(r))*exp(lambda(+1));


   //5. Eq. (11), Definition marginal utility
```

exp(lambda)=(exp(c)-((chi*exp(h)^omega)/omega))^(-gamma)-exp(eta)*(-psi_1*(1+exp(c)-omega^(-1)*chi*exp(h)^omega)^(-psi_1-1));

//6. Eq. (16), Law of motion Lagrange mulitplier on discount factor equation

exp(eta)=-util(+1)+exp(eta(+1))*beta_fun(+1);

//7. Eq. (12), Labor FOC

((exp(c)-(chi*exp(h)^omega)/omega)^(-gamma))*(chi*exp(h)^(omega-1)) +

exp(eta)*(-psi_1*(1+exp(c)-omega^(-1)*chi*exp(h)^omega)^(-psi_1-1)*(-chi*exp(h)^(omega-1))) = exp(lambda)*(1-alpha)*exp(y)/exp(h);

//8. Eq. (21), Investment FOC

exp(lambda)*(1+phi*(exp(i)-exp(i(-1)))) = beta_fun*exp(lambda(+1))*(alpha*exp(y(+1))/exp(k)+exp(Q(+1))*(1-delta)+phi*(exp(i(+1))-exp(i)));

//9. Eq. (8), Technology shock

a = rho*a(-1)+sigma*e;

//10. Eq. (9), Interest rate shock

r-log(r_bar) = rho_r*(r(-1)-log(r_bar))+sigma_r*e1;

//11. Definition endogenous discount factor

beta_fun =(1+exp(c)-omega^(-1)*chi*exp(h)^omega)^(-psi_1);

```
   //12. (4) Definition endogenous discount factor

   util=(((exp(c)-omega^(-1)*chi*exp(h)^omega)^(1-gamma))-1)/(1-gamma);


   //13. Eq. (26), country interest rate

   exp(r)= ((alpha*exp(y)/exp(k(-1)))+(1-delta)*exp(Q(+1)))/exp(Q)-1;



   //14. p. Definition of trade balance to ouput ratio from budget constraint

   tb_y = 1-((exp(c)+exp(i)+(phi/2)*(exp(i)-exp(i(-1)))^2)/exp(y));


   //15. p. Definition of trade balance to ouput ratio from budget constraint

   ca_y = (1/exp(y))*(b(-1)-b);

end;


steady_state_model;

   Q    = 0;

   r    = log(r_bar);

   b    = b_bar;

   h         =  log((((1-alpha)/chi)*(alpha/(r_bar+delta))^(alpha/(1-alpha)))^(1/(omega-
1)));

   k    = log(exp(h)/(((r_bar+delta)/alpha)^(1/(1-alpha))));

   y    = log((exp(k)^alpha)*(exp(h)^(1-alpha)));

   i    = log(delta*exp(k));

   c    = log(exp(y)-exp(i)-r_bar*b);
```

```
    tb_y    = 1-((exp(c)+exp(i))/exp(y));

    util=(((exp(c)-omega^(-1)*chi*exp(h)^omega)^(1-gamma))-1)/(1-gamma);

    psi_1=-log(1/(1+r_bar))/(log((1+exp(c)-omega^(-1)*chi*exp(h)^omega)));

    beta_fun =(1+exp(c)-omega^(-1)*chi*exp(h)^omega)^(-psi_1);

    eta=log(-util/(1-beta_fun));

    lambda=log((exp(c)-((chi*exp(h)^omega)/omega))^(-gamma)-exp(eta)*(-
psi_1*(1+exp(c)-omega^(-1)*chi*exp(h)^omega)^(-psi_1-1)));

    a     = 0;

    ca_y    = 0;

end;



resid(1);


check;


steady;




shocks;

    var e; stderr 1;

    var e1; stderr 1;

end;
```

```
stoch_simul(order=1, irf=15) c h y  i k r tb_y ca_y a;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%

//-------------------------------------------------------------------------

//      Bayesian Estimation and Simulation

//-------------------------------------------------------------------------

estimated_params;

stderr e1,     INV_GAMMA2_PDF,0.4, 2; //interest rate shock

stderr e,     INV_GAMMA2_PDF,0.5, 2; //technology

rho_r, beta_pdf, 0.8, 0.01; //interest rate shock autoregressive parameter

rho, beta_pdf, 0.8, 0.05; //Productivity shock autoregressive parameter


end;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% OBSERVABLE VARIABLES

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

varobs r y ;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%5

% sample periods 1976-2014

% 2 years for initialisation

% this estimates the original model (with the rule) with 2000 MH
```

%%
%%%%%%%%%%%%%%%%%%%%%%%

options_.plot_priors=1;

identification(advanced=1,max_dim_cova_group=3);

estimation(datafile=consumption3,presample=2,prefilter=0,mh_replic=1000000,
mh_drop=.2, mode_check, mode_compute=6,mh_nblocks=2,mh_jscale=0.2,bayesian_irf)
c h y i k r tb_y ca_y ;

steady;// recompute ss with post. means or modes

stoch_simul(order=1,irf=40) c h y i k r tb_y ca_y ;

shock_decomposition (parameter_set=posterior_mode) r a;

Appendix 4.6: Graph Plotter MATLAB Code

```
clear;

close all;

clc;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%OPTIONS TO BE CHANGED BY THE USER%%%%%%%%%%%%%%%%%

%RESULT_names={'NK_results', 'NKlinear_results'}; %%EXACT NAMES OF THE RESULTS FILES TO LOAD

%lin_vs_nonlin=[0,1]; %=0 IF THE CORRESPONDING MODEL IN RESULT_NAMES IS NON-LINEAR, 1 IF IT IS LINEAR

RESULT_names={'Model_1', 'Model_2', 'Model_3', 'Model_4'}; %%EXACT NAMES OF THE RESULTS FILES TO LOAD


lin_vs_nonlin=[0,0,0,0]; %=0 IF THE CORRESPONDING MODEL IN RESULT_NAMES IS NON-LINEAR, 1 IF IT IS LINEAR



VAR_IRFs_nonlin = {'c','h','y','i','k', 'tb_y', 'ca_y'}; %% NAMES OF ENDOGENOUS VARIABLES OF INTEREST FOR THE IRFS (NON-LINEAR MODELS) - NEED TO HAVE EXACTLY SAME NAME AS IN THE .MOD FILE


%%VAR_IRFs_linear= {'Y','C','I','H','W','ER','Rn','Q','PIE'};

NAME_SHOCKS={'_e', '_e1'};%% NAMES OF EXOGENOUS SHOCKS OF INTEREST FOR THE IRFS - NEED TO HAVE EXACTLY SAME NAME AS IN THE .MOD FILE
```

names = char('Consumption', 'Hours Worked', 'Output', 'Investment', 'Capital', 'Trade balance to output','current a/c to output'); % NAMES OF THE EDOGENOUS VARIABLES FOR THE GRAPHS. YOU CAN SPECIFY ANY NAME YOU WANT BUT NEED TO HAVE THE SAME NUMBER OF ELEMENT OF VAR_IRFs

%Model_names=char('NK (non-linear)', 'NK (linear)'); %NAMES OF THE MODEL VARIANTS TO APPEAR IN THE LEGEND OF THE GRAPHS

Model_names=char('Model 1','Model 2', 'Model 3', 'Model 4'); %NAMES OF THE MODEL VARIANTS TO APPEAR IN THE LEGEND OF THE GRAPHS

Rows_figure=3; % NUMBER OF ROWS IN EACH PLOT

Column_figure=3; % NUMBER OF COLUMNSS IN EACH PLOT

irf_horizon=15; %LENGTH OF THE IRFS GENERATED BY THE .MOD FILE

%%%%%%%%%%%%%%%%%%%%%%%%%END OF OPTIONS%%%%%%%%%%%%%%%%%%%%%%%%%

%% DO NOT CHANGE ANYTHING BELOW.

Num_models=length(RESULT_names); %%NUMBER OF MODELS TO COMPARE

NUM_SHOCKS=length(NAME_SHOCKS); %%NUMBER OF SHOCKS TO COMPARE

NUM_VAR=length(VAR_IRFs_nonlin);%%NUMBER OF VARIABLES TO COMPARE

irfs_matrix=zeros(irf_horizon,NUM_VAR,NUM_SHOCKS,Num_models);

for mm=1:Num_models;

```
%load Model
eval(['load ' RESULT_names{mm} ';']);
if lin_vs_nonlin(mm)~=0
   VAR_IRFs=VAR_IRFs_linear;
else
   VAR_IRFs=VAR_IRFs_nonlin;
end
for xx=1:NUM_SHOCKS;
for jj=1:NUM_VAR;
%Rename the IRFs for each variable of interest
genrate_irf_names=[VAR_IRFs{jj},NAME_SHOCKS{xx},'=','oo_.irfs.',VAR_IRFs{jj},NAME_SHOCKS{xx},';'];
evalin('base', genrate_irf_names);
%generate_irf_matrix=['irf_',num2str(mm),NAME_SHOCKS{xx},'(jj,:)=',VAR_IRFs{jj},NAME_SHOCKS{xx}];
%evalin('base', generate_irf_matrix)
irfs_matrix(:,jj,xx,mm)=eval([VAR_IRFs{jj},NAME_SHOCKS{xx}]);
end
end


end






%%PLOT
```

```
color = {'-k','--r','.-g','+b','*y'};%color and line style for the plots



for xx=1:NUM_SHOCKS;


%Options for the plot

h=figure('Position', [600, 0, 1000, 900]);

axes ('position', [0, 0, 1, 1]);


%Figure

%Loop over the number of endogenous variables to plot

F1=figure(xx);

set(F1, 'numbertitle','off');

set(F1, 'name', ['Impulse response functions to',NAME_SHOCKS{xx}]);

for jj = 1:length(VAR_IRFs);

   for mm=1:Num_models;

            subplot(Rows_figure,Column_figure,jj),
plot(irfs_matrix(:,jj,xx,mm),color{mm},'LineWidth',2); hold on;

              xlabel('years');

              ylabel('% dev from SS');

              grid on

              title(names(jj,:),'FontSize',10)
```

```
axis tight;
   end;
end;
legend(Model_names)
end;
```

Chapter 5: SOE Model with financial friction: role of interest rate and financial accelerator

5.1 Introduction

Post 2007-2008 recession, several studies have focused on the role of financial markets in explaining real business cycles. Conventional real business cycle models assume frictionless capital markets in which a no arbitrage condition ensures that the return to capital and risk-free rate are the same and the financial structure is irrelevant. This assumption has a far-reaching consequence: borrowing agents are the same as lending agents, exogenous world interest rate being always equal to country interest rate unless using a debt elastic formulation.

Chapter 4 incorporated interest rate shock into canonical real business cycle model which enabled a few theoretical moments to be match the empirical moments in the data. Variance decomposition from the calibrated model shows that the interest rate shocks account for: 3% movement in output, consumption, and hours; 18% movement in investment; 26% movement in capital, and 33% and 34% movement in trade balance to output ratio and current account to output ratio. The post-estimation variance decomposition using estimated parameters shows that interest rate only explains 5% change consumption and output and 13% changes in investment. It also shows that 20% of the changes in current account and 27% changes in trade balance can be explained by interest rate shock. While the results in Chapter 4 estimation are reasonable to conclude the role of interest rate in driving business cycle, the assumption of completely exogeneous interest rate[21] faced by emerging and small open economies is too restrictive.

[21] Uribe and Yue (2006), Neumeyer and Perri (2006) Cline and Barnes (1997), Cline (1995), Edwards (1994) allows domestic variables to influence the interest rate faced by small and emerging economies in international markets.

There is an establish body of empirical studies which show that in small and emerging open economies, the country interest rate is different from the exogenous ‘risk free rate’ assumed by standard RBC models. The difference between these two rates is due to country specific risk premium (spread) which has potential to play a key role in driving business cycle for emerging economies. For instance, Uribe and Yue (2006) shows that for the US, interest rate shocks explain 20% of the movements in emerging economies real aggregates while risk premium shocks explain 12% of movement in business cycle. These recent empirical results call for relaxation of frictionless capital market assumption in real business cycle models and incorporate capital market frictions which would enable external finance premium to be integrated into a canonical real business cycle model.

Several studies have attempted address this gap in literature and replicate empirical results by focusing the role of interest rate in explaining real business cycle (see Monacelli and Sala (2018); Uribe and Yue (2006); Neumeyer and Perri (2005)). Compared to conventional real business cycle models, the focus of these studies is on how the presence of an external finance premium in real interest rate drives business cycles in emerging economies. This strand of research contradicts with studies that aims drive emerging economies business cycle through technology shock such as Kydland and Zarazaga (2002) and Aguiar and Gopinath (2007). However, as noted by García-Cicco, Pancrazi and Uribe (2010), the results of Aguiar and Gopinath (2007) cannot be extended to a long horizon. Their estimation, based on a century of data on Argentina demonstrated that Aguiar and Gopinath (2007) framework performance poorly in explaining business cycle compared with interest rate shocks in open economies. Neumeyer and Perri (2005) in their seminal work arrived at similar conclusions.

In the previous chapter, I have allowed interest rate shocks to directly compete with technology shock without modelling any characteristics for financial market[22]. Such a

[22] In a frictionless setup financial intermediation process plays a passive role as savers are the same as borrowers.

setup can underestimate the role of interest rate as positive technology shock can absorb country specific reduction in risk premium due to expansion in output[23]. At the same time, in Chapter 4, the assumption is that the country interest rate is exogenously determined when in theory and observation shows that it is linked to country specific characteristics. This Chapter aims endogenies interest rate determination for a small and emerging economy to establish the role of interest rate and country risk premium play in driving business cycle. The emphasis will be to contextualise the model to the Maldivian economy. A key characteristic of Maldivian economy, which will explored in greater detail in Chapter 6 is the presence of financial dollarization and soft exchange rate pegging regime with the US dollar. These country specific characteristics makes this topic of investigation highly relevant to the Maldives as changes in US interest rate will have an impact on Maldivian economy through interest rate channel. While the US interest rate is exogenously determined, the rate at which small open economy borrows/lend in international markets are subject to a risk premium that are endogenous to domestic conditions.

Figure 5.1 and 5.2 establishes correlation between interest rate and output and total factor productivity (TFP). These figures show that for the Maldives, the co-movement between real interest rate with output and TFP is significant. For instance, as per Figure 5.1 domestic real interest rate is counter cyclical and Figure 5.2 shows that real interest rate is negatively correlated with the total factor productivity.

[23] Increase in output improves a country's ability to repay debts, therefore investors will be willing to reduce its risk premium. A detailed discussion can be found in Uribe and Schmitt-Grohe (2017).

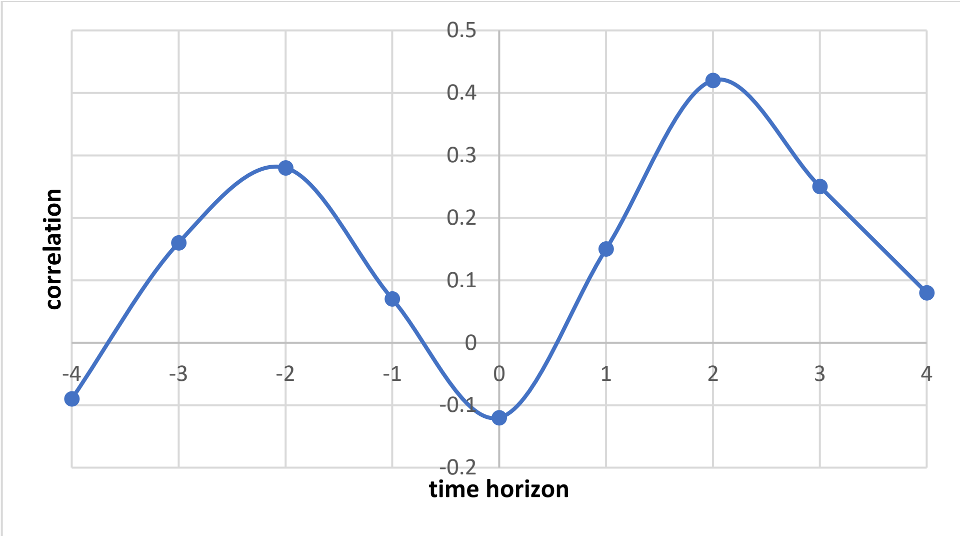


Figure 5.1: Cross-correlation between the real interest rate (t+j) and log GDP(t)

Figure 5.1 shows that real interest rate shocks create significant volatility in output. As shown in the correlation, the real interest rate lags the cycle by 2 periods (years). In the standard business cycle literature on small and emerging economies, the cross correlation between real interest rate and output and time *t* is negative but relatively small. In the data for the Maldives, this appear to support the conventional finding, but the magnitude of the negative correlation is higher than suggested by the literature. This is less surprising when one looks at the level of dollarization in the Maldives. On average, the dollarization ratio of the Maldives is over 50% in the last 30 years as a result one would expect changes in world interest rate would bring significant impact to the Maldivian output.

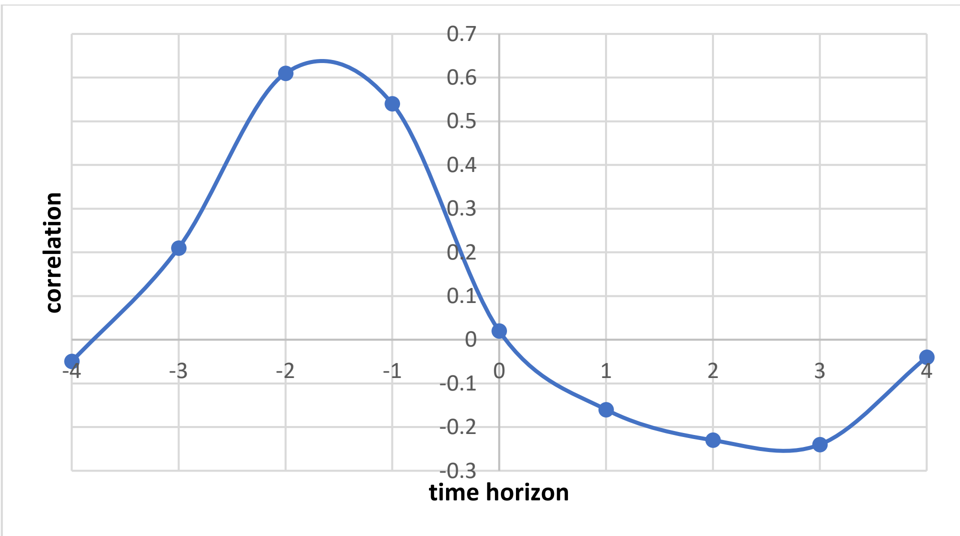


Figure 5.2: Cross-correlation between the real interest rate (t+j) and log TFP(t)

Note: real interest rate is calculated by subtracting average yearly nominal federal funds rate (RN) from average yearly expected inflation in the United States (ie $R_t = RN_t^{US} - E\pi_t^{US}$). The TFP is estimated using method proposed by Fernald (2014) and Aguiar and Gopinath (2006) in which I assume output is produced using a Cobb-Douglas by employing capital K_t and labour, $L_t$where the share of each of these inputs are fixed overtime. Using this assumption, TFP is proxy derived for Solow's residual using the production function $Y_t = A_t K_{t-1}^{\alpha} H_t^{1-\alpha}$. All data are then filtered using HP filter with a smoothing parameter of $\lambda = 100$ as the data is annual data.

Figure 5.2 shows the impact of real interest on total factor productivity of the Maldives. While it is positively correlated, the real interest rate brings a lagged effect on total factor productivity by two periods. It can be seen from Figure 2 that an exogenous rise in real interest rate therefore is correlated to TFP.

Table 5.1 construct a correlation matrix between real interest rates, risk premium, output, consumption, and trade balance to output ratio for the Maldives. Annual real interest rates in the Maldives and USA are gathered from World Bank data. Real interest rate data for the Maldives is only available from 1996. Due to lack of data for earlier years all the series are restricted to 1996-2019. Risk premium is computed by subtracting Maldivian real interest rate from the USA real interest rate[24]. Output, consumption and trade balance to output ratio are taken from Penn World Tables for consistency with the previous chapters. All data are HP filtered with a $\lambda = 100$.

	Consumption	rMDV	rUSA	Risk Premium	Output	TB/Y
Consumption	1.0					
rMDV	0.1	1.0				

[24] In the literature such as García-Cicco, Pancrazi and Uribe (2010), Neumeyer and Perri (2005) and Schmitt-Grohe and Uribe (2003) defines country interest rate as $R(S^t) = R^*(S^t) + D(S^t)$. Where R and R* are domestic and foreign interest rate respective and D is the country risk premium. Therefore the difference between home and foreign interest rate will be the country specific risk premium.

rUSA	0.6	0.4	1.0			
Risk Premium	-0.3	0.8	-0.3	1.0		
Output	0.4	-0.1	0.3	-0.3	1.0	
TB/Y	-0.8	-0.1	-0.4	0.2	0.1	1.0

Table 5.1: Correlation Matrix

As shown in Table 5.1, the correlation between Maldivian real interest rate (rMDV) and output is negative and small. At the same time, risk premium is negatively correlated with consumption and output but affects the trade balance and output ratio positively. The table also shows that US interest rate r(USA) has a notable correlation with Maldivian interest rate, output, consumption, risk premium and trade-balance to output ratio. These results are no surprising due to the high level of dollarization and continued fixed exchange rate regimes that exists in the Maldives. Han (2014) developed a partial dollarized DSGE model for Peru to understand how US interest rate and trade with China affect Peruvian economy. The result shows that there is high correlation between US interest rate and Peru's interest rate and output. Empirical work by Iacoviello and Navarro (2019) demonstrates that for emerging economies with a pegged exchange rate regime with US dollar or are dollarized, there exists a very high positive correlation between US interest rate and home interest rate. However, for these economies, the relationship between US interest rate and GDP is less pronounced. The correlation matrix shows that that rise in US interest rate contemporaneously leads to expansion in domestic output. Uribe and Yue (2006) found a similar relationship and concludes that the rationale for the observed relationships among these economies are difficult to rationalize. For emerging economies that are not dollarized, Iacoviello and Navarro (2019) showed a lagged impact on output, where it takes three years for output to contract following an increase in US interest rate. This therefore indicates that for a group of emerging countries, the positive contemporaneous correlation between US interest rate and home output is not surprising due to a delayed response.

In a standard real business cycle model with frictionless capital market, there would be no arbitrage opportunities between return on capital and the riskless rate. In the benchmark real business cycle model of Chapter 4, this implies that $E_t\Lambda_{t+1}(1 + R^K_{t+1}) = E_t\Lambda_{t+1}(1 + R_t)$ where Λ_{t+1} is the stochastic discount factor. In such a setting financial intermediation structure is irrelevant. The presence of friction in capital market however creates a wedge between return to capital and riskless rate due to presence of external finance premium. In such a setting one would expect $E_t\Lambda_{t+1}(1 + R^K_{t+1}) > E_t\Lambda_{t+1}(1 + R_t)$ where the difference presence risk premium.

Based on the discussions and initial empirical findings in the previous paragraphs, this Chapter contributes to RBC literature by establishing the role of interest rate, financial friction and risk premium in small and dollarized economies. To this end, I will modify the simple RBC model developed in Chapter 4 by introducing financial market frictions through a borrowing constraint and redefine the country interest rate as a function of international risk-free rate and country specific risk premium. The borrowing constraint will be imposed on the demand side (borrowers) of credit, linking availability of credit to borrower's balance sheet. The directional effect between external risk premium and borrowers balance sheet will influence propagation and amplification mechanism following disturbances to the economy. In the presence of imperfect capital markets, one should expect the borrowers' balance sheet moves procyclically, where external premium would fall following a positive balance sheet effect. Berganza et. al (2004) empirically demonstrated for emerging economies the inverse relationship between risk premium and balance sheet changes. Further evidence of this relationship can be found from Akinci (2021) and Gertler and Kiytaki (2010). These studies have established that risk premium is counter cyclical. Berganza et. al. (2004) for a panel of emerging countries concluded that changes in balance sheet of agents affect risk premium negatively where deterioration of agents balance sheet through increase in servicing of debts results in a rise in risk premium in the presence of financial market frictions. These empirical finding points the existence of a 'financial accelerator' mechanism which generates feedback between financial sector and real sector. The model developed in this chapter will attempt to validate the existence of the financial accelerator mechanism.

The model developed in this chapter follows from the work by Neumeyer and Perri (2005) and Uribe and Yue (2006). In Neumeyer and Perri (2005) framework, firms take an intra-period loan to finance its wage bill – working capital. Jermann and Quadrini (2012) and Uribe and Yue (2006) introduced a constraint which limits the working capital firm can borrow from financial intermediaries. Under their setup, the loanable working capital is limited to a fraction of firm's net worth. As described in Chapter 2, this style of financial friction in the literature is referred to as limited enforcement problem. Under such a framework, firm can only borrow up to a fraction of their net worth due to lenders not being able to fully enforce the contract in case of a default. The introduction of working capital requirement to finance the wage bill will also makes demand for labour sensitive to interest rate as firm charged interest on loaned funds by intermediaries. Therefore, changes to cost of borrowing will affect hiring decision by firms.

Intraperiod loans are not a common feature in business cycle models. Among the literature surveyed above on working capital loans, Neumeyer and Perri (2005) subjects the loan to a net interest. Jermann and Quadrini (2012) and Uribe and Yue (2006) however assume intraperiod loans to be interest free. This paper therefore combines Neumeyer and Perri (2005) framework with Uribe and Yue (2006). The modelling novelty of this paper is associated with incorporation of a more realist setup than the predecessor. For instance, Neumeyer and Perri (2005) subject working capital to interest, the authors failed to impose a limit on how much firms can borrow. Meanwhile Uribe and Yue (2006) subjects borrowing to a constraint but fails to charge interest on working capital. Both these setups fall short of realities of intra-period borrowing and hence this paper establishes a more complete setup. In addition, the model presented in this chapter also features a country specific risk premium consistent with García-Cicco, Pancrazi and Uribe (2010). A further contribution of this chapter is that the model is calibrated to fit the regularities of Maldivian economy. The significance of this has been discussed in Chapter 3 and 4.

The results shows that that there is lack of evidence on existence of a financial accelerator which amplifies the effect of shocks to an economy. The model, however, demonstrates that credit markets play an important role in transmission mechanism in the presence of collateral constraint. In the context of the model, technology shock dominates business cycle followed by interest rate shock. Credit market shocks account for 5% of the variation in the output.

The paper is organised as follows. In the next section, I will outline the key features and innovations to the RBC model from Chapter 4. This will be followed by estimation of the theoretical model where I will compare the results of the model with credit market friction with an alternative model without credit market friction to establish the extent to which a model with financial friction fit with stylized facts and predictions from literature. The chapter will conclude by providing a summary of the main findings and directions for future development.

5.2 The Model

5.2.1 Model Framework

The basics elements of the theoretical model follow closely the work of Neumeyer and Perri (2005) and Uribe and Yue (2006). The model is a standard one-good neoclassical model set in discrete time with two representative agents – a firm and a household. The model builds on the frictionless model introduced in Chapter 4 as outlined below. The household supplies labour to the firm and the firm owns capital and makes capital accumulation decision. Firms are owned by households therefore upon realisation of sales and payment of bills and debts, the profit is returned to household by the Firm. The only asset traded is a non-contingent real bond. The household trade this asset.

The RBC model departs from the model presented in Chapter 3 in six dimensions. First, production and absorption decisions like Uribe and Yue (2006) and Neumyer and Perri (2005) are done prior to the realisation of interest rate for the period causing a one period lag in transmission of periodic interest rate to the economy. Second, the model introduces labour market friction into the representative firm problem. The firm due to labour market friction requires to set aside the entire wage bill before the commencement of production. As representative firm does not maintain any reserve or retained earnings, this amount needs to be raised through borrowing. Third departure from Chapter 3 model therefore is associated with the working capital requirement imposed on firm.   Fourth, to finance the working capital representative firm is required to hold, the firm participate in the financial sector by borrowing working capital to finance the wage bills through an intra-period loan that it must payback with interest. Fifth, the intraperiod loan market is subject to frictions where firm are able to only borrow up to a fraction of its total assets measured by the value of capital. The sixth departure is the interest rate at which representative agents can borrow or save is subject to an endogenous risk premium linked to domestic conditions.

In this specification, interest affects the labour demand function which will trigger cyclical fluctuations. For instance, a rise in interest rate makes it costly for firms to borrow working capital required to employ labour hence it will reduce labour demand. Labour supply will remain unchanged causing equilibrium labour to fall. This will result in fall in output that originates from labour market. Section 5.6.2 provides a detail account on transmission mechanism associated with interest rate in this model economy.

The above specification allows to understand the role of financial friction and real interest rate in driving business cycle in the Maldives. As shown in Figure 5.1 and Table interest rate is countercyclical for the Maldives. Furthermore Table 2.4 shows that for EMEs interest rate is countercyclical hence the model aims to capture this characteristic specific to EMEs.

The working capital requirement imposed on firm and nature of effective interest rate warrants specification of time horizon for the firm to distinguish different decision and realization points. The formulation for time horizon follows from Neumeyer and Perri (2005). The model's timing convention is discrete where within each period, there are two times: one to mark the beginning of the period labeled as t and the other at the end of the period marked as t^{+}. The time t^{+} and $(t+1)$ are arbitrary close. Figure 5.3 represent the timeline to demonstrate the indexing of periods. The economy is subject to shocks S_t which are temporary (one period) and is revealed on period t and entire history of the shocks to the economy for the whole period is denoted by the state vector, S^t at the beginning of the time is $S^t = (S_0, \dots \dots \dots, S_t)$. The shocks affect technology in period t, $A(S^t)$, and interest rate $R(S^t)$, on bonds that mature on period and working capital loans that needs to be repaid on $(t+1)^+$ which are issue or borrowed either at $(t-1)^-$ or at t^+. In section 5.2.2, using the realisation of shock and timeline in Figure 5.3, I have specified in greater detail behaviour of household and firm. When setting the optimisation problem to minimise the excessive use of notations, the timing of shock and how it affects each variable will be not shown.

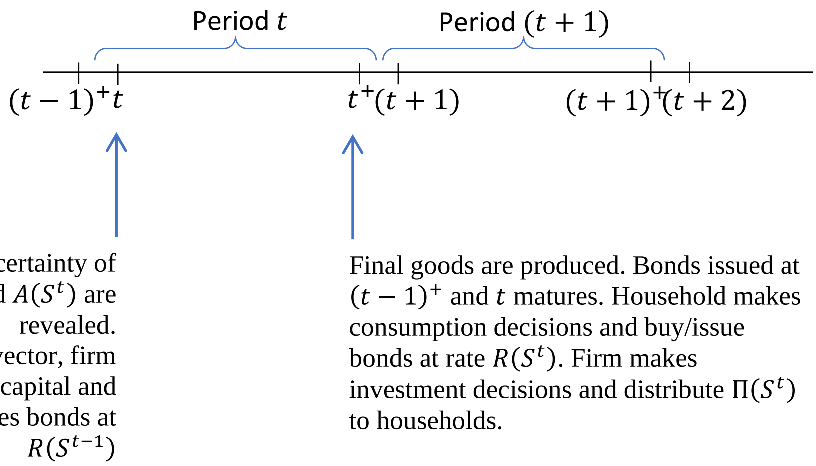


Figure 5.3: Timing convention between period t and $(t+1)$ extracted from Neumeyer and Perri (2005, p.357)

5.2.2 Firms and Technology

At the beginning of period t, firm hires labour $L(S^t)$, capital $K(S^{t-1})$ and produce final goods $Y(S^t)$ that becomes available at t^+. There is a friction in the technology for transferring resources to the household that provides labour services. For each hour of labour rented by household, firm pays $W(S^t)$ in wages. The firm pays to the household for the total labour services equivalent to $W(S^t)L(S^t)$ at the realization of sales of goods at t^+. But the friction in transfer for these labour services requires firm to set aside a fraction θ of wage bill at t when it makes labour decision. This sum is raised by the firms through the financial intermediation process in the form of an intraperiod loan.

This loan is a within the period loan which is contracted at the beginning of the period and paid at the end of the period upon realization of sales of output. The reminder of the wage bill $(1-\theta)$ is recovered at sales of goods at t^+. The total sum for wages is then transferred to household at t^+. As firm only realizes cash flow at t^+, it needs to borrow at t, $\theta W(S^t)L(S^t)$ units of goods (working capital) between t and t^+ at a rate $R(S^{t-1})$. Output is produced at the end of the period and firm realises $Y(S^t)$ worth of resources from selling output in the market. Firm upon realisation of sales, pays the back the loan interest $R(S^{t-1})\theta W(S^t)L(S^t)$ and the principal $\theta W(S^t)L(S^t)$. The net interest firm pays on the borrowed working capital is therefore equal to $(R(S^{t-1}) - 1)\theta W(S^t)L(S^t)$.

Capital evolves according to the following law of motion

$$K(S^t) = (1-\delta)K(S^{t-1}) + I(S^t) - \frac{\emptyset_X}{2}\left(I_t(S^t) - I_{t-1}(S^{t-1})\right)^2$$

Investment is subject to a quadratic adjustment cost and is financed out of dividend. The dividend payout is expressed as below. Firm return to household all dividend payment.

$$\Pi^f(S^t) = Y(S^t) - W(S^t)L(S^t) - I(S^t) - (R(S^{t-1}) - 1)\theta W(S^t)L(S^t)$$

Financial friction is modelled à la Kiyotaki and Moore (1997) through costly state verification. The maximum firm can borrow is subject to the following borrowing constraint:

$$\theta W(S^t)L(S^t) \leq \xi(S^t)Q(S^t)K(S^{t-1})$$

The parameter θ shows the importance of working capital. If $\theta = 0$, then firm does not need to borrow working capital and the model returns to a standard real business cycle model. The above expression indicates that total wage payment firm can borrow as working capital is up to the fraction of the value of its capital. $\xi(S^t)$ is an exogenous stochastic borrowing limit. $Q(S^t)$ is the shadow price of capital and equivalent to Tobin's Q. The imposition of this borrowing constraint implies that if the firm default on its borrowing, then the lenders can only recover a fraction $\xi(S^t)$ of the total borrowed amount where $0 \leq \xi(S^t) \leq 1$. This setup allows firm to renege on its debt and lenders, due to costly enforcement only allows firm to borrow up to a fraction of debt.

Using this we can write the firm's intertemporal maximization problem as

$$\max_{\Pi^f} E(S^t)\sum_{t=1}^{\infty} Y(S^t) - W(S^t)L(S^t) - \ I(S^t) - (R(S^{t-1}) - 1)\theta W(S^t)L(S^t)$$

Subject to the following constraints:

technology,

$$Y(S^t) = \ A(S^t)K(S^{t-1})^{\alpha}L(S^t)^{1-\alpha}$$

motion for evolution of capital, and

$$K(S^t) = (1-\delta)K(S^{t-1}) + I(S^t) - \frac{\emptyset_X}{2}\left(\ I_t(S^t) - \ I_{t-1}(S^{t-1})\right)^2$$

borrowing constraint

$$\theta W(S^t)L(S^t) \leq \ \xi(S^t)Q(S^t)K(S^{t-1}).$$

The household faces standard problem where they seek to maximise utility subject to the budget constraint. The household problem takes the following form:

$$\max_{C(S^t),L(S^t),B(S^t)} \ U(C(S^t)\ L(S^t))$$

Subject to

$$C(S^t) + D(S^t) \ \leq \ W(S^t)L(S^t) + \Pi(S^t) + \ R(S^{t-1})D(S^{t-1})$$

Household problem to choose a state-contingent sequence of consumption $C(S^t)$, labour $L(S^t)$, and debt holding $D(S^t)$ that maximises the expected utility subject to budget constraint and no-Ponzi game constraint for given initial level of debt $D(0)$ and given sequence of prices, $W(S^t)$ and $R(S^t)$.

5.2.3 Dynamics of interest rate

In this model I assume frictions in financial intermediation process which makes the international interest rate faced by the agents depart from risk-free rate to risky rate. In addition, given the level of financial friction, there are also country specific factors such as indebtedness, economic factors and structural rigidities which affect the investors' willingness to lend giving rise to a risk premium which is specific. A number of recent studies such as Monacelli and Sala (2018), Akinci (2013), García-Cicco, Pancrazi and Uribe (2010) and Neuymer and Perri (2005) demonstrates that risk premium contributes much more significantly to business cycles in emerging economies compared with international risk-free rate traditional real business cycle models uses. I therefore present here a simple framework to model interest rate faced to the economy using the literature.

The model assumes that international financial intermediaries are willing to lend any amount at the risky rate $R(S^t)$. As the firms which borrow has incentives to renege on its debts the rate these financial intermediaries are willing to charge on loans would be above the international risk-free rate $R^*(S^t)$. Therefore, interest rate faced by domestic agents $R(S^t)$ is becomes a function of international risk-free rate $R^*(S^t)$ and a risk premium specific to country. As described in the previous section, there are number of studies on the relationship between domestic interest rate and international interest rate faced to small and emerging economies. For instance, Uribe and Yue (2006) summarized the evidence which states that there is no one-on-one transfer of world interest rate on domestic interest rate faced by agents in small and emerging economies. In fact, when the world interest changes, it also affects the country spread due to changes in the debt burden and therefore the domestic interest rate diverge from world interest rate. I therefore specify the domestic interest rate faced by agents considering the importance of country spread.

$$R(S^t) = R^*(S^t) + D(S^t)$$

In the expression above $R^{*}(S^{t})$ is the risk-free interest rate. In this model I assume domestic firms only borrows from international lenders and existence of a single asset implies that both the domestic and foreign lenders and borrowers will face the same international rate $R(S^{t})$. Contrary to the RBC assumption, we will assume the interest rate is not completely exogeneous. In order words, lenders will treat all lending to be risky and charge a country specific risk premium linked to the domestic condition of a country, $D(S^{t})$. This formulation of country risk premium similar to Neuymer and Perri (2005) and Schmitt-Grohe and Uribe (2003).

There are three main strands of literature, which attempts to model risk premium in small open economies. The main distinction between these three strands is now the mechanism used to formulate risk premium. For instance, the first strand of literature subject the risk premium to be arising from measurable factors associated with state of macroeconomic aggregates of a country. The second strand assumes risk premium is a result of immeasurable factors, therefore it is set exogenously. Within the first strand, domestic condition such as indebtedness, output growth rate and etc affects risk premium (see Edwards (1984), Cline (1995) and Cline and Banes (1997)). The second strand of literature as exemplified by Cantor and Packer (1996) and Eichengreen and Moody (2000) is that risk premium is affected country's credit rating therefore can be treated as an exogenous factor. The third strand of literature, which is used in Neuymer and Perri (2005) assumes the risk premium to be exogenously determined through a joint combination comprising of economy dependent factors and economy independent factors.

In this chapter, similar to García-Cicco, Pancrazi and Uribe (2010) and Uribe and Yue (2006), I have introduced country's risk premium through an endogenous country specific risk. In such setting, country specific risk premium arises as a result of deviation of current level of debt per capital from its steady state level. This allows for an endogenous fluctuation in risk premium due to changes in macroeconomic aggregates. The larger the excess deviation of current debt-to-output from steady state debt-to-output ratio, the more perceived risk of default by lenders and hence would demand a higher risk premium. The existence of this relationship has been documented in various literature on international finance such as Akinci (2013). Uribe and Schmitt-Grohé (2017) using EME data on a sample of countries demonstrate that country premium rises with indebtedness. Using the theoretical background outlined above, the risk premium component of the interest rate is set as follows.

$$D(S^t) = \psi\left(e^{\left(\frac{\widetilde{D_{t+1}}}{Y_t} - \frac{D}{Y}\right)} - 1\right)$$

$\widetilde{D_{t+1}}$ denotes the aggregate level of external debts accumulated in period t, Y_t is the output in period t, D and Y are parameters denoting steady state level of debt and output. The expression also establishes that at steady state $\frac{\widetilde{D_{t+1}}}{Y_t} = \frac{D}{Y}$. ψ is a financial friction parameter which captures the magnitude at which country specific condition affects the risk premium and gross interest rate faced by the representative agent. In the literature, it is also commonly referred as debt-elasticity parameter and measures the degree of financial market friction Notz and Rosenkranz (2021). More formally ψ governs the effect on country risk premium because of changes in stock of external debts relative to its steady state level. For instance, when ψ is elastic and high, if a country's debt to GDP ratio falls below its steady state level, it improves country's overall debt position and hence will reduce country spread which will result in a fall in country interest rate.

In the context of RBC models with one traded bond, debt elastic interest rate serves two purposes. First as explain above, theoretically, the debt elastic interest rate is a simplified framework to capture financial market frictions. Second, the use of debt elastic interest rate in the literature is for the technical purpose to overcome the random walk (non-stationarity) problem in consumption, net external debt and external balances when a constant real interest rate is used. This approach as initially used by Senhadji (1994) in RBC model was popularised by Schmitt-Grohé and Uribe (2003). As noted in Schmitt-Grohé and Uribe (2017), the intuition associated with stationarity inducting properties of debt elasticity is to do with its ability to induce household to save while reducing consumption when the level of debt exceeds the steady state level of indebtedness (increasing risk premium) and vice-versa when risk premium falls. In Chapter 4, I have used endogenous discount factor to achieve stationarity. In this chapter, in keeping with the main literature based on which the theoretical model is formulated, I will use debt-elastic interest rate to induce stationarity as well as to capture international financial market frictions. This is also point of departure from Neumeyer and Perri (2005) who uses other methods to introduce stationarity.

5.2.4 Functional forms and parameters

Preferences take Uzawa (1968) functional form as used in Chapter 4 and is expressed as:

$$U_t = E_0 \sum_{t=0}^{\infty} \frac{(1+C_t-\chi \frac{H_t^{\rho}}{\rho})^{1-\sigma}-1}{1-\sigma}.$$

The parameter χ, in the utility function is introduced for the technical purpose of ensuring that the balance growth path of the economy is consistent with long run averages of the model economy. This is a standard practice in simulations.

Technology takes Cobb-Douglas form as

$$Y_t = A_t K_{t-1}^{\alpha} H_t^{1-\alpha} \quad 0 \leq \alpha \leq 1.$$

Interest rate facing domestic agents takes the following form

$$R_t = R_t^* + \psi \left(e^{\left(\frac{\widetilde{D_{t+1}}}{Y_t} - \frac{D}{Y}\right)} - 1 \right).$$

5.2.5 Equilibrium

Given the initial condition for capital K(0) and bonds D(0), state contingent interest rate $R(S^{t-1})$ and total factor productivity $A(S^t)$, we can arrive to an equilibrium which gives state contingent allocation of our endogenous variables $C(S^t), D(S^t), L(S^t), I(S^t), K(S^t)$ and price for $\{W(S^t), r(S^t)\}$ such that (a) it satisfy the household and firm problem at equilibrium prices and (b) factor markets clear. A balanced growth path for the economy is one where $R(S^t)$, $A(S^t), r(S^t)$ and $L(S^t)$ are constant and all other endogenous variables grows at a constant rate. If the working capital requirement is set to zero then the model comes down to a standard real business cycle model. If the collateral constraint is set to zero, then we will get a model similar to Neumeyer and Perri (2005). The introduction of working capital requirement and collateral constraint distorts the standard business cycle equilibria by introducing credit-channel effects as described in Chapter 2 at the same time affects the debt burden through external financing premia on firms and households.

As this is a small open economy setup, the national accounting identity would imply the household's debt position , $D(S^{t-1})$ net of firms working capital borrowed $\theta W(S^t)L(S^t)$ is country's net foreign asset position for period t. At the same time goods produced that is not spent on consumption and investment is equivalent to country's net export.

5.2.6 Closing the Model

The model economy is subject to the following transitory shocks.

The technology follows the following AR(1) process

$$\text{InA}(S^t) = \rho_A \text{In}A(S^{t-1}) + \epsilon_A(S^t); \qquad \epsilon_A(S^t) \sim NIID\ (0, \sigma_A^2); t \geq 0$$

The financial friction parameter $\xi(S^t)$ follows the following AR(1) process

$$\text{In}\xi(S^t) = \rho_A \text{In}\xi(S^{t-1}) + \epsilon_\epsilon(S^t) \qquad \epsilon_\xi(S^t) \sim NIID\ \left(0, \sigma_\xi^2\right); t \geq 0$$

The world interest rate is subject to the following AR(1) process

$$\text{In}R^*(S^t) - \bar{R} = \rho_R(\text{In}R^*(S^{t-1}) - \bar{R}) + \epsilon_R(S^t); \qquad \epsilon_R(S^t) \sim NIID\ \left(0, \sigma_{R^*}^2\right); t \geq 0$$

5.2.7 Representative Agents Problems

Based on the description of model's framework and functional forms from 5.2.4, this section lays out the representative household and firm's maximisation problem and their associated first order conditions:

5.2.7.1 Representative Household's problem

Setting λ_t^1 as the multiplier associated with the household's budget constraint, the representative household's problem described above can be written in the form of the following Lagrangian:

$$\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta^t \left[\left(\frac{\left(1 + C_t - \chi \frac{H_t^\rho}{\rho}\right)^{1-\sigma} - 1}{1-\sigma} + \lambda_t^1 (W_t H_t + \Pi_t + (1 + R_{t-1}) D_{t-1} - C_t - D_t) \right) \right]$$

The first order conditions of the household with respect to C_t, H_t, D_t and λ_t^1 are summarized below:

$$\lambda_t^1 = \left(1 + C_t - \chi \frac{H_t^\rho}{\rho}\right)^{-\sigma} \quad 5.1$$

$$\lambda_t^1 W_t = \left(1 + C_t - \chi \frac{H_t^\rho}{\rho}\right)^{-\sigma} \chi H_t^{\rho-1} \quad 5.2$$

$$1 = E_t \left[(1 + R_t) \beta \frac{\lambda_{t+1}^1}{\lambda_t^1} \right] \quad 5.3$$

$$0 = W_t H_t + \Pi_t + (1 + R_{t-1}) B_{t-1} - C_t - D_t \quad 5.4$$

By combining (5.1) and (5.2) we arrive to similar expression as the benchmark RBC model

$$\chi H_t^{\rho-1} = W_t \quad 5.5$$

Expression (5.5) shows that hours worked as solely determined by the wage rate. The wealth effect of changes in consumption is excluded in determining hours worked. This is a direct result from the preference specification adopted in the model.

In expression (5.3) $E_t\beta\frac{\lambda_{t+1}^1}{\lambda_t^1}$ is known as household stochastic discount factor. I will use Λ_t to denote the stochastic discount factor for convenience in final expression where $\Lambda_{t+j} = E_j\beta^j\frac{\lambda_{t+j}^1}{\lambda_t^1}$ where $j \in (0, \dots, \infty)$ in discrete time. It can be seen from equation (5.3) that at steady state $\beta = \frac{1}{(1+R)}$.

5.2.7.2 *Representative Firm's problem*

As firms are owned by the households, the firm discount all its future profits by household's stochastic discount factor $E_t\beta^j\frac{\lambda_{t+j}^1}{\lambda_t^1}$ and faces two constraints as outlined in the previous section.

(1) let Q_t be the multiplier on capital accumulation equation as Q_t in our benchmark model and this model represent the shadow value/price of capital (how much firm is willing to give up in terms of goods for an additional unit of capital)

(2) let μ_t be the multiplier on borrowing constraint / collateral constraint

Using the stochastic discount factor and multiplier Q_t and μ_t, representative firm's problem described in previous part can be expressed as the following Lagrangian:

$$\mathcal{L} = E_t\sum_{j=0}^{\infty}\beta^j\frac{\lambda_{t+j}^1}{\lambda_t^1}\Big\{A_tK_{t-1}^{\alpha}H_t^{1-\alpha} - W_tH_t - I_t - (R_{t-1}-1)\theta W_tH_t$$

$$+ Q_t\left[(1-\delta)K_{t-1} + I_t - \frac{\emptyset_X}{2}(I_t - I_{t-1})^2 - K_t\right] + \mu_t[\xi_tQ_tK_{t-1} - \theta W_tH_t]\Big\}$$

The first order conditions with respect to H_t, I_t, K_t, Q_t, and μ_t are below:

$$(1-\alpha)A_tK_t^{\alpha}H_t^{-\alpha} = W_t\big(1+\theta(R_{t-1}-1+\mu_t)\big) \qquad 5.6$$

$$1-Q_{t+1}E_t\beta\frac{\lambda_{t+1}^1}{\lambda_t^1}\phi_X(I_{t+1}-I_t) = Q_t\big[1-\big(\phi_X(I_t-I_{t-1})\big)\big] \qquad 5.7$$

$$Q_t = E_t\beta\frac{\lambda_{t+1}^1}{\lambda_t^1}\begin{pmatrix}\alpha A_tK_t^{\alpha-1}H_t^{1-\alpha}+\\ Q_{t+1}\big((1-\delta)+\mu_{t+1}\xi_{t+1}\big)\end{pmatrix} \qquad 5.8$$

$$0 = \big((1-\delta)+\mu_t\xi_t\big)K_{t-1}+I_t-\frac{\emptyset_X}{2}(I_t-I_{t-1})^2-K_t \qquad 5.9$$

$$0 = \xi_tQ_tK_{t-1}-\theta W_tH_t \qquad 5.10$$

A comparison between equation (5.2) and (5.6) shows that with the presence of binding collateral constraint ($\mu_t \neq 0$), it drives a wedge between wage rate and marginal product of labour. The tighter the constraint, the higher would be the shadow price μ_t which would increase the wedge. One could consider this in a similar fashion as a labour tax (that is tax is equivalent to $(R_{t-1}-1+\mu_t)$) where the tighter the constraint on firm, the more tax on labour income. If the constraint does not bind (that is where $\mu_t = 0$) then this become similar to benchmark RBC model with investment adjustment cost. It can be seen from expression (8) that if the working capital requirement is removed ($\theta = 0$), then the model is equivalent to a benchmark model with adjustment cost in Chapter 4.

From equation (5.7) it can be confirmed that at steady state Tobin's Q, $Q = 1$. At the sametime, as there is no friction in capital market, we can get the rental rate for capital to be $R^K = \alpha AK^{\alpha-1}H^{\alpha} + (1-\delta)$. And one can see from expression (5.8) and (5.9), that in steady state discount factor is equal to $\beta = \frac{1}{(1+R)}$ such that there are no arbitrage opportunities between capital and financial markets at equilibrium.

5.3 Characterisation of equilibrium

In this section, I will discuss how interest rate shock and productivity shock enters the real economy through labour market and domestic interest rate. I will also make further comment on how balance sheet effects are measured in the context of this model. A more detailed framework will be presented during the discussion of impulse responses.

5.3.1 interest rate shocks

The impact of interest rate shock to the economy travels through changes in labour market, capital market and consumption. The effect on labour market can be derived by combining household first order condition for hours worked and consumption (5.5) and firms first order condition with respect to hours employed in production (5.6).

$$\frac{(1-\alpha)A_t K_t^{\alpha} H_t^{-\alpha}}{\left(1+\theta(R_{t-1}-1)+\mu_t\right)} = W_t = \chi H_t^{\rho-1} \qquad 5.11$$

The consequence of intraperiod loan and borrowing constraint can be seen in (5.11) where it drives a wedge between wage rate and marginal product of labour. As show in (5.11) wage rate depends on marginal product of labour, interest rate, fraction of wage bill paid in advance and shadow price of the borrowing constraint. The left-hand side of (5.11) can be interpreted as labour demand curve and right-hand side as the labour supply curve. For any $\theta > 0$ it can be seen that interest rate shock in period t will affect the production decision in $t+1$ such that for any given wage rate, the $t+1$ period demand for labour would reduce.

Another important issue to highlight here is the role of borrowing constraint. μ_t is the LaGrange multiplier on borrowing constraint and represent the shadow price of borrowing. If μ_t increases, that implies that the constraint become tighter and less binding. This also signals that the change in value of the firm's assets compared to the increase in working capital requirement is smaller. This endogenous mechanism therefore capture the balance sheet effect on firms. If an external shock results in reduction in value of firm's assets (fall in its real value of capital stock), it will make the constraint more binding (increase in μ_t) that will feedback to the real economy through lower labour demand and hence employment.

5.3.2 Productivity shock

Given the specification of interest rate where interest rate is a function of risk-free rate and risk premium, any changes in productivity will affect the country risk premium causing domestic interest rate to change. A positive technology shock will reduce country risk premium and interest rate. Concurrently, the firm will increase its demand for labour (therefore total wage payment due) above the net worth. Therefore, the interaction of country risk and working capital demand will amplify the effect of productivity shock compared to standard model produced in the previous chapter. The empirical evidence presented in Table 1 shows that the correlation between risk premium and output is much larger compared with the correlation between output and domestic interest rate. This signals the importance of output in influencing risk premium. For a small open economy this theoretical prediction is not surprising due to its heavy reliance on external finance. Creditors often relies on observed economic fundamentals such as output and debt level to establish its lending criteria and risk premium.

5.4 Non-stochastic steady state of the model

At steady state $I_{t-1} = I_t = I_{t+1}$ and henceforth, from equation (5.7), we can see that $Q = 1$. Using steady state relations, Euler equation in (5.3) can be written as $\beta = \frac{1}{1+R}$ or equivalently

$$R = \frac{1}{\beta} - 1. \quad 5.12$$

First order condition with respect to capital in (5.8) can be used to pin down steady state capital to labour ratio as follows:

$$Q = \beta\big(\alpha K^{\alpha-1} L^{1-\alpha} + Q(1 - \delta + \mu\xi)\big).$$

At steady state as $Q = 1$ and $A = 1$, the above expression combined with (5.12) can be used to derive steady state capital to labour ratio as a function of model's parameters as shown below.

$$\frac{1}{\beta} - (1 - \delta) - \mu\xi = \alpha K^{\alpha-1} L^{1-\alpha}$$

$$\left(\frac{K}{H}\right)^{\alpha-1} = \frac{\frac{1}{\beta} - (1 - \delta) - \mu\xi}{\alpha}$$

$$\frac{K}{H} = \left(\frac{\frac{1}{\beta} - (1 - \delta) - \mu\xi}{\alpha}\right)^{\frac{1}{\alpha-1}} \qquad 5.13$$

Expression (5.13) demonstrate that compared with the standard RBC model, the need to finance working capital through a loan reduces steady state capital to labour ratio. In this model, similar to Chapter 4, in steady state $H = 0.33$. Therefore, expression in (13) can be re-arranged to arrive steady state level of capital as function of model parameters and steady state hours as

$$K = \left(\frac{\frac{1}{\beta} - (1 - \delta) - \mu\xi}{\alpha}\right)^{\frac{1}{\alpha-1}} H \qquad 5.14$$

I will now demonstrate parameterization needed to ensure Lagrangian multiplier on borrowing constraint, μ binds. A binding μ will ensure collateral constraint binds in the model economy. First I will obtain an expression for μ, using two relations from firms first order conditions and pin down the necessary condition required for the collateral constraint to bind. Evaluating first order condition with respect to LaGrange multiplier in (5.10) at steady state gives

$$W = \xi \frac{K}{H}. \qquad 5.15$$

From the first order condition in (5.6), one can arrive to

$$W = (1 - \alpha)\left(\frac{K}{H}\right)^{\alpha} \frac{1}{(1 + \theta(R_{t-1} - 1 + \mu_t))}. \qquad 5.16$$

Combining (5.15) and (5.16) and substituting for capital-to-hours worked ratio at (5.14), gives the following expression.

$$\left(\frac{\alpha}{\frac{1}{\beta}-(1-\ \delta)-\mu\xi}\right)=\frac{(1-\alpha)}{\xi}\frac{1}{\left(1+\theta(R_{t-1}-1+\mu_t)\right)} \qquad 5.17$$

In my parameterization, I set $\theta = 1$, denoting firm needs to set aside the entire wage bill as working capital. With this parameterisation, expression in (5.17) can be then solved for μ as below.

$$\mu = \frac{(1-\alpha)}{\xi}\left(\frac{1}{\beta}-(1-\ \delta)\right)-\alpha R \qquad 5.18$$

Expression in (5.18) shows that the multiplier is decreasing in ξ. The variable ξ represents the percentage of capital against which the firm can borrow its working capital. This variable therefore captures the borrowing power (limit) of the firm. If ξ, rises, firms experience an increase in its borrowing limit therefore the multiplier will fall. Therefore, the bigger the ξ, the less binding the collateral constraint would be. This formulation makes intuitive sense as rise in ξ makes borrowing easier and hence lower shadow value of borrowing. If $\xi = 1$, it would make μ to not binding as firms can freely borrow without any constraint. Using (5.18) one can arrive at the cut-off value for ξ for the constraint to bind.

$$\xi < \frac{(1-\alpha)}{\alpha R}\left(\frac{1}{\beta}-(1-\ \delta)\right) \qquad 5.19$$

Equation (5.11) can be used to arrive at steady state hours worked.

$$\frac{(1-\alpha)A_tK_t^{\alpha}H_t^{-\alpha}}{\left(1+\theta(R_{t-1}-1+\mu_t)\right)} = \ \chi H_t^{\rho-1}$$

$$(1-\alpha)AK^{\alpha}H^{-\alpha} = \ \chi H^{\rho-1}\left(1+\theta(R-1+\mu)\right)$$

$$(1-\alpha)\left(\frac{K}{H}\right)^{\alpha} = \ \chi H^{\rho-1}\left(1+\theta(R-1+\mu)\right)$$

$$H^{\rho-1} = \frac{1}{\chi} \frac{(1-\alpha)\left(\frac{K}{H}\right)^{\alpha}}{\left(1+\theta(R-1+\mu)\right)} \quad 5.20$$

Substituting (5.13) into (5.20), steady state Hours can be pinned down as

$$H^{\rho-1} = \frac{1}{\chi} \frac{(1-\alpha)\left(\frac{\frac{1}{\beta}-(1-\delta)-\mu\xi}{\alpha}\right)^{\frac{\alpha}{\alpha-1}}}{\left(1+\theta(R-1+\mu)\right)} \quad 5.21$$

In this model hours worked are fixed to match the long run average from the data. As $\beta, \delta, \mu, \xi, \theta, R$ as fixed at stead state, to ensure hours hit the target hours based on data, parameter χ is calibrated to achieve target hours. Expression (5.21) shows the directional effect of financial friction on dynamics of hours. The financial friction enters through hours worked through both μ and ξ. It can be seen that rise in μ and ξ reduces hours worked due to tightening of collateral constraint.

Steady state consumption can be arrived from the household resource constraint as

$$C = Y - I - RWH + RD \quad 5.22$$

Where steady state output is arrived as

$$Y = AK^{\alpha}H^{1-\alpha} \quad 5.23$$

Wage rate at steady state is set as follows:

$$W = (1-\alpha)\frac{Y}{H}\frac{1}{(R+\mu)} \quad 5.24$$

Steady state investment can be derived from steady state equation of motion of capital as follow:

$$I = \delta K \quad 5.25$$

Steady state external balance is set as follows using household budget constraint

$$\frac{TB}{Y} = 1 - \frac{(C + I + (R-1)WH)}{Y} \quad 5.26$$

As demonstrated in section 5.4 this representative model economy departs from Neumeyer and Perri (2005) towards Uribe and Yue (2006). However, unlike the latter, I have abstained from introducing trend shock into the model economy for number of reasons. Firstly, this thesis does not aim to study the role of trend shock in generating business cycle. While the literature on cycle is trend is influential, there are also competing classes of models which are equally influential to study EME business cycle. Secondly, to incorporate trend, one needs to be able to predict the trend using a long data series. As data on Maldives is limited to last 37 years, I lack sufficient information to look at the behaviour of trend in the context of the Maldives.

5.5 Calibration and Estimation

The model is calibrated by fixing values for parameters. The standard RBC parameters relating to preferences, steady state hours, capital share of output, risk free interest rate, depreciation, autocorrelation of technology shock and investment adjustment cost are taken from the Chapter 4. Parameters governing interest rate shock and standard deviation of shocks are taken from Neumeyer and Perri (2005). Parameters governing risk premium shock are fixed to obtain as close solution to standard deviation of output, Full details on model parameters, its sources and values are summarised in Table 5.2.

The theoretical model presented in the previous section will be estimated using the calibrated values presented in Table 5.2. Unlike Chapter 4, I have decided against using Bayesian estimation due number of reasons. First, the model in this chapter significantly overlaps with the model presented and estimated in Chapter 4 using Bayesian method. Therefore, the gain from estimating this chapter's model is limited both in terms of new information and efficiency. Second, the model presented in Chapter 6 represent a better departure from the models in this chapter while incorporating the main financial friction mechanism presented in this chapter. I have estimated the model in Chapter 6 using Bayesian estimation. The estimation strategy used in Chapter 6 includes two versions of the model – a model with collateral constraint and a model without collateral constraint. This therefore makes the output of Chapter 6 sufficient to provide empirical evidence on role of financial market friction to fulfil the objective of this thesis while minimising duplication of empirical output and results. Similar to previous chapter, I will estimate the model using Dynare where the model will be coded as a non-linear model and Dynare will run the model having performed the linearization.

Parameter		Source	Calibrated Value
α	Capital share of income	ratio of labour income to net national income at factor prices	0.33
R_bar	world interest rate (annual)	extracted from literature usually indexed to real interest rate of US economy	0.05
σ	Coefficient of risk aversion parameter	Fixed based on real business cycle literature.	2.00
ω	Frisch-elasticity parameter (inverse of labour supply elasticity)	Calibrated based on Heckman and MaCurdy (1980) and MaCurdy (1991). This figure must correspond to percentage of variability in hours	1.455
H	Steady-state hours worked	Calibrated using average daily hours worked for the Maldives normalised as a fraction in 24 hours	0.33
$\emptyset_X$	investment adjustment cost parameter	Calibrated to match standard deviation of investment or counter cyclicality of external balances	0. 05
δ	Annual depreciation rate	Calibrated by taking long run average for	0.10

		depreciation reported in Penn World Data	
ρ_A	autocorrelation of TFP	Using data on the Maldives for real GDP, Capital and Labour hours worked, A_t computed similar to Aguiar and Gopinath (2004) and coefficient for ρ_A is computed by running a first order autoregressive model of A_t in MATLAB.	0.52
ρ_R	autocorrelation of interest rate	Taken from Neumeyer and Perri (2005).	0.81
ρ_ξ	Autocorrelation of financial friction parameter (% of wage bill that need to be set aside)	Calibrated to match standard deviation of output	0.50
ϵ_R	Standard deviation of Interest rate shock	Taken from Neumeyer and Perri (2005) and Uribe and Yue (2006).	0.63
ϵ_A	Standard deviation of output shock	Taken from Neumeyer and Perri (2005)	1.98
ϵ_ξ	Standard deviation of financial friction shock (fraction of the value of capital against which firm can borrow)	Fixed to match the standard deviation of output	0.90
ξ	Cut-off value for the borrowing fraction	Set to ensure the constraint bind so that borrowing can occur.	0.09

ψ	Debt-elasticity parameter governing the effect of country specific condition on risk premium	Taken from Schmitt-Grohe and Uribe (2004) for baseline analysis.	0.000742 (baseline) 0.004 (sensitivity analysis)

Table 5.2: Parameters values and sources

5.6 Impulse responses

In the absence of working capital requirement, the competitive equilibrium of the small open economy is the same as Chapter 4. The introduction of working capital requirement, a credit constraint in the form of collateral requirement and subjecting domestic interest rate to a country specific risk premium distort the equilibrium through an endogenous credit channel. The credit channel, as a result, becomes the propagation and amplification mechanism following realization of shocks. Due to this, one can expect the results of this model economy to differ from Chapter 4. The difference in mechanism can be attributed to the impact credit market imperfection has on the household and the firm's financing costs. In this model, the household's external financing cost is affected by changes in country risk premium meanwhile the firm's external financing cost is affected by both the value of credit constraint and as well as risk premium. This section presents impulse responses following each shock. Where applicable, I have also discussed how the results of the present model will differ from standard predictions in RBC literature and Neumeyer and Perri (2005).

5.6.1 Impulse responses following a positive technology shock

Prior studies of RBC models with working capital constraint includes Neumeyer and Perri (2005) and Uribe and Yue (2006). Mendoza (2011) states that working capital requirement combined with collateral constraint provides results which are different from the above papers as the decision on labour hire is determined jointly by the impact on interest rate and value collateral constraint. The difference in results is partly due to the role of collateral constraint accompanying the working capital requirements being filtered into the labour demand function of firms. Unlike the work of Neumeyer and Perri (2005), labour demand as shown in (5.6) is now affected shadow price of borrowing, μ_t. First order condition in (5.6) after solving for wages is re-written as follows.

$$w_t = \frac{(1-\alpha)A_t K_t^{\alpha} H_t^{-\alpha}}{\left(1+\theta((R_{t-1}-1)+\mu_t)\right)} \qquad 5.27$$

As shown in (5.27) capital market imperfection enters into labour demand function which shifts the transmission dynamics away from the prediction of standard RBC model. In standard RBC models, a positive technology shock increases marginal product of labour at any given wage rate. In response to this, in a closed economy it would cause intratemporal substitution between consumption and hours worked. The intratemporal substitution act as the main propagation and amplification mechanism which causes movements in macroeconomic aggregates. In subsequent periods, it leads to intertemporal substitution between hours worked and consumption as households aim to smooth consumption overtime. Given that the domestic absorption is the difference between household income and expenditure, the difference would be also equal to investment as household aims to smooth its consumption. In an open economy, the consumption smoothing occurs through capital account where household smooth their consumption through accumulation of one period international debts. As a result, one would expect the current account to deteriorate following a positive technology shock.

The path following a technology shock under Neumeyer and Perri (2005) is consistent with the prediction from canonical real business cycle model except for magnitude of impact. The difference in magnitude comes from the wedge created by working capital requirement between wage rate and marginal product of labour. Under Neumeyer and Perri (2005) as firm can freely borrow without any constraint, shadow value of borrowing in expression (5.27) will be equal to zero but the interest on borrowed fund will remain. This therefore implies that compared to standard real business cycle predictions, with the imposition of working capital requirement on firms would result in optimal labour hired by the firms at any given states to be lower compared with standard RBC models and Neumeyer and Perri (2005).

However, when labour demand is subject to further frictions such as a borrowing constraint, any changes to the value of the constraint would further exacerbate the wedge between marginal product of labour and wage rate. Under this setup labour demand will be much smaller as increasing marginal product of labour discounted by the capital market friction parameters present in denominator of (5.27). Demand for labour given by (5.27) now encompass shadow value of working capital μ_t, representing changes in the value of collateral constraint. For instance, if value of collateral required increases, then μ_t gets tighter. Expression (5.27) shows that the working capital requirement and collateral constraint creates a wedge (similar to a tax on labour income) between the wage rate and marginal product of labour. Any changes into the value of μ_t, in response to a technology shock can therefore alter the directional effect on demand for labour away from the predictions of standard RBC models. The difference in effect on labour under these three scenarios are shown in Figure 5.4.

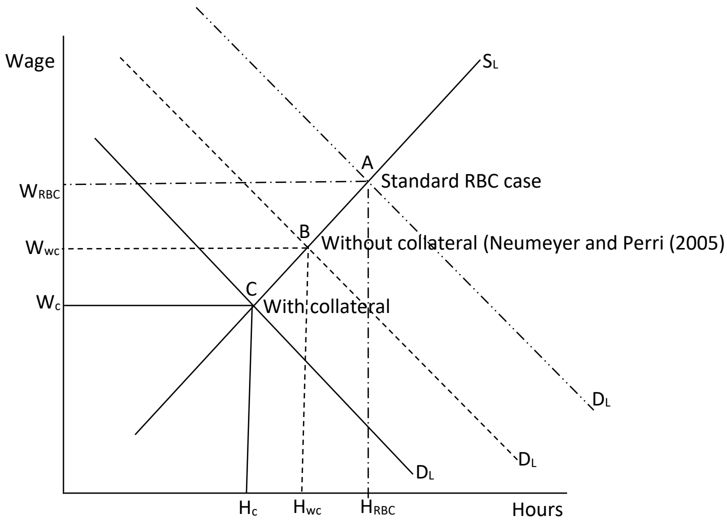


Figure 5.4: Effect on labour and wages under alternative formulations

In Figure 5.4 above, the point marked as 'A' represent equilibrium labour market condition following a positive technology shock which results in hours worked at H_{RBC} and wage rate of w_{RBC} under standard RBC setup in Chapter 4. The Labour demand curve cutting the labour supply curve at point B represent the impact on labour demand and hours worked when there is working capital requirement imposed on firms as covered in Neumeyer and Perri (2005). This is due to the wedge working capital requirement draws between wage rate and marginal product of labour which results in lower wage rate and equilibrium employment than standard RBC model. The curve that intersects at point C shows the impact under current model. As shown above, one would expect labour hours to show a smaller growth under the case with collateral constraint as opposed to one without collateral constraint as the wedge in (5.27) is greater under the present setup as compared with Neumeyer and Perri (2005) framework.

Figure 5.5 shows the impulse responses of the current model compared with the case where there is no borrowing constraint imposed on working capital à la Neumeyer and Perri (2005) specification. As a result of (5.27), hours worked increase by a smaller fraction following a 1% positive technology shock. The impulse responses show that following a technology shock, the increase in μ_t offsets part of the increase in marginal product of labour causing a smaller increase in employment.

As per the borrowing constraint, the firm's ability to borrow depends on the shadow price of capital, Q_t and any given stock of capital in each period. The impulse responses shows that when the shadow value of borrowing constraint rises upon impact, the shadow price of capital Q_t also rises and then gradually falls in a similar fashion. Even though I have not modelled capital side explicitly, Chapter 4 shows that Q_t increases with return on capital. A technology shock will increase return on capital and hence the value of Q_t. As shown in Figure 5.5, under both constrained and unconstrained case, the path of Q_t in response to a shock is identical. This implies that the collateral constraint has no direct effect on price of capital. In the context of this model, Q_t is the both the price of capital and multiplier on the motion for accumulation of capital

The comparison between the path of μ_t, with the path of shadow price of capital, Q_t would enable us to understand the role of the collateral constraint in the transmission mechanism. The comparison of two impulse responses μ_t and Q_t shows that the rate at which μ_t change throughout the period under consideration is higher than the Q_t. As firms borrow against the value of its capital, a rise in Q_t increases firm's ability to borrow (similar to rise in net worth of the firm). The benefit of rise in value of firm's capital due to Q_t increase needs to be compared with the effect on shadow price of borrowing. In response to a positive technology shock, the firm would want to expand output by rising hours contracted. At the same time, it also needs to increase the investment in capital to facilitate the additional wage payments. As shadow price of borrowing μ_t rises more than Q_t it signals that the total wage bill, W_tH_t the firm wants to commit to is more than the increase in total net worth. In this case, the positive effect on borrowing created by higher value of capital is not adequate to compensate the increase in total wage payment firms wants to pay to its labour. As collateral constraint facing to the firm is $\theta W_tH_t \leq \eta_t Q_t K_{t-1}$, the faster increase in left-hand side compared with right hand side rises the shadow value of borrowing. This would make the firm to contract less hours compared to unconstrained case following a positive technology shock. In the setup of this model, the parameterisation of the fraction of capital that can be borrowed against is determined such that the shadow value of borrowing is positive and binding. As this model is solved using perturbation techniques, it is approximated at a point where the collateral constraint bind (by fixing value for ξ) ignoring any possibility at which the constraint would not bind.

As shown in Figure 5.5, in response to technology shock, when firms borrowing is constrained, the largest change occurs to μ_t where upon impact μ_t increases. The implication of higher μ_t in response to a positive productivity shock is that it rises the value of collateral making the constraint tighter. This change triggers a similar feedback mechanism to real variables as in the case of tax on labour income in a standard RBC models. The higher μ_t as shown by labour demand function in (26) implies that it increases the wedge between wage rate and marginal product of labour, hence interpreted as a tax on labour income. Therefore, unlike standard RBC model in which propagation mechanism originates from factor markets, in this model it originates through the credit market.

For the reasons outlined above, upon impact, the impulse responses show sluggish adjustment in hours H_t but rise in capital, K_t and Investment, I_t. The magnitude of rise in K_t leads Y_t to rise. As shown from the impulse responses, the largest response at impact comes from investment. The presence of collateral constraint affects firms' incentive to invest more due to the fact higher investment translates into more capital in the future and thus would contribute to higher borrowing power in the future to finance the working capital. This implies investment today eases the value of credit constraint in the future.

As output increases along with investment, consumption also increases. The trade balance upon impact deteriorates due to domestic absorption raising faster than output. This therefore captures the countercyclical nature of external balances and output.

The expansion in economic activities caused by technological shock makes collateral constraint more binding as shadow price of borrowing, μ_t increases significantly. This shows that firms want to increase its employment of labour but are unable to as a result of slow capital accumulation. Therefore, the shadow price for borrowing influence labour demand decision as μ_t captures the tightness of the borrowing constraint. In fact, the Figure 5.4 and 5.5 shows that impact on labour is response is muted when a borrowing constraint is in place compared to the unconstrained case. Investment behaves in a similar fashion under both cases. This is because firm recognises the importance of investment to ensure borrowing capacity is maintained. As investment is fairly the same, but hours rise significantly in unconstrained case, and trade balance deteriorates upon impact.

In order to establish the existence of a financial accelerator, one need to consider the extent to which productivity shock, manifests an endogenous response in credit market which amplifies the impact on real economy (Bernake et. al, 1999). The concept of 'financial accelerator' therefore is based on the premise that exogenous shocks affect the value of capital which then translate into a firm's ability to borrow in the market. As described above, and shown in impulse responses, the technology shock affects price of capital and borrowing limit and the combined impact on output appears smaller compared with no credit market frictions. Therefore, there is limited support for the presence of a financial accelerator mechanism in the case of a productivity shock.

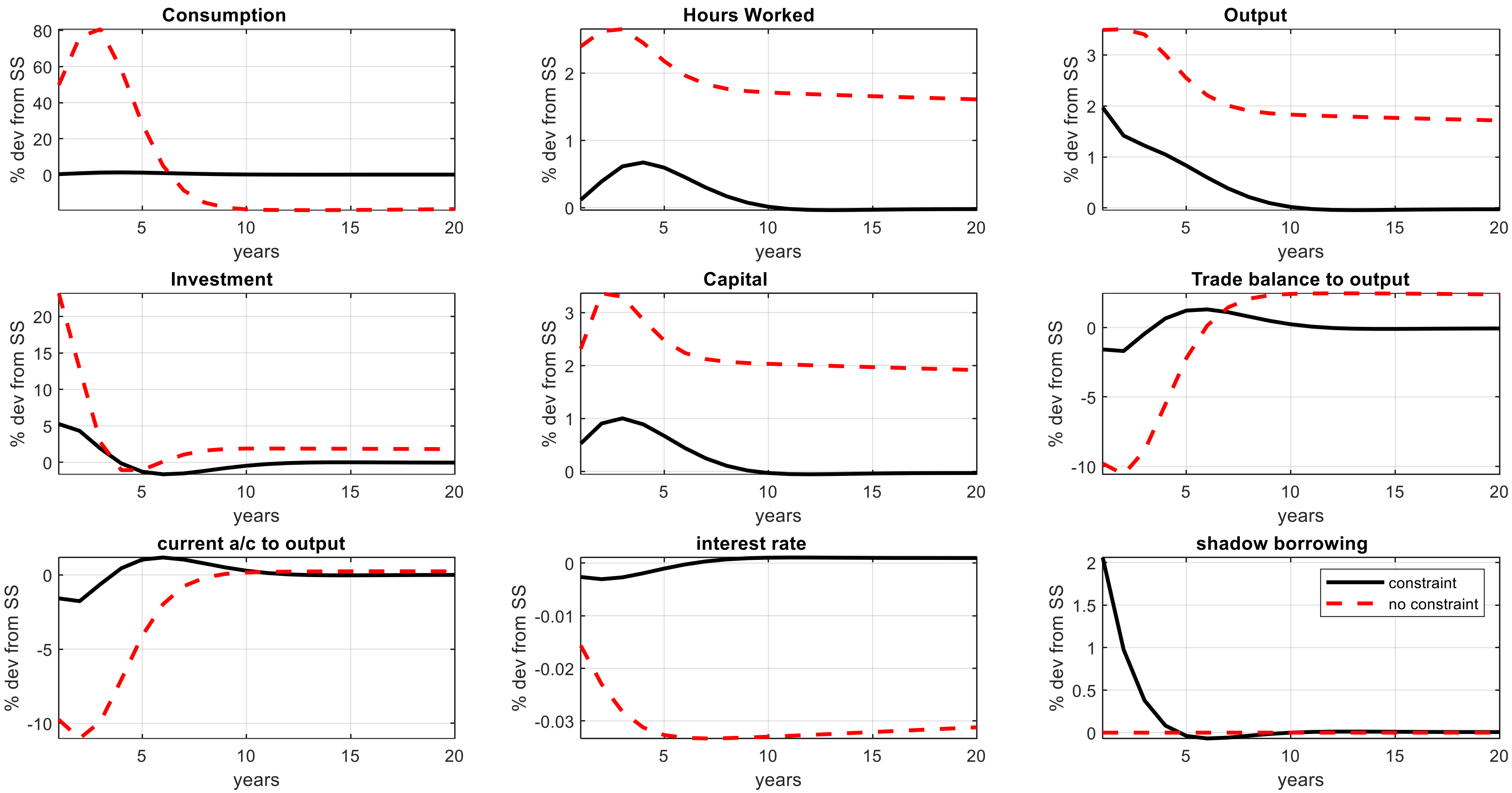


Figure 5.5: Impulse responses following 1% positive technology shocks with collateral constraint and without collateral constraint

5.6.2 Impulse response following interest rate shock

In open economy RBC models, interest rates play an important in the propagation mechanism despite the debate surrounding the approaches used to model interest. The methodological position of interest rate has led to considerable differences in conclusions on role of interest rate in explaining business cycle (See Chang and Fernadez (2012), Uribe and Yue (2006), Aguiar and Gopinath (2006) and Neumeyer and Perri (2005)). In a standard RBC model with frictionless, incomplete international financial markets, interest rate shocks affect the economy by affecting the decisions of agents in three ways. First, a positive interest rate shock induces a wealth effect on agents; however, the directional effect is determined based on the net foreign asset position of the economy. Secondly, in the household's intertemporal budget constraint, interest rate represents opportunity cost of consumption today versus future, therefore a positive shock would raise the price of consumption resulting household forgoing today's consumption in favour of savings (future consumption). Thirdly, as interest rates are the price of debt, a shock to it would results in representative agents' reallocation of their portfolio between investment and debts. Changes to former would affect the capital accumulation in subsequent periods while the latter would affect the external balance. For instance, a rise in the world interest rate would result in an increase in debt repayment burden, and make return on saving more attractive compared to return on capital. Therefore, capital stock would decline in subsequent periods while household purchases more bonds. Under such a setting, as shown in Chapter 4, in the standard RBC model the labour demand is not directly affected by changes in interest rate but rather the transmission mechanism start from intertemporal substitution which results in changes to domestic absorption which then affects labour demand in subsequent periods.

In this model with financial friction, the specification of interest rate facing the economy captures another aspect of friction in international financial markets where an endogenous risk premium arises when the debt-to-GDP ratio diverge from its steady state level. The elasticity parameter, ψ governs the responsiveness of this endogenous risk premium in influencing the domestic interest rate. Therefore, any shock to interest rate would affect both the household consumption smoothing behavior and economy's debt-to-GDP ratio in subsequent periods. The transition path for domestic interest rate as a result of the shock will come from two sources. First, as international risk-free rate starts to converge to its steady state level, domestic interest rate should experience similar path. However, whether the domestic interest rate converge to its long run level at the same speed as international risk-free rate will be determine by the risk premium. Following initial shock, one should expect the debt burden of domestic agents to increase which will result in an endogenous change in interest rate associated with changes in risk premium. In this case, one should expect country spread to increase. In the subsequent periods, as household save, it may result in a fall in risk premium. The timing of risk premium movement therefore will determine the speed at which domestic interest rate will converge to its long run level.

A further importance of debt elasticity parameter ψ is it determines the volatility of trade balance to output ratio and the flatness of autocorrelation function of trade balance. One of the key feature of EMEs are documented in Chapter 2 is the downward sloping autocorrelation function for trade balance to output ratio. Figure 5.6 shows the impact ψ has on autocorrelation function for trade balance to output ratio compared with the empirical autocorrelation function of the Maldives.

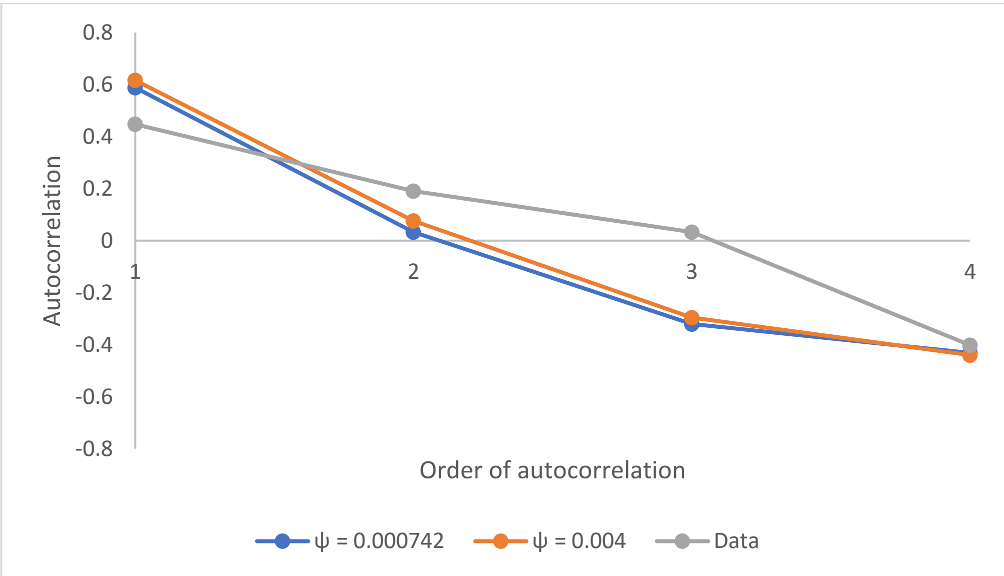


Figure 5.6: The autocorrelation function of trade-balance to output ratio

As shown in Figure 5.6, the larger the debt elasticity parameter the steeper the autocorrelation function becomes. This is due to the influence of risk premium on debt burden of representative household and their ability to smooth consumption over time through external balance. As argued in Uribe and Schmitt-Grohe (2017), the smaller the debt elasticity parameter, the more persistent the external debt becomes causing a flatter autocorrelation function. However, the larger the debt-elasticity parameter, it generates an endogenous self-stabilising effect which forces household to reduce consumption and service debt whenever the period's debt-to-output ratio exceeds the steady state level. The household engage in this behaviour to prevent future interest rate and servicing of debt from getting larger due to risk premium. However, it must be noted that debt elasticity parameter ψ is not the only parameter governing the shape of autocorrelation function in Figure 5.6. As explain in chapter 4, investment adjustment cost parameter, $\emptyset_X$ also plays a role in governing the behaviour of trade balance to output. In the context of this model, along with these two parameters, the working capital constraint will also contribute towards the shape of autocorrelation function. Based on Figure 5.6, each parameterisation provides similar pattern to what is observed for Maldivian empirical autocorrelation function for trade balance to output ratio. However, the baseline parameterisation appears to match the observed patter much more closely than the alternative parametrisation.

To explain the how interest rate shock transmits to the real economy, I will outline the how interest rate affects the working capital and borrowing. When the working capital firm need to set aside is subject to a borrowing constraint, the labour demand is affected by both changes in interest rate and shadow value of borrowing constraint from the following period. As the firm borrow working capital based on a predetermined interest rate, at impact, there would not be a change in repayment value for outstanding loan. In subsequent periods however the cost of borrowing will rise. As firm makes labour and capital decisions at the beginning of the period following the state of the world, it will reduce labour demand. In addition, the increase in cost of borrowing leads to a fall in investment. As a result, there will be a fall in the value of capital stock once depreciation is factored in. The reduction in value of capital stock can be considered as fall in net worth of the firm. This will make borrowing constraint to become more binding. The firm will, as interest rate starts move towards its pre-shock level, increases investment. In the subsequent periods, due to slower rate of capital accumulation and overshooting of risk premium which feeds into domestic interest rate, the labour market will experience a further squeeze as firms find themselves paying larger interest while experiencing fall in its net worth. This results in shadow borrowing constraint to momentarily fall before becoming more binding again in response to contraction in the economy as result of delayed overshoot of risk premium.

In Figure 5.6 it shows following world interest rate shock, at the jump period there is no effect on hours and output. Similar to figure 5.5 the presence of borrowing constraint creates impact much smaller in magnitude for all real variables. The decomposition of effect in subsequent periods, can be summarised as follows: first, higher interest rate increases the firm's repayment of intraperiod loan for financing working capital which would result in fall in demand labour; second, higher interest rate makes investment costly for firms therefore investment declines which would reduce capital stock in the following period thereby reducing the price of capital; third, due to fall in capital stock and investment, collateral constraint becomes more binding as fall in capital stock and investment is larger than the hours decline; Fourth, the household due to higher interest on debts would experience increase in debt repayment burden thus results in fall in consumption and accumulation of future debts. Therefore, with financial market friction, the effect interest rate shock transmits to real economy through its impact on labour market and intertemporal substitution effects as described above. Comparison of this model without borrowing constraint shows that impulse response following an interest rate shock follows closely the predictions from Uribe and Yue (2006) and Neumeyer and Perri (2005).

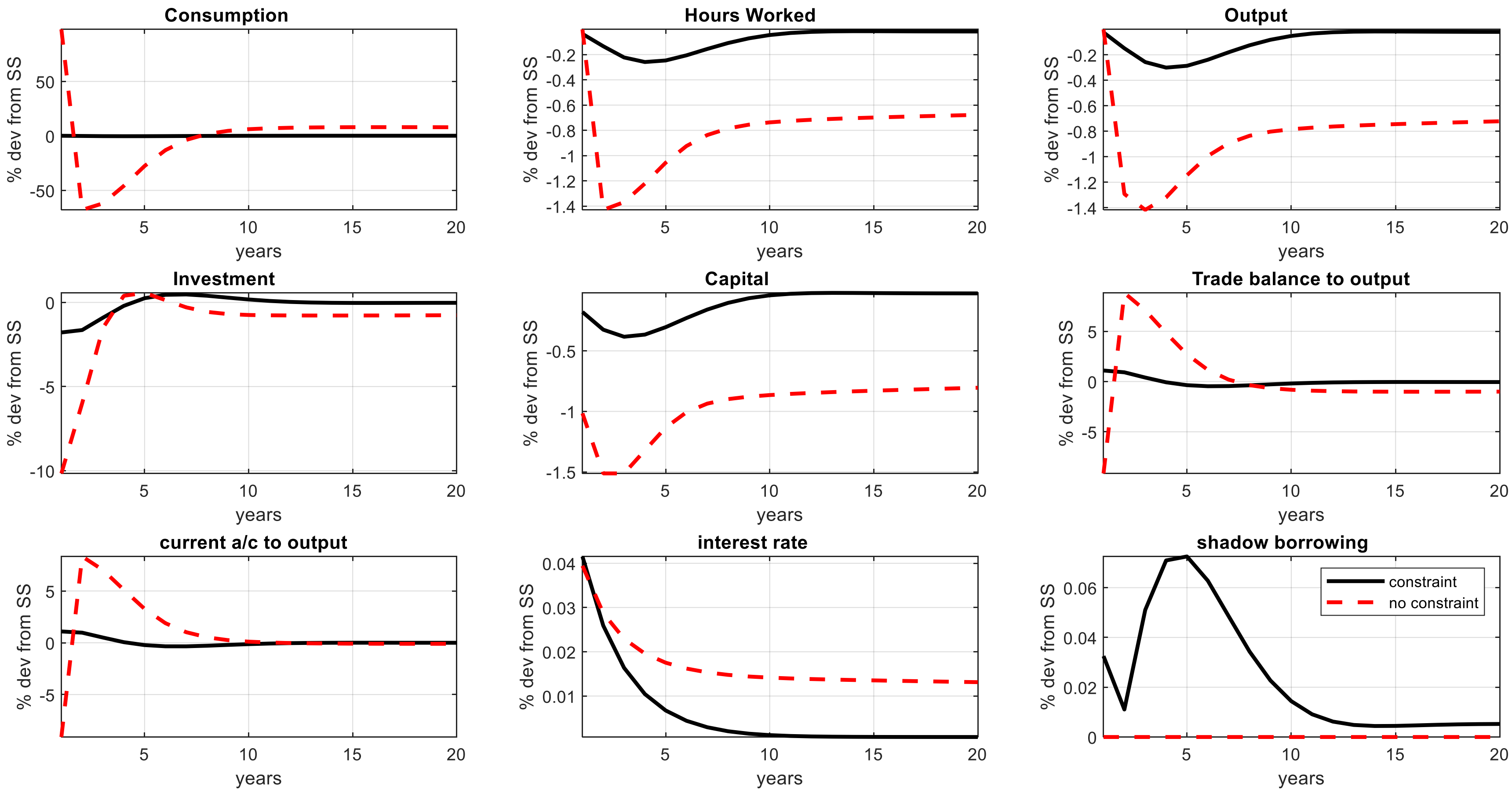


Figure 5.7: Impulse responses following 1% increase in world interest rate shocks with collateral constraint and without collateral constraint

Figure 5.8 shows the impulse responses relating to domestic interest rate and risk premium due to 1% increase in world interest rate (risk-free rate). It is interesting to find that as a result of world interest rate shock, risk premium experiences a delayed overshoot under both the credit constrained and unconstrained case. In fact, the overshoot under unconstrained case is much larger than the constrained case which results in a slower transition path to long run domestic interest rate. The result is consistent with the finding of Uribe and Yue (2006), Eichengreen and Mody (2000) and Kamin and von Kleist (1999). The impulse responses in Figure 5.7 also shows that interest rate is countercyclical.

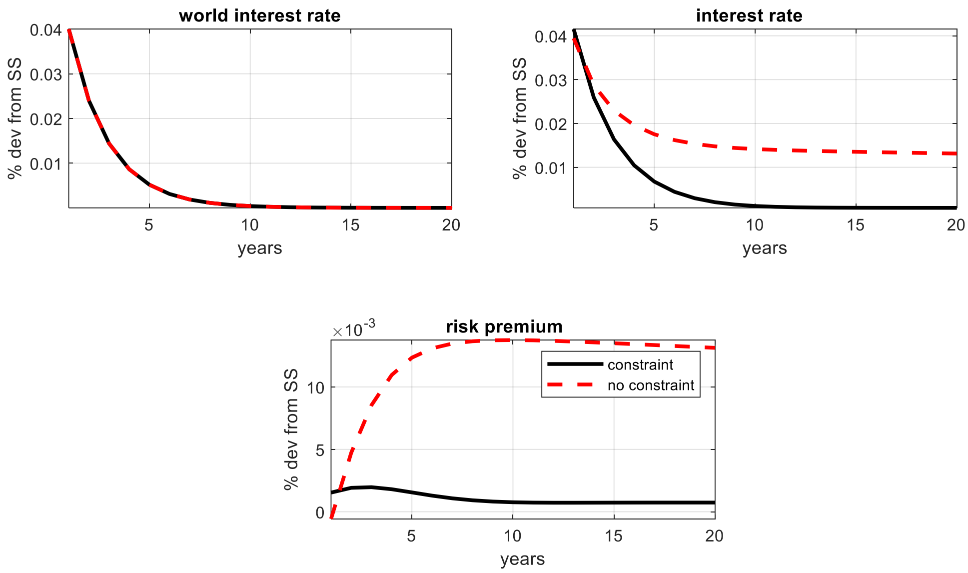


Figure 5.8: Impulse response documenting the impact on risk premium and country interest rate following 1% shock to international risk-free rate

In this model, working capital requirement disrupt labour market as shown in (5.27). In the presence of collateral constraint, magnitude of contraction in labour demand will be larger than unconstrained case due to rise in shadow value of borrowing as result of higher interest rate. This implies that the initial contraction in the output under constrained case will be larger than the unconstrained case making household and firms less optimistic under unconstrained case. This would imply that household in the subsequent periods will accumulate less debt in constrained case compared with unconstrained case which would imply that risk premium will rise faster in the subsequent periods under unconstrained case the constrained case. This behaviour can explain the delayed overshooting of risk premium under unconstrained case which results in interest rate to becoming larger under unconstrained case after a few periods.

As shown in Figure 5.8, due to the collateral constraint, a rise in interest rate increases risk premium due to rising cost of servicing debt and larger decrease in output as hours reduce much smaller due to the friction in the economy compared with a model without collateral constraint. Therefore, the economic prospect under collateral constraint economy will look less optimistic making representative household more conservative causing lower accumulation of debt hence a smaller rise in risk premium compared with unconstrained economy. This theory of a less severe negative impact during unconstrained causes a larger rate of accumulation of debt which explain the overshooting of risk premium under unconstrained case while in the constraint model.

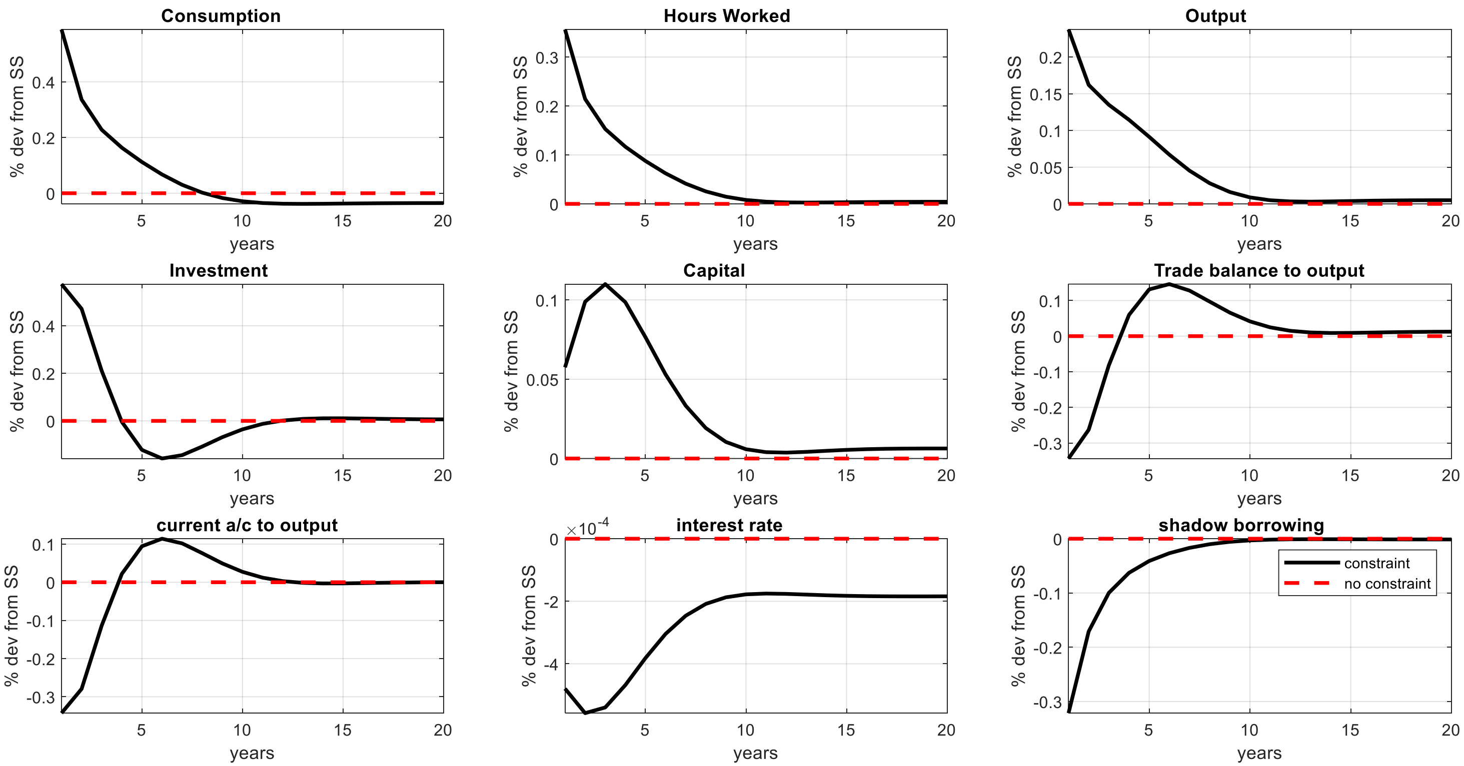
5.6.3 Impulse response following a financial shock

In this model, financial friction through credit market frictions is established using the parameter ξ_t. This parameter controls representative firm's ability to borrow working capital to fund labour for any realised state of capital and its shadow price Q_t. Therefore, any changes to the shadow price or ξ_t would influence firm's borrowing capacity which will subsequently determine the labour demand. A larger value for ξ_t implies an increase in firm's ability to borrow and hence would reduce the value of borrowing constraint, μ_t. Similar case applies if there is an increase in Q_t or K_t. In the context of this model, any shock to this parameter ξ_t would affect the shadow value of borrowing constraint (credit market friction), μ_t and induce a propagation mechanism which originates in the labour market. Based on the specification of the mode, in steady state, the cut-off value of ξ_t for the collateral constraint to bind is given by expression (5.18).

Following a 1% positive shock to collateral constraint, ξ_t, the collateral constraint becomes less binding, and firm would be able to borrow more funds to finance its working capital. The resulting impulse responses are shown in Figure 5.9. A positive shock to this parameter implies improved lender optimism on firms' ability to repay since this parameter also determines the amount lenders can recover in an event the firm renege on its debt. As a result of increased availability of credit, for a given state of capital, it would result in fall in shadow value of borrowing, μ_t as the constraint has become less binding. This scenario is like the case of a rise in supply of debt available to firm for a given demand for borrowing, that would result in fall in the price of borrowing. If the value of the ξ_t increases beyond its cut-off value, then the collateral constraint would not bind, and this model would return to a model without borrowing constraint. Therefore, a positive shock to ξ_t can be interpret as a temporary increase in supply of working capital as lenders are more certain that the funds borrowed would be returned as a result of which the shadow price of borrowing would fall. A shown in Figure 5.9, in response to 1% increase in borrowing capacity, shadow cost of borrowing falls by 0.32%. This resulting relation is directly driven from expression (5.8) where the shadow value of collateral constraint is decreasing function of the fraction of capital against which firm can borrow, ξ.

Using the analogy of tax on labour income described earlier, the wedge between wage rate and marginal product of labour would decrease in response to fall in μ_t thus it would be similar to a case of reduction in tax on labour income. As shown in (5.27), in response to a fall the shadow value of borrowing, μ_t demand for labour will increase which will result in increase in hours as shown in Figure 5.9. The rise in hours increases output, which results in higher consumption by representative household. Firm also increases it investment as it needs to maintain its borrowing capability through capital accumulation. Due to output rising faster than the domestic absorption, trade balance deteriorates. However, as rate of increase in output is larger than accumulation of debt, risk premium falls causing domestic interest rate to fall. This therefore support the thesis that changes in firms' collateral constraint can bring real changes into the economy.

Figure 5.9: Impulse responses following 1% increase in borrowing limit (financial friction) shocks with collateral constraint and without collateral constraint



5.7 Second moments

The second moments from the simulations are presented in Table 5.3. The moments of the model are presented alongside with the moments on data for the moment reported in Chapter 3. For comparison purpose, I have also included the moments of the model without borrowing constraint in Table 5.3.

	Data (1976-2014)			With Collateral Constraint $\sigma = 2;\ \emptyset_X = 0.05;$ $\omega = 1.455$			Without Collateral Constraint $\sigma = 2;\ \emptyset_X = 0.05;$ $\omega = 1.455$		
	σ_x	$\rho_{xt,GDP}$	$\rho_{x,t}, \rho_{x,t-1}$	σ_x	$\rho_{xt,GDP}$	$\rho_{x,t}, \rho_{x,t-1}$	σ_x	$\rho_{xt,GDP}$	$\rho_{x,t}, \rho_{x,t-1}$
GDP	4.28	1	0.12	3.85	1	0.51	4.09	1	0.55
Consumption	1.31	0.35	0.59	0.64	0.62	0.68	28.9	0.88	0.69
Hours	0.98	0.06	0.46	0.36	0.56	0.76	0.77	0.99	0.57
Investment	4.08	0.36	0.47	3.12	0.82	0.56	6.40	0.67	0.33
Capital	1.26	0.23	0.70	0.52	0.72	0.80	0.86	0.94	0.70
Current account-to-output	0.61	-0.04	0.55	12.5	-0.71	0.68	15.8	-0.96	0.61
Trade-balance to output	0.64	-0.08	0.45	4.87	-0.64	0.58	15.3	-0.94	0.62
Interest Rate				0.02	-0.28	0.47	0.04	-0.61	0.56

Table 5.3: Second moment of the model with borrowing constraint and without borrowing constraint

The results in Table 5.3 shows that that the model with collateral constraint is able to match the standard deviation of output and investment. I am unable to replicate the consumption volatility compared with output using the parameterization used to report results in Table 5.3. However, by increasing standard deviation of interest rate shock from 0.80 to 1.5, the order of volatility between output, consumption and investment can be achieved. This however results in loss in closer match obtained for other standard aggregates and relations. The contemporaneous correlation shows that the model can replicate the counter cyclical feature of interest rate current account and trade balance. Empirical data on interest rate is not included due to lack of interest rate data on the Maldives prior to 1996. The correlation between interest rate and output based on quarterly data on the Maldives as presented in Table 5.1 shows a value of -0.1. Except these variables, the magnitude of the correlation is much larger than the values observed from the data. The model with collateral constraint is very successful in matching the persistence for consumption, investment, capital and external balances.

The results obtained by shutting the collateral constraint is less attractive in terms of matching the moments. As shown in Table 5.3, the model overestimates the volatility of consumption, investment and external balances. This result can be attributed to differences in risk premium under both frameworks. For instance, as shown in Figure 5.5, lack of collateral constraint would result in higher employment in case of a positive technology shock to the economy which would increase output, profit and household accumulation of debt causing higher increase in risk premium. The result of delayed overshooting of risk premium in the absence of collateral constraint makes consumption and external balances much more volatile.

Table 5.4 presents the variance decomposition of both the model. As predicted in RBC literature, output fluctuations are mainly explained by TFP shocks. However, the result also shows that borrowing constraint account for 5% of all output fluctuations. An interesting observation from variance decompositions is that borrowing constraint affects variation in consumption and hours to a significant degree (approximately 47%). This observation lend support to the fact that onset of a financial crisis, the propagation mechanism develops through household channel via fall in employment and consumption. This also gives evidence that if a financial accelerator is to emerge, it develops from household sector. As shown in the opposite column, when borrowing constraint is factored out, majority of the variations in aggregates are absorbed by TFP shock. Comparison of the variance decomposition in Table 5.4 with empirical variance decomposition in Table 4.9 shows that when financial intermediation is introduced, interest rate shock captures much more empirically consistent shares of variance decomposition for external balances. The main conclusion based on the results below is that in explaining real business cycle properties, technology shocks and interest rate shock plays a larger role than financial friction shocks.

Aggregate variables	With borrowing constraint			Without borrowing constraint	
	% deviation from each shock			% deviation from each shock	
	Technology	Borrowing	Interest rate	Technology	Interest rate
Capital	31%	2%	67%	68%	32%
Output	73%	5%	22%	80%	20%
Consumption	34%	29%	37%	70%	30%
Hours	22%	30%	47%	67%	33%
Investment	33%	2%	65%	70%	30%
Trade Balance to output	15%	2%	83%	71%	29%
Current Account to output ratio	15%	2%	83%	71%	29%

Table 5.4: Variance decomposition following shocks

5.8 Conclusion

This chapter addresses two fundamental issues that most RBC models ignores – the role of interest rate and financial intermediation process while maintaining properties of real business cycles intact. I have refrained from introducing any nominal rigidities to remain true to RBC core.

This chapter has highlighted the importance of financial intermediation process and interest rate in explaining business cycle. It shows that international interest rate shock results on overshooting of country risk premium. Further, the results show that interest rate is counter cyclical and there is very weak evidence on the presence of a financial accelerator mechanism which shifts propagation mechanism, from factor market to credit market. In other words, while there is a role credit market plays in affecting real economy, the impact it generates is much smaller than advocated in the literature. When financial shock and interest rate shock directly completes with the total factor productivity shock, the result shows not all variation in output can be explained TFP shock as financial shocks explains 5% of the variation in output while interest rate shocks explain 22%. This result therefore supports one of the criticisms made against canonical RBC model which overemphasize the role of technology shock. These finding supports the recent efforts to expand the frontiers of RBC models by incorporating other mechanisms that are observed in small and emerging economies.

The results also signal the importance of external interest rate and risk premium for emerging and small open economies. Interest rate changes are responsible for the dynamics we observe in these economies more than technology and financial market frictions. While this chapter shows the importance of departing from traditional structure of RBC model, the model's ability to closely match stylized facts are mixed. The findings however highlight the importance of embedding financial and interest rate channel to RBC models to better understand small and emerging market economies.

The work presented in this Chapter is subject to number of limitations. First, I need to establish the mechanism through which domestic economy is connected to international markets by modelling rest of the world. Second, as this model is aimed at the Maldives, key structural features such as dollarization needs to integrate into the modelling framework. One plausible reason for lack of evidence of financial accelerator mechanism is the over simplified framework applied in this chapter to model the credit market. In order to accurately model the rigidities of factor and credit market a larger scale RBC model is required. In Chapter 6 I will aim to address these limitations by developing a larger model with more realistic domestic conditions specific to the Maldives such as dollarization, non-traded goods sector and role of real exchange rate. Such a model is likely to improve the overall fit with the data and show more evidence on the importance of financial accelerator mechanism in explaining business cycle.

Appendix 5.1: Dynare Codes

```
var c lambda b pi w n RStar R y kk yy invest k A eta miuu q cc tb_y tb_yy nn ii ca_y ca_yy
rp rr;

varexo epsilon_eta epsilon_A epsilon_Rstar;




parameters
  alpha
  beta
  theta
  delta
  xi
  phi_k
  sigma_eta
  rho_eta
  RStar_bar
  sigma_Rstar
  rho_Rstar
  sigma
  sigma_A
  kappa
  by
```

```
   psi_2
   r_bar
   eta_bar
   rho_A;


beta=0;
r_bar=0.050;
delta=0.10;
alpha=1/3;
sigma=2.00;
xi=1.455;
by=0.10;
theta=0; //set in SS
sigma_A=0.5;
rho_A=0.52;
phi_k=0.05;
rho_eta=0.50;
eta_bar=0.09;
rho_Rstar=0.60;
sigma_eta=0.5;
sigma_Rstar=0.80;
psi_2=0.000742;
```

```
model;

//1. Resource Constraint

b=w*n+pi+(1+R(-1))*b(-1)-c;



//2. Firm profit

pi=y-w*n-R(-1)*w*n-invest;


//3. LOM capital

k=invest+(1-delta)*k(-1)-(phi_k/2)*(invest - invest(-1))^2;



//4. Lagrange multiplier

lambda=(c-theta*(xi)^(-1)*n^(xi))^(-sigma);


//5. FOC labor

((c-theta*(xi)^(-1)*n^(xi))^(-sigma))*theta*n^(xi-1)=lambda*w;


//6. Euler equation capital

lambda=beta*lambda(+1)*(1+R);


//7. Output
```

```
y=A*k(-1)^alpha*n^(1-alpha);

//8. FOC labor
w*(1+(R(-1)-1)+miuu)=(1-alpha)*y/n;

//9. FOC wrt K
q=beta*(lambda(+1))/lambda*(alpha*A(+1)*k^(alpha-1)*n(+1)^(1-alpha)+q(+1)*((1-delta)+miuu(+1)*eta(+1)));

//10. FOC wrt investment
1-q(+1)*((lambda(+1))/lambda)*phi_k*(invest(+1) - invest)=q*(1-phi_k*(invest - invest(-1)));

//11. collateral constraint
w*n=eta*q*k(-1);

//12. interest rate
R=RStar+psi_2*(exp((b(+1)/y)-by)-1);

//13. Risk premium
rp = psi_2*(exp((b(+1)/y)-by)-1);

//14. financial friction parameter shock
```

log(eta)=(1-rho_eta)*log(eta_bar)+rho_eta*log(eta(-1))+sigma_eta*epsilon_eta;

//15. technology shock

log(A) = log(A(-1))*rho_A +sigma_A*epsilon_A ;

//16. Interest rate shock

log(RStar) = (1-rho_Rstar)*log(r_bar)+rho_Rstar*log(RStar(-1))+sigma_Rstar*epsilon_Rstar;

//17. Trade balance to output ratio

tb_y = 1-(c-pi-w*n)/y;

//18. Current account to output ratio

ca_y = 1-(b(-1)-b)*(1/y);

//19. All endogenous variables converted to get IRFs as % deviation from SS

kk=k/STEADY_STATE(k);

yy=y/STEADY_STATE(y);

cc=c/STEADY_STATE(c);

tb_yy=tb_y/STEADY_STATE(tb_y);

nn=n/STEADY_STATE(n);

ii=invest/STEADY_STATE(invest);

ca_yy=ca_y/STEADY_STATE(ca_y);

```
rr=R/STEADY_STATE(R);

end;

shocks;

var epsilon_eta; stderr 1;
var epsilon_A; stderr 1;
var epsilon_Rstar; stderr 1;

end;

steady_state_model;
q=1;
A=1;
Rfree=r_bar;
beta=1/(1+r_bar);
R=1/beta-1;
RStar=r_bar;
n=0.33; //calibrate
eta=eta_bar;
miuu=((1-alpha)/eta)*(1/(beta)-(1-delta))-alpha*(1+(R-1));
k_bar=(((1/(beta)-(1-delta)-eta*miuu)/(alpha))^(1/(alpha-1)))*n;
k=k_bar;
```

```
y_bar=(k_bar)^alpha*n^(1-alpha);

y=y_bar;

b=by*y;

w=((1/(1+(R-1)+miuu))*(1-alpha))*y/n;

invest = delta*(k_bar);

pi=y-w*n-R*w*n-invest;

c=w*n+pi+R*b;

%%c=y-invest-R*w*n+R*b;

theta=w/n^(xi-1);

lambda=(c-theta*(xi)^(-1)*n^(xi))^(-sigma);

%%theta=lambda*w/n^xi;


tb_y = 1-(c-pi-w*n)/y;

ca_y=1;

kk=1;

yy=1;

cc=1;

tb_yy=1;

nn=1;

ii=1;

ca_yy=1;

rr=1;
```

```
end;

resid;

steady;
check;

stoch_simul(order=1, hp_filter=100, irf=20) kk yy cc nn ii w R b tb_yy ca_yy q miuu rp
RStar;
```

Chapter 6: Can Real Dollarization Explain Business Cycle in the Maldives?

6.1 Introduction

A problem that is inherent in small and emerging economies is their reliance on international financial markets to fund the economy's external financing requirements. As these economies are unable to issue debt in their home currency, all borrowings are made in units of foreign currency. In the literature this is known as 'original sin'. The consequence of original sin for these economies is their balance sheets will feature liabilities denominated in dollar. Changes in liabilities side of these economies balance sheets therefore can result in business cycle.

A growing body of literature currently studies the impact of liability dollarization in small and emerging economies (Mendoza and Roja (2019); Calvo (2006); Choi and Cook (2004); Cook (2004); Schmitt-Grohe and Uribe (2001). These studies look at propagation and transmission mechanism following unexpected shocks to exchange rate which alters assets and liability position of agents. Models which introduce liability dollarization also introduces other forms of financial frictions that arises as a result of original sin, such as debt-elastic interest premium and a credit market friction which results in creation of a financial accelerator. According to Garcıa-Cicco (2009) the financial accelerator mechanism and liability dollarization can explain business cycle regularities in small and emerging economies. Dalgic (2018) uses a DSGE model with financial friction to study the use of dollarization by domestic agents in emerging economies to insurance their wealth and income from exchange rate risks associated with recessions. The financial intermediation through foreign currency while can be used as a protective measure against risks, it also becomes the vehicle through which shocks that originates in international financial markets enter domestic economies. In such a setting, impact of foreign shock propagates through balance sheet effects.

The inability of agents in emerging and small open economies to borrow from international markets in units of national currency is a form of imperfect financial intermediation. As a result, financial intermediation in these countries is carried out in international markets using 'hard currencies' (in units of tradable goods). These hard currencies borrowing however enters into domestic transections in national currencies (ie, in units of national prices) Mendoza and Roja (2019). As a result, household borrow (lend) in units of hard currency to finance their domestic expenditure (saving) in national currency which expose their budget constraints to exchange rate risks. Firms are exposed to similar conundrum as the household with respect to their participation in the capital market, exposing their borrowing and debt repayment to foreign exchange shocks.

This paper aims to contribute to the growing literature on liability dollarization in small and emerging economies. The emphasis of this paper is to model real dollarization as opposed to nominal dollarization used in much of the literature through a real business cycle model. In this liability dollarization model, agents can only borrow (save) through international financial markets in units of foreign currency. To keep the model tractable and as close to a real model, I achieve real liability dollarization by expressing all nominal variables such as dollarized borrowing (saving) in units of tradable goods. The model will be calibrated and estimated to fit the Maldivian economy.

In addition to liability dollarization, I will also introduce capital market imperfections by tapping into financial friction literature. The financial frictions framework presented in this paper is drawn from Mendoza and Roja (2019), Jermann and Quadrini (2012), and Neumeyer and Perri (2004). The liability dollarization in this model follows the work of Mendoza and Roja (2019) and Notz and Rosenkranz (2021). Unlike many other papers on liability dollarization, the above authors use a canonical real business cycle to study dollarization. The model presented in this chapter differs from all models listed above in three dimensions. Firstly, this paper explicitly model non-traded goods sector and establish a feedback mechanism between both sectors by allowing changes in traded goods sector to influence the net worth and hence borrowing capacity in non-traded good sectors. Secondly, this paper emphasizes the role of real exchange rate in affecting household's bond holding and cost of servicing debt. I achieve this by introducing debt elastic risk premium into the interest rate faced by domestic agents where the interest rate is a function of risk-free rate and debt-elastic risk premium indexed to real exchange. This formulation of interest rate captures the effect of unexpected changes in real exchange rate on level of debt and cost of servicing debt. Thirdly, this model allows financial shocks that affect non-traded sector to influence the optimal allocations in traded goods sector. Therefore, in the context of this model financial shocks and real exchange rate changes act as a source of business cycle. This setup is inline with the conclusions by Christiano, Motto, and Rostagno (2008); Del Negro et al. (2016); and Kiyotaki and Moore (2019) where shocks that originates in financial sector are an important source of macroeconomic fluctuations.

The result shows that real dollarization, tradable sector, and real exchange rate a key drivers of business cycle in the Maldives. The paper organized as follows. Section 2 outlines the structural characteristics of the Maldivian economy. In section 3, I develop a two-sector, two country real business cycle model with real dollarization, real exchange rate and financial friction. The module is calibrated and estimated in section 4 and 5. Finally I conclude the paper in section 6 outlining main findings and limitation of research.

6.2 6.2. Characteristics of Maldivian Economy and motivation of the modelling assumptions

This model of dollarization would be calibrated and estimated to fit the Maldivian economy. Maldives is a small open economy whose features fits well within the context of this model. The Maldives takes pride in its unique tourism offer and has a large non-traded sector goods. Tourism is the main source of growth and vehicle through which non-traded goods are consumed by foreign agents. In order to further elaborate on two sector setup and establish the tradability of tourism as a product, I will first distinguish between tradable and non-traded aspect of an economy's output. According to Zeugner (2013) there are 14 different competing standards used to classify goods into tradable and non-tradable goods. Obstfeld and Rogoff (1996) classify goods into tradable and non-traded based on its ability to be consumed internationally in a country that is different from it originated through the means of international trade. Frocrain and Giraud (2019) states that most studies in international economics assumes services are non-traded. However, tourism should be classified into tradable or non-tradable based on who consumes it. For instance, if tourism service is consumed by domestic residents, it is classified as non-tradable but when the service is consumed by foreign agents it should be classified as tradable. According to Clarke (1995) and Hazari and Ng (1993) as tourists physically move for the purpose of consumption, tourism becomes an exportable good. A determinant of tradability according to Sachs and Larrine (1994) is reaction overseas consumers following a price change. For instance, if price of hair cut in Europe increases compared to rest of the Maldives or vice-versa, consumers in these countries will not rush to take advantage of cheaper haircuts in the competing place making haircut a non-tradable good. Tourism on the other hand is different as consumer will travel to take advantage of cheaper prices or exotic destinations when price or popularity changes. Therefore, as described above, there are sufficient arguments in favour of classifying tourism as a traded good for the Maldives due to its share of GDP.

Arrival of tourist to the domestic economy will lead to consumption of non-traded goods and services by foreign agents which are not exportable such as meals in a restaurant, local transportation and etc. Therefore, rise in influx of foreign tourists will increases demand for non-traded goods resulting in expansion of non-traded goods sector in an economy. For a country like the Maldives, this implies that tourism would be a key contributor that expands non-traded sector output due to its significant contribution to GDP. For instance, in 2018 tourism contributed to 23% of Maldivian GDP while non-traded sector account for approximately 40% of the GDP (Ministry of Tourism, 2018). Figure 6.1 shows the share of tourism revenue in Maldivian balance of payment account as a percentage of total service export, export, and trade value. As shown from the figure, tourism represents approximately 82% of total export and 41% of total trade value (total export plus imports).

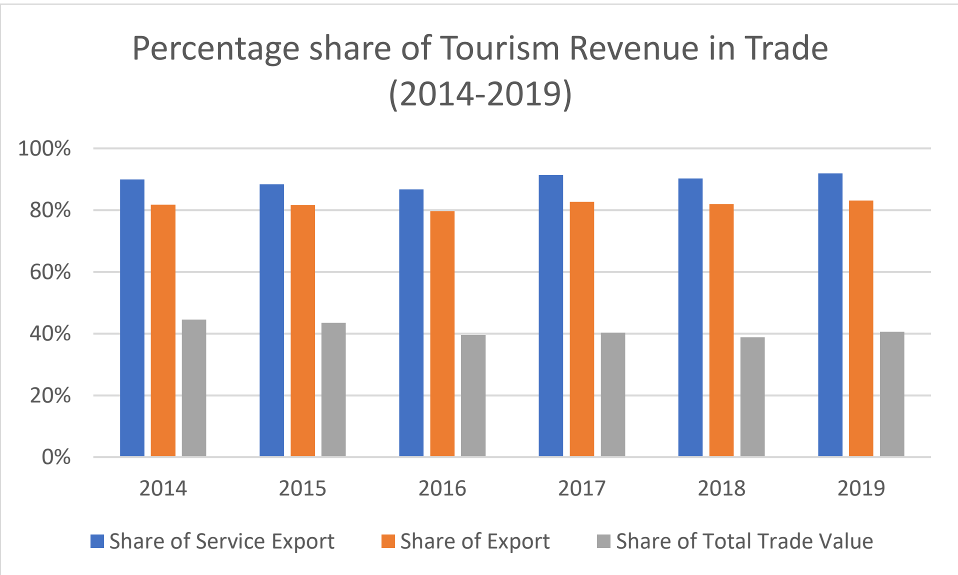


Figure 6.1: Share of tourism receipt in Maldivian Balance of Payment Account

Source: Computed using data from Maldivian Monetary Authority (2020)

Number of studies have aimed to capture the impact of foreign tourism on growth of non-traded sector. Empirically, for instance Copeland (1991) and Chao, Hazari, Laffargue, Sgro, and Yu (2006) shows that an increase in tourism increases the consumption of non-traded goods. In order to observe this relationship, I have used the Maldivian sectoral representation in the Gross Domestic Product and classified different sectoral compositions to tradable and non-traded using AMECO25 database classification. Based on this classification, Figure 6.2 shows the evolution of tradable and non-traded sector between 2003-2018. As shown in the figure, non-traded sector over this period is rapidly catching up with tradable sector. To further establish the role of tourism in development of non-traded sector, Figure 6.3 shows share of tourism, fishing and tourism related non-traded goods such as domestic travels, food and restaurants and etc in the national output of the Maldives. As shown in Figure 3, there is a significant increase in tourism related non-traded goods and services over this period contributing to overall growth in non-traded sector due to tourism.

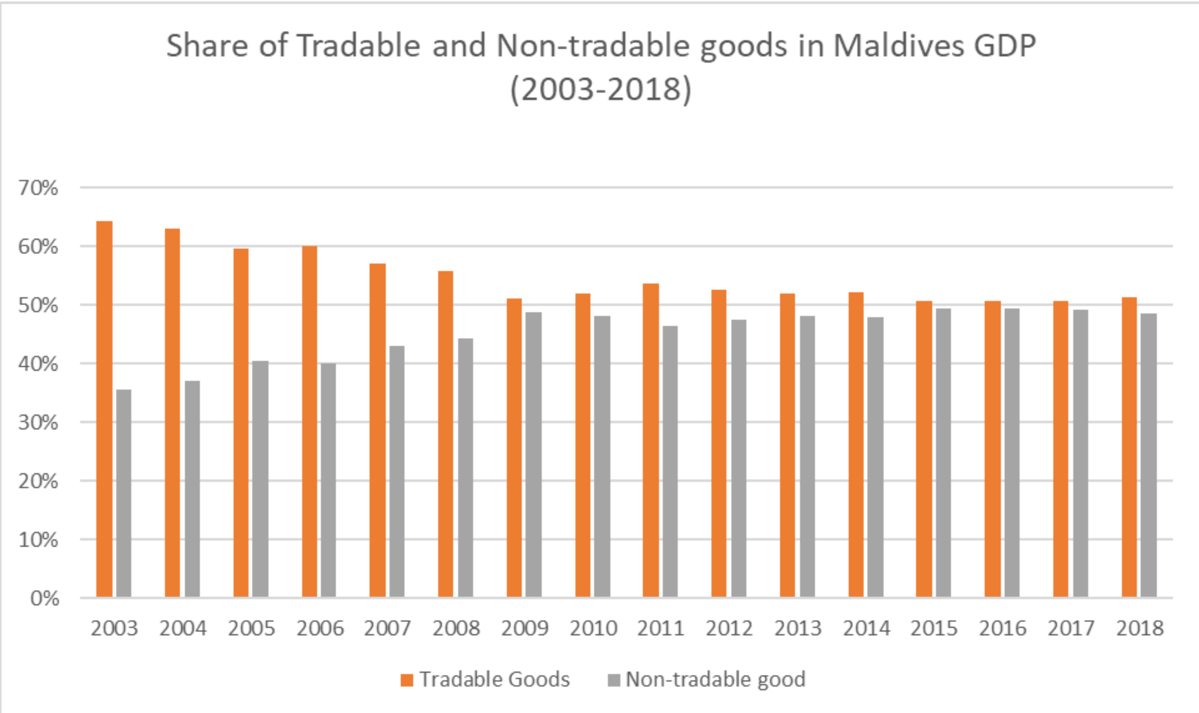


Figure 6.2: Evolution of tradable and non-traded sector in the Maldives, 2003-2018

[25] AMECO classifies agriculture and fishing, mining and utilities, manufacturing, trade, hotels, communications as tradable sector of the economy while construction, finance and business services, market services, other service activities are treated as non-traded sectors.

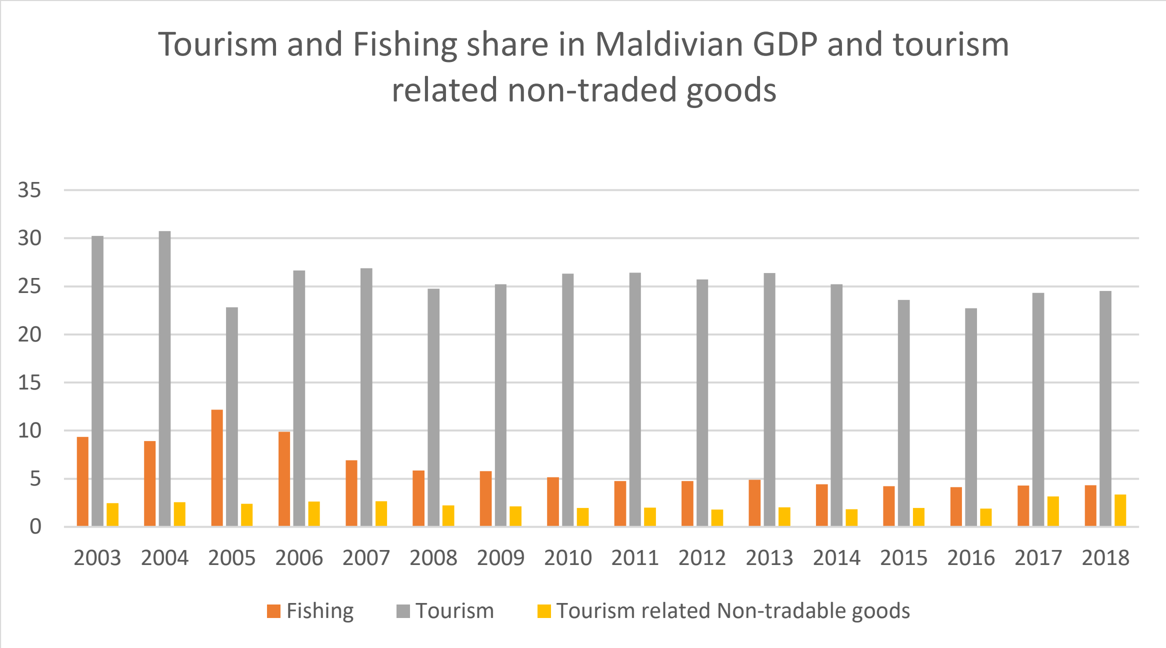


Figure 6.3: Fishing, Tourism and tourism related Non-traded goods and services share in GDP of Maldives (2003-2018)

Source: Source: National Bureau of Statistics

An important economic feature of the Maldivian tourism industry is the universal acceptance of foreign currencies as a medium of exchange. In many countries, tourists are required to acquire local currency before travelling to the destination or from foreign exchange located locally at the destination to enable them to make necessary local transections. However, in the Maldives, tourists can pay for their expenses using one of the major international currencies such as US dollar, Euro and Pounds. The foreign currency income from tourism accounts to a significant portion of the revenue. For instance, in 2017, as per the Maldivian Inland Revenue authority, compared with the GDP of US$4.745 billion, the total foreign currency receipt is over US$2 billion. These dollarized revenues enter local banking system and secondary US dollar exchange market enabling both the financial institution and domestic residents to access US dollar. Residents who work in resorts, especially for major international brands are also paid in US dollar. These residents also make a significant income from gratuities directly given by tourists they serve. Furthermore, financial institutions and state heavily borrow in international markets to finance tourism development investments and state expenditure. The reliance on foreign borrowing to bridge gaps in local credit market is well documented through net foreign assets position of the Maldives. Since 1976, the net foreign asset position has stayed in negative (higher liabilities than asset) and is on average 44.72% of GDP. The above characteristics therefore makes Maldives an appropriate benchmark economy to study the impact of liability dollarization due to the significant role dollarization plays within the country.

Figure 6.4 shows the annual dollarization in the Maldives calculated from various data sources. I have used International Monetary Fund's (IMF) definition of dollarization ratio in the computation of this figure. IMF defines dollarization ratio as foreign currency deposit in percentage of broad money. Deposit dollarization is a good proxy for liability dollarization as documented in the literature. Christiano et. al (2021) and Dalgic (2018) presents empirical evidence on this relationship where deposit dollarization mirrors the liability dollarization such at every one $ deposited in the banking sector, there is a dollar debt.

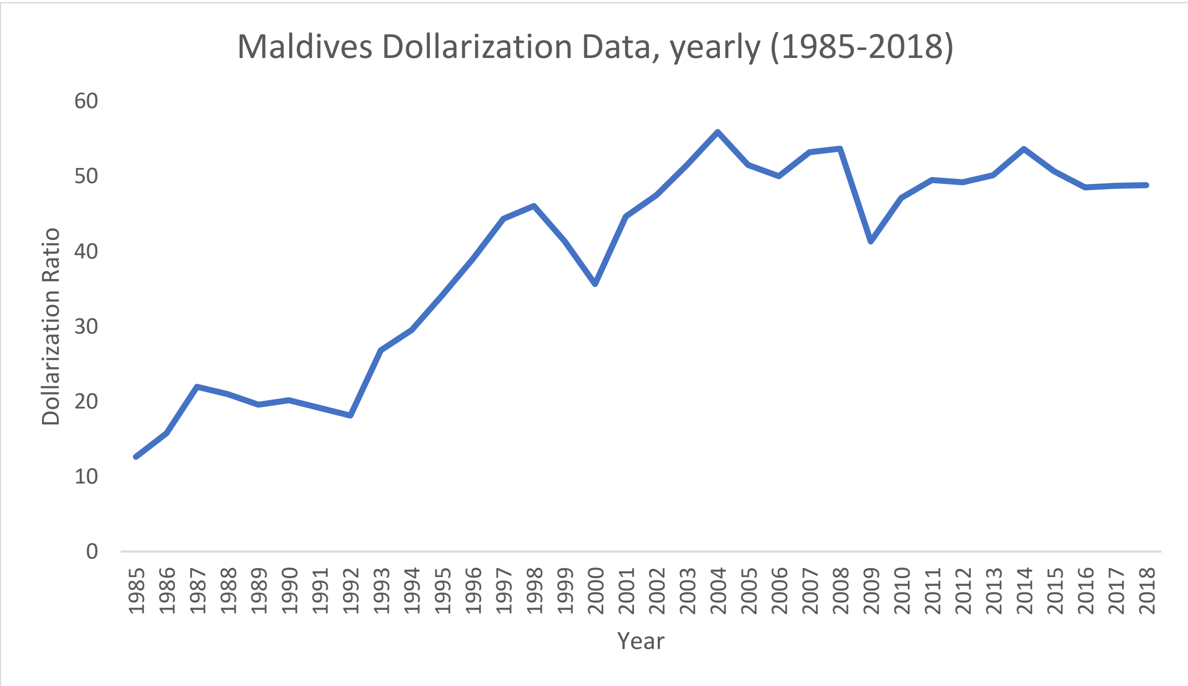


Figure 6.4: Maldives Dollarization Ratio (1985-2018)

Source: various (see Appendix for more details)

As shown in Figure 6.4, dollarization is a significant feature of Maldivian economy. The yearly average currently is over 50% of the broad money, making Maldives one of the most heavily dollarized economies. Some of the reasons for the high-volume of dollarization in the Maldives are: dominant role played by tourism in national output where the receipts are in units of foreign currency; the over dependence on international product markets goods and services as consequence of being resource poor; and the enclave nature of tourism sector which has significant foreign ownership and workforce who regularly remit the income from tourism related activities. Figure 6.5 shows monthly fluctuation of dollarization ratio from 2001. As shown in Figure 6.5, the dollarization ratio as defined by International Monetary Fund (IMF) over the last 18 years have remained high.

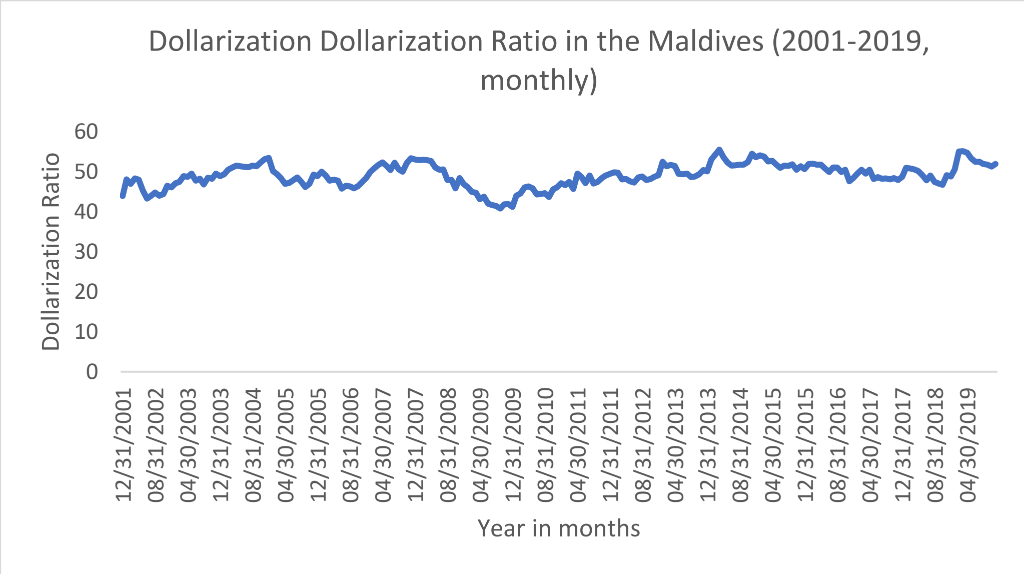
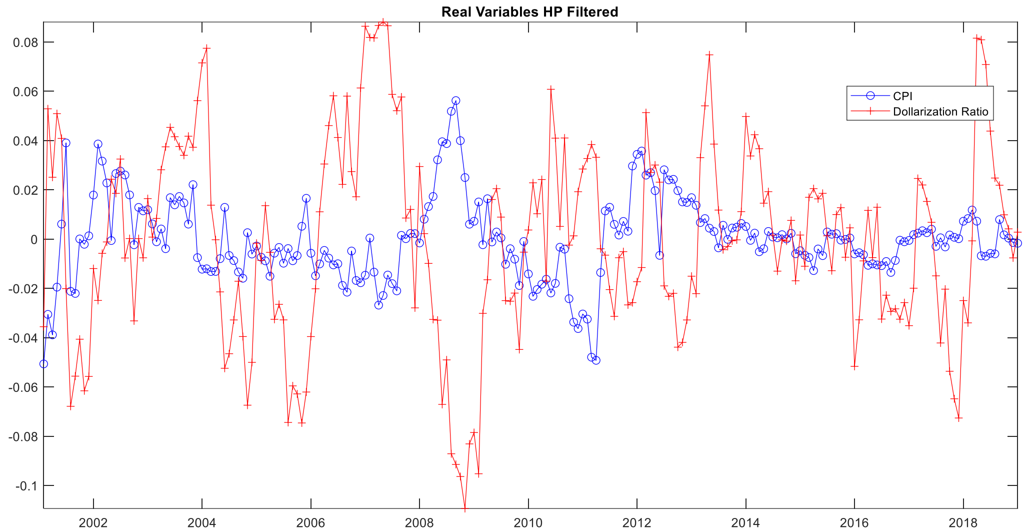


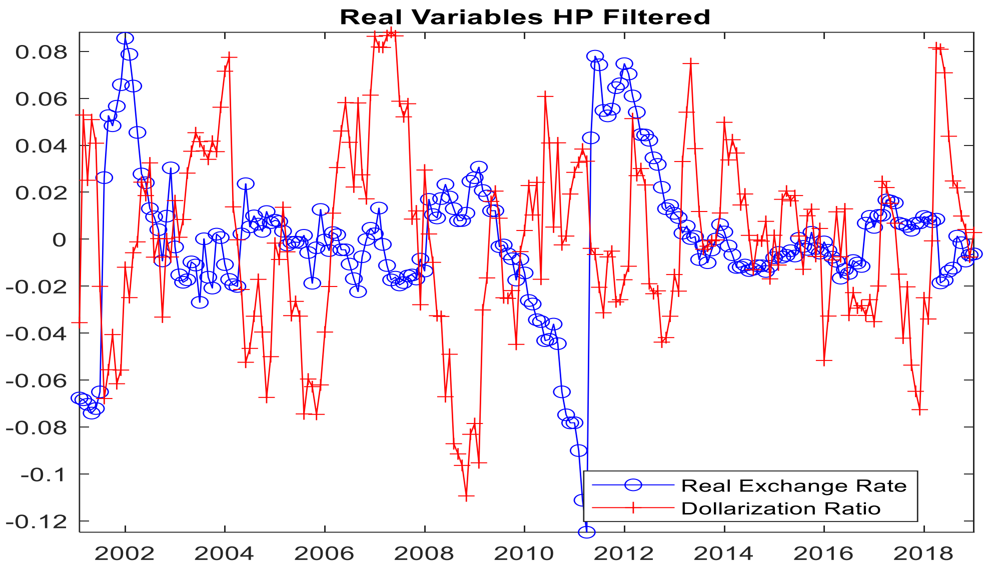
Figure 6.5: Monthly Dollarization Data, Maldives

Source: Maldives Monetary Authority

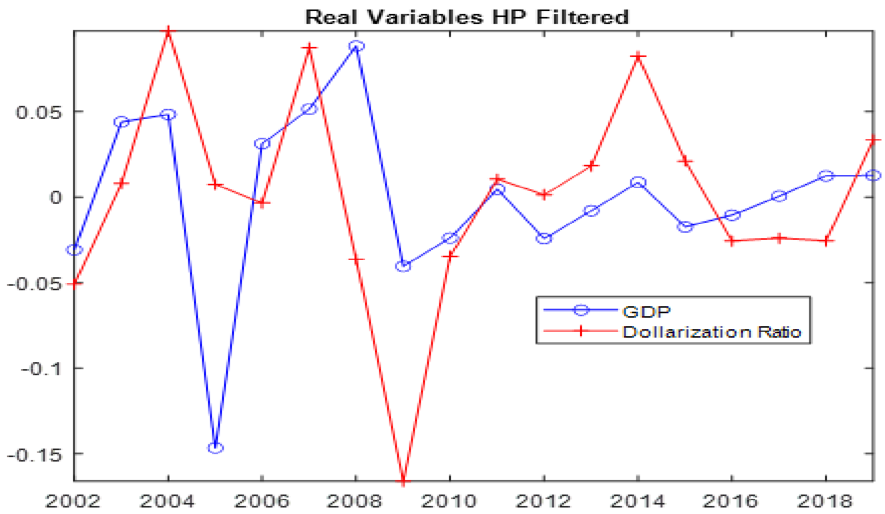
The presence of heavy dollarization is likely to affect Maldivian GDP and its macroeconomic aggregates exposure to exchange rate. Figure 6 looks at the correlation that exist between dollarization with GDP and real exchange rate in the Maldives. Panel (a) and (b) presented in Figure 6.6 establishes correlation between CPI, dollarization and real exchange rate for monthly data. Panel (c) due to lack of availability of monthly or quarterly data for GDP, establishes correlation between GDP and dollarization ratio using annual data. Subsequent contemporaneous correlation coefficients between dollarization ratio and various macroeconomic aggregates are presented in Table 1. The table also features the correlation between dollarization and risk premium for the Maldives. Risk premium is calculated assuming uncovered interest parity (UIP) holds as demonstrated in Dalgic (2018).



Panel A: Co-movement between dollarization and CPI



Panel B: Co-movement between dollarization ratio and real exchange rate



Panel C: Co-movement between dollarization ratio and GDP

Figure 6.6: HP Filtered series, Maldives (2002-2018)

Data Source: Maldives Monetary Authority

Variable	Correlation with dollarization ratio
Real GDP	0.2945
CPI	-0.3258
Real Exchange Rate	-0.3310
Net Foreign Assets	0.4610
Risk Premium	-0.075

Table 6.1: contemporaneous correlation of Dollarization ratio with macroeconomic aggregates

As shown in the Table 6.1, dollarization ratio and consumer price index are negatively correlated. This may be due to domestic agents relying on US Dollar during period of economic turbulence such as high inflation. For instance, if purchasing power of the Maldivian currency falls due to rise in cost of living, household and firms hedge against the fall by accessing their dollar savings which reduces the dollarization ratio. In the Maldivian parallel markets26 for US$, the exchange rate used for sales of US$ is above

[26] In the Maldives, there is a set limit on quantity of US$ one can acquire at official exchange rate from currency traders registered with the Central Bank (set at $300 per day). As a result, there exists a parallel

upper bound set under managed floating regime allowing agents to compensate the rise in cost of living through sales of US$. Furthermore, dollarization ratio and real exchange rate are negatively correlated. As real exchange rate rises, dollarization ratio falls. This implies when real exchange rate increase (depreciation), foreign economy becomes more expensive relative to local economy. As Maldives being a resource poor country, this negatively affect the dollar holding of agents due to the economy's heavy reliance of foreign import for essential and medical supplies. The contemporaneous correlation coefficients presented in Table 6.1 further confirms this and is consistent with empirical results from Corrales and Iman (2019) and Dalgic (2018).

The results in Table 6.1 also shows that dollarization ratio and risk premium are negatively correlated. In the empirical literature there is a mixed result for different countries and depend on various factors such as existence of a forward market and other regulations around holding of dollars. Montamat (2020) shows that a positive correlation between risk premium and dollarization will exist when household aims to insure against risk by holding dollar deposits and has a higher risk aversion behaviour compared with firms. This theory is known as insurance hypothesis. Christiano et. al. (2021) demonstrates that agents in emerging market economies uses dollarized deposits to hedge against business cycle income risk resulting in a positive correlation between dollarization and risk premium for countries with a forward exchange market. The result in Table 1 for Maldives is not surprising due to its underdeveloped money market which limits access to financial products. For instance, according to (Hayaath, 2019) forward exchange transection in the Maldives only started in 2011.

Lack of forward market as explained above combined with loan dollarization and parallel black market for dollar can explain negative correlation. As shown in Christiano et. al. (2021), higher deposit dollarization also means higher loan dollarization. In the case of the Maldives, Christiano et. al. (2021) shows average loan dollarization between 2000-2018 to be approximately 50% translating nearly a one-to one relationship between deposit dollarization and loan dollarization. The lack of forward market, fixed exchange rate regime until 2011 followed by a managed floating regime and lack availability of US$ at official exchange rate has given banks the opportunity to charge

market which fills the excess demand for US dollar. The parallel market charges a premium on all sales of US$. Both household and firms participate in this market by buying and selling US$.

excessive interest rate on dollarized loans. For instance, HSBC provides 0.03-0.10% interest rate on dollar deposit while the interest charged on dollar loans stands at LIBOR + 5.00-9.00%. The largest bank in the Maldives charges more than 9% spread between dollar lending and deposit rate. Interest on local currency denominated savings and loans are higher than the US$ denominated deposits and saving. Bocola and Lorenzoni (2020) rationalizes this using insurance hypothesis where domestic residents require a premium to save in in local currency to compensate for any loss in purchasing power. This results in local currency loans to be more expensive compared with foreign currency loans. Against the backdrop of this, one must note that household and firms in the Maldives hold dollar deposit for two reasons. First, to safeguard their international transections from shortage of dollar (dollar limit) imposed by the government. Second, to sell dollar in the unregulated market during times of severe shortages at a hefty premium such as at times of a global recessions which limits the inflow of dollar into the economy through tourism. This therefore would imply irrespective of how risk premium is measured, when foreign currency risk premium increases, household will be attracted to save in foreign currency as it provides a higher return and a mechanism safeguard against loss of purchasing power of local currency.

Figure 6.1 shows a positive correlation between dollarization and output. This result is consistent with the result reported for the Maldives by Christiano et. al. (2021). Furthermore, this study also shows that similar countries to the Maldives such as Seychelles, Nepal and Indonesia has a positive correlation. In the context of the Maldives, while there is no official dollarization, dollar denominated assets are used in parallel with local currency assets. Due the wide spread of tourism, dollar always circulate within the economy through multiple channels. At the same time there is a parallel market for dollar making its unofficial dollarization possible. Combined with this, the reliance on dollar denominated liability to fund state and private debt supports the results shown in above business cycle properties of the Maldives in the context of dollarization. For instance, positive economic outlook increases dollar circulation in the economy result in domestic agents holding more dollar as their dollarized earning has increased. This effectively makes the dollar a shadow investment vehicle for domestic agents. When cost of living increases, to ensure agents purchasing power is maintained, they access dollar assets.

The discussion above highlights mechanism through which deposit dollarization impact Maldivian macroeconomic aggregates. It also points to the significant role tourism plays in dollarization, economic growth, and development of non-traded sectors. I have also further established that higher deposit dollarization translates into loan dollarization using evidence from Christiano et. al. (2021) and Bocola and Lorenzoni (2020). These observations underpin the assumptions of the model in section 3 where I will introduce two sectors – tradable sector to denote tourism and non-tradable along with liability dollarization to study the cyclical features of the Maldivian economy.

6.3 The Model

I have used Mendoza and Roja (2019) framework to develop the model of liability dollarization. Mendoza and Roja (2019) present a model of sudden stops using a pure endowment economy without production. This paper significantly deviates from their original model in number of aspects. First, in this model, both household and firm problems are explicitly modelled. Second, given that the objective of this model is to study the propagation and transmission mechanism in small open economies subject to liability dollarization, participation of both household and firms in financial markets are introduced using simple and tractable framework. Third, this model can accommodate both the aspects of financial dollarization – liability and asset dollarization. In this model firm engage in liability dollarization while household can from time to time have a net liability (asset) dollarization based on its debt holding level $D_t < 0 (D_t > 0)$. This model therefore mirrors more closely to what one would observe in terms of dollarization in small open economies.

Liability dollarization enhances understanding of international business cycle transmission by emphasizing the role of exchange rate in business cycle dynamics. In literature, to model liability dollarization, currency mismatch is introduced to agents' balance sheets. Two main approaches are used to model currency mismatch. In the first approach, dollarized debts are added to representative agent(s) resource constraint. For instance, Choi and Cook (2004) introduces dollarized debts onto representative firm's budget constraint while Mendoza and Roja (2019) introduce dollarized debt to representative consumers' resource constraint. These studies also introduce financial frictions which results in development of a financial accelerator mechanism. The second approach introduces financial intermediaries such as banks to feature balance sheet effects arising from mismatch of currencies. Bocolo and Lorenzoni (2020) models' representative consumers and banks to study liability dollarization while Basso et. al (2007) uses household, firms, and banks to model liability dollarization. The focus of latter approach is on the risk premium and portfolio decisions. In this paper, I will introduce financial dollarization through the first approach as the objective of this thesis is to determine the role of liability dollarization in driving business cycle in small and emerging economies. This is a model of representative household, representative firm producing non-traded goods and risk averse international lenders. The model introduces financial friction in the form of collateral constraint on borrow.

In this two-sector model, I treat traded sector as an endowment. The implication of this setup is that the household will consume both traded and non-traded good but will only work in non-traded sector as traded sector is taken as given. This assumption fits well with the Maldivian economy due to Tourism being the single largest contributor to Maldivian GDP. The tourism industry, due to its reliance on natural resources and rest of the world for expansion can be regarded as an endowment. By treating tourism as an endowment, the model assumes traded sector is exogenous and size of this endowment economy is determined by exogenous events. Evidence from Covid-19 pandemic shows that this assumption is realistic as global lockdowns halted the tourism earning and brought the sector to a standstill. Similarly natural disasters such as Indian Ocean tsunami of 2004 had immediate impact on tourism including availability of resorts and islands to build resorts. Below, I will be summarizing relevant characteristics of the agents and conditions facing the domestic economy.

6.3.1 Household problem

The household problem is analogous to the previous section, where household aims to maximise utility by choosing optimally the composite consumption and hours. As traded sector is taken as an endowment, household only works in non-traded sector while consuming output from traded and non-traded sector. The representative household preferences and objective function is as follows.

$$\max_{C_t, H_t} E_j \sum_{j=0}^{\infty} \beta^{t+j} \, U(C_t, H_t^{NT})$$

where

$$U(C_t, H_t) = \frac{\left[C_t - \chi \frac{\left(H_t^{NT}\right)^{\rho}}{\rho}\right]^{1-\sigma} - 1}{1-\sigma} \qquad 6.1$$

In (6.1) C_t is the composite consumption function and H_t^{NT} is hours worked in non-traded goods sector. χ is the inverse of Frisch elasticity parameter similar to other chapters. As noted by Povoledo (2017, p. 704) this parameter affects the effect of technology shock to terms of trade. Composite consumption C_t takes standard Dixit and Stiglitz (1977) Constant Elasticity of Substitution (CES) aggregator form and is given by

$$C_t = [\omega(C_t^T)^{-\eta} + (1-\omega)(C_t^{NT})^{-\eta}]^{-\frac{1}{\eta}}, \eta > -1; \; \omega \in (0,1) \qquad 6.2$$

The household problem can be solved in two stages. First, household intratemporal optimization leads to the following demand functions and prices.

$$P_t^{NT} = \left(\frac{\omega}{1-\omega}\right)\left(\frac{C_t^T}{C_t^{NT}}\right)^{\eta+1} \qquad 6.3$$

$$C_t^T = \omega P_t^{c\,\eta} C_t \qquad 6.4$$

$$C_t^{NT} = (1-\omega)\left(\frac{P_t^c}{P_t^{NT}}\right)^{\eta} C_t \qquad 6.5$$

The composite price index, is given by

$$P_t^c = \left[\omega^{\frac{1}{1+\eta}} + (1-\omega)^{\frac{1}{1+\eta}}(P_t^{NT})^{\frac{\eta}{1+\eta}}\right]^{\frac{1+\eta}{\eta}} \qquad 6.6$$

P_t^c the relative price of the composite good C_t in units of tradable good that can be regarded as consumer price index or overall price level. In this model, as tradable sector is given, without loss of generality, I have normalised the price of tradable goods to one and assumed price of tradable good is same between home and foreign country, making the terms of trade equal to one. This makes P_t^{NT} price of non-traded goods in units of tradable goods. The implication of (6.3) - (6.6) is that at equilibrium price of non-traded goods and price of consumption are increasing function of tradable consumption.

Next, I move into intertemporal household maximization problem. Household has access to foreign borrowing D_t in units of foreign currency which has a gross interest of $1 + R_t$ between period t and $t + 1$. Sequential budget constraint of the household takes the following form.

$$\frac{D_t}{RER_t} + P_t^c\, C_t = \frac{Q_t^C D_{t+1}}{RER_t} + Y_t^T + P_t^{NT} W_t^{NT} H_t^{NT} + \Pi_t^{NT} \qquad 6.7$$

As evidenced from (6.7), I have treated tradable goods as the numeraire. The left-hand side of this expression is the domestic household's expenditure in units of tradable composite goods while the right-hand side show the domestic household's income sources. Y_t^T is the realised endowment of tradable sector and it follows a standard AR(1) process. $P_t^{NT} W_t^{NT} H_t^{NT}$ is the income from working in the non-traded goods sector paid in units of tradable goods and Π_t^{NT} is the profit representative firm transfers to household at each period. RER_t is the real exchange rate between home and rest of the world. Section 6.3.3 elaborate on exchange rate determination. $\frac{D_t}{RER_t}$ denotes dollarized debt position assumed in period $t - 1$ and is due in period t. This term represents the repayment of principal and interest on maturing bonds in units of domestic consumption goods, As per the right-hand side, in order to purchase bond (sell), household requires to raise $\frac{Q_t^C D_{t+1}}{RER_t}$ when $D_{t+1} > 0$ ($D_{t+1} < 0$). This is a real dollarization model as household borrows in units of consumption goods. It can be seen from the budget constraint debt is denoted in units of tradable composite goods and changes in real exchange rate impact the value of debt household holds in each period.

6.3.2 Financial Intermediation

I assume financial intermediation occurs through international financial markets. Q_t^c is the price charged by international financial intermediaries to domestic agents. This price is assumed to be equal to inverse of gross interest rate ($Q_t^c = 1/(1 + R_t)$) in units of composite consumption goods. There are large masses of international intermediaries who are willing to lend to domestic agents at this price. Intermediaries also consider international lending risky to emerging economies, therefore charges a premium in addition to risk free rate R_t^*. Details on how this premium is constructed are discussed in section 6.3.4. Domestic agents can also save with international financial intermediaries at Q_t^c.

6.3.3 Real Exchange Rate

This section details on real exchange rate determination process. I have followed closely the work of Schmitt-Grohe and Uribe (2017). Based on the formulation thus far, one can establish that given terms of trade between home and rest of the world is 1, relative price of non-traded goods in units of tradable would play a crucial role in linking rest of the world prices to home macroeconomic indicators. The non-traded goods price differences across countries therefore would affect the real purchasing power of domestic agents, hence real exchange rate. Holden (1988, p.2) defines real exchange rate as "relative price of tradable to nontradable goods". To establish an expression for real exchange rate, I begin with the premise that real exchange rate is defined as a ratio of consumer price index between the home country and foreign country (rest of the world). By denoting foreign country's consumer price index in units of foreign currency as P_t^* and the nominal exchange rate between home and foreign country (price of one unit of home currency in units of foreign currency) as $\mathcal{E}_t$, real exchange rate (RER_t) can be written as follows.

$$RER_t = \frac{\mathcal{E}_t P_t^*}{P_t}$$

Analogous to foreign country, P_t denotes the nominal price of consumption in home country in units of local currency. As show in the above expression, a rise in cost of living at home denoted by increase in P_t results in a fall in real exchange rate (appreciation), where home basket of commodities becomes expensive relative to foreign basket. If P_t falls, real exchange rate depreciates as cost of living in home country has fallen relative to foreign country. To establish the relationship between real exchange rate and composite price index in units of tradable goods, I divide both numerator and denominator by the nominal price of tradable goods in home country. This gives

$$RER_t = \frac{\mathcal{E}_t P_t^* / P_t^T}{P_t / P_t^T}$$

The denominator of this expression is home relative price of final consumption goods in units of tradable good (ie. composite price index), P_t^c. As I assume law of one price holds for tradable goods between home and rest of the work, it implies $P_t^T = \mathcal{E}_t P_t^{T*}$ where P_t^{T*} is the nominal price of tradable goods in terms of foreign country prices. This reduces the RER_t expression to

$$RER_t = \frac{P_t^* / P_t^{T*}}{P_t / P_t^T}$$

The numerator now has an analogous meaning for the foreign country as the home (ie, foreign relative price of composite consumption in units of tradable goods). Letting $P_t^c = P_t / P_t^T$ and $P_t^{c*} = P_t^* / P_t^{T*}$, real exchange rate reduce to ratio of composite price index of between foreign and home country in units of tradable.

$$RER_t = \frac{P_t^{c*}}{P_t^c} \qquad 6.8$$

This expression shows that real exchange rate is the ratio of composite price index between home and foreign country. As show in (6.3) the one-to-one positive relationship between price of non-traded goods with the composite price index makes non-traded goods prices a key determinant of the real exchange rate between home and foreign country. A rise in price of non-traded good will result in country's composite prices relatively expensive. As stated in Schmitt-Grohe and Uribe (2017), tradable goods will become more expensive if and only if the price of non-traded goods falls. This implies, the competitiveness of the model economy is determined through the price of non-traded goods. Furthermore, Burstein and Gopinath (2014) documents that a real exchange rate has a negative (positive) relationship with non-traded (tradable) goods. In the context of this model, for home country, a rise in composite price index is due to rise in relative price of non-traded goods. Therefore, real exchange rate will fall (appreciate). If RER_t increases, domestic economy becomes cheaper compared to foreign economy, causing real exchange rate depreciates and vice-versa for foreign economy.

6.3.4 Determination of interest rate

I follow the debt elastic interest rate formulation in Chapter 5 with adjustment made to introduce real dollarized debt per capita into the risk premium. The interest facing domestic agents therefore is expressed as:

$$R_t = R_t^* + \psi\left(exp\left(E_t\left(\frac{D_{t+1}}{RER_{t+1}}\right) - \frac{D}{RER}\right) - 1\right)$$

Where R_t^* is the risk-free rate, $\frac{D_{t+1}}{RER_{t+1}}$ is the real dollarized debt in this period, $\frac{D}{RER}$ is the steady state real dollarized debt per capita. In this formulation, interest rate is a function of risk-free rate and risk premium that is based on deviation of debt-per capita from its steady state level. The debt elastic interest rate premium parameter ψ measures the overall sensitivity of the interest rate premium on borrowing. In the presence of liability dollarization, value of debt now depends on the path of real exchange rate. Household is unable to pin down the total repayment following issuing of new debt until exchange rate is realized. If the real exchange appreciates, home borrowers' foreign debt repayment becomes larger in units of tradable goods.

6.3.5 Representative Household's Competitive Equilibrium

The competitive equilibrium comprises of sequences of allocation $\{C_t,\ H_t^{NT},\ B_t\}_{t=0}^{\infty}$, taking as given prices $\{P_t,\ W_t^{NT},\ Q_t^c\}_{t=0}^{\infty}$and initial conditions $[B_0, \bar{Y}_t^T]$ to maximise lifetime utility of representative household subject budget constraint, no arbitrage condition, market clearing condition for tradable and non-traded consumption and no-Ponzi game constraint $\lim_{j\to\infty} RER^{-j}Q_{t+j}^c D_{t+j} \leq 0$. Taking β^{t+j} and λ_t^1 as discount factor and Lagrange multiplier associated with household resource constraint, the household optimisation problem and its first order conditions are as below.

$$\mathcal{L} = \sum_{j=0}^{\infty} \beta^{t+j} \left\{ \frac{\left[1 + C_t - \frac{(H_t^{NT})^{\rho}}{\rho}\right]^{1-\sigma} - 1}{1-\sigma} \right.$$

$$\left. - \lambda_t^1 \left(\frac{D_{t+1}}{RER_t} + P_t^c\, C_t - \frac{D_t(1+R_t^*)}{RER_t} - Y_t^T - P_t^{NT} W_t^{NT} H_t^{NT} - \Pi_t^{NT} \right) \right\}$$

The first order conditions associated with household problem is as follows.

$$\frac{\partial \mathcal{L}}{\partial C_t}: \left[1 + C_t - \frac{(H_t^{NT})^{\rho}}{\rho}\right]^{-\sigma} = \lambda_t^1 P_t^c \qquad 6.9$$

$$\frac{\partial \mathcal{L}}{\partial H_t}: \left[1 + C_t - \frac{(H_t^{NT})^{\rho}}{\rho}\right]^{-\sigma} (H_t^{NP})^{\rho-1} = \lambda_t^1 P_t^{NT} W_t^{NT} \qquad 6.10$$

$$\frac{\partial \mathcal{L}}{\partial B_{t+1}}: \frac{1}{RER_t} \lambda_t^1 \beta^t = E_t(1 + R_{t+1}) \beta^{t+1} \frac{1}{RER_{t+1}} \lambda_{t+1}^1 \qquad 6.11$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_t^1}: \frac{Q_t^c D_{t+1}}{RER_t} + P_t^c\, C_t = \frac{B_t}{RER_t} + Y_t^T + P_t^{NT} H_t^{NT} + \Pi_t^{NT} \qquad 6.12$$

Combining (6.9) and (6.10) gives

$$W_t^{NT} = \frac{P_t^c}{P_t^{NT}} (H_t^{NT})^{\rho-1} \qquad 6.13$$

Re-arranging (6.11) shows Euler equation for bonds as

$$\lambda_t^1 = \beta E_t(1 + R_{t+1}) \frac{RER_t}{RER_{t+1}} \lambda_{t+1}^1 \qquad 6.14$$

Expression (6.14) shows that compared with a standard model, in the Euler equation, there is a wedge drawn between marginal cost and marginal benefit of borrowing by the expected exchange rate changes. As shown in (6.14) for a given cost of servicing debt, marginal cost of holding debt increases if there is expectation that the following period exchange rate will fall (appreciation).

6.3.6 Representative Firm's Competitive Equilibrium

In the context of this model, the representative firm operating in non-traded sector, the price of investment and price of capital are denoted in units of tradable goods, P_t^T where $P_t^T = 1$. This indexation allows real exchange rate to enter representative firm's intertemporal decision making.

The production technology of the firm is given as

$$Y_t^{NT} = A_t^{NT}(K_{t-1}^{NT}, H_t^{NT}) = A_t^{NT}(K_{t-1}^{NT})^{\alpha}(H_t^{NT})^{1-\alpha} \qquad 6.15$$

The equation for motion of capital is given by

$$K_t^{NT} = I_t^{NT} + (1-\delta)K_{t-1}^{NT} - \frac{\phi_X}{2}\left(\frac{I_t^{NT}}{K_{t-1}^{NT}} - \delta\right)^2 K_{t-1}^{NT} \qquad 6.16$$

The motion for capital features capital adjustment and assumes to satisfy the restrictions from literature where $\phi_X(o) = \phi_X'(0) = 0$ and $\phi_X'' > 0$.

Due to a friction in labour market, at the beginning of each period, the firm, prior to commencing production, is required to set aside a fraction (θ) of its wage bill given by $\theta P_t^{NT} H_t^{NT}$ where $\theta \in [0,1]$. The firm directly borrows this sum at the beginning of each period at the rate R_{t-1}via international financial markets. Upon realisation of sales, the firm pays the total wage owed to its workers and return the borrowing with interest to financial intermediaries.

International financial intermediaries are unable to fully determine the credit worthiness of the firm due to presence of asymmetric information. As a result, the total amount firm can borrow at the beginning of any period is subject to the following constraint.

$$\theta P_t^{NT} W_t^{NT} H_t^{NT} < \xi_t Q_t K_t^{NT} \qquad 6.17$$

K_t^{NT} is the capital stock of the firm, Q_t is the shadow price of capital, also known as Tobin's Q. This formulation makes $Q_t K_t^{NT}$ equal firm's net worth. As shown in (6.17), firm can borrow up to fraction $\xi_t$of its capital. This setup is constituent with limited enforcement problem associated with international financial intermediation, where the stochastic borrowing constraint in (6.17) determines the proportion of net assets lenders can recover in an event where representative firm renege on its debt obligation.

The representative firms profit maximisation problem is as follows.

$$\max_{\{K_{T_{t-1}}, H_{NT_t}\}} E_j \sum_{j=0}^{\infty} \beta^t \frac{\lambda_{t+j}^1}{\lambda_t^1} [P_t^{NT} Y_t^{NT} - W_t H_t^{NT} - (1 - R_{t-1})\theta P_t^{NT} W_t H_t^{NT} - I_t^{NT}] \qquad 6.18$$

The firm's profit function given in (6.18) shows total revenue, costs and gross interest paid on firms borrowing in units of tradable goods by non-traded goods producers.

Representative firm aims to maximise its profit function in (6.18) subject to equation for motion of capital in (6.16), borrowing constraint (6.17) by optimally choosing K_{t-1}^{NT}, H_t^{NT} and I_t^{NT} and taking as given the price of non-traded good P_t^{NT}, interest rate R_{t-1}, fraction of wages that needs to be set aside θ, wages W_t and fraction of capital value that can be borrowed, η_t. By assigning λ_t^2 as lagrange multiplier for capital, which is also known as shadow price of capital (also known as Tobin's Q), the firm's problem and associated optimality conditions for firm's problem with respect to hours, capital, and investment are as follows:

$$\begin{aligned}\mathcal{L} = E_j \sum_{j=0}^{\infty} \beta^t \frac{\lambda_{t+j}^1}{\lambda_t^1} \Bigg\{ \Bigg(& [P_t^{NT} Y_t^{NT} - W_t H_t^{NT} - (R_{t-1} - 1)\theta W_t H_t^{NT} - I_t^{NT}] \\ & + Q_t \left(I_t^{NT} + (1-\delta) K_{t-1}^{NT} - \frac{\phi_{X_i}}{2} \left(\frac{I_t^{NT}}{K_{t-1}^{NT}} - \delta \right)^2 K_{t-1}^{NT} - K_t^{NT} \right) \\ & + \mu_t \left(\xi_t Q_t K_{t-1}^{NT} - \theta W_t H_t^{NT} \right) \Bigg) \Bigg\}\end{aligned}$$

The first order conditions associated with representative firm's profit maximisation problem is given below.

$$\frac{\partial \mathcal{L}}{\partial H_t^{NT}}: (1-\alpha)A_t^{NT}P_t^{NT}(K_{t-1}^{NT})^{\alpha}(H_t^{NT})^{-\alpha} = W_t(1+\theta[(1-R_{t-1})+\mu_t]) \quad 6.19$$

$$\frac{\partial \mathcal{L}}{\partial K_t^{NT}}: \lambda_t^2 = E_t\beta^t\frac{\lambda_{t+1}^1}{\lambda_t^1}\left\{(\alpha P_{t+1}^{NT}A_t^{NT}(K_{t-1}^{NT})^{\alpha-1}(H_t^{NT})^{1-\alpha}) + \lambda_{t+1}^2\left((1-\delta)+\mu_{t+1}\xi_{t+1} + \phi_X\left(\frac{I_{t+1}^{NT}}{K_t^{NT}}-\delta\right)\frac{I_{t+1}^{NT}}{K_t^{NT}} - \frac{\phi_X}{2}\left(\frac{I_{t+1}^{NT}}{K_t^{NT}}-\delta\right)^2\right)\right\} \quad 6.20$$

$$\frac{\partial \mathcal{L}}{\partial I_t^{NT}}: 1 = \lambda_t^2\left[1-\phi_X\left(\frac{I_t^{NT}}{K_{t-1}^{NT}}-\delta\right)\right] \quad 6.21$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_t^2}: K_t^{NT} = I_t^{NT} + (1-\delta+\mu_t\xi_t)K_{t-1}^{NT} - \frac{\phi_X}{2}\left(\frac{I_t^{NT}}{K_{t-1}^{NT}}-\delta\right)^2 K_{t-1}^{NT} \quad 6.22$$

$$\frac{\partial \mathcal{L}}{\partial \mu_t}: \theta W_t^{NT}P_t^{NT}H_t^{NT} = \xi_t K_t^{NT} \quad 6.23$$

The first order condition in (6.19) implies that at the optimal path for labour, there is a wedge imposed by collateral constraint between marginal cost and marginal benefit of labour. The marginal cost is wage rate and it's augmented by the net interest paid on borrowing and effectiveness of the enforcement constraint which would make μ_t tighter.

To determine the mechanism through which real exchange rate affects intra-period borrowing by the representative firm can be establish using collateral constraint. The collateral constraint presented in (17) shows that the representative firm's total value of capital is expressed in units of tradable goods where tradable goods prices are normalized to 1. As a consequence, at the optimal path, the impact of real exchange rate therefore enters into the representative firm problem indirectly through changes in firms net worth following any disturbances in tradable goods sector.

6.3.7 Trade balance and current account

Incomplete market model enables us to study the dynamics of trade balance and current account following shocks to the economy. In order to derive the trade balance to output ratio and current account to output ratio, the household budget constraint in (6.7) is combined with firm's profit function in (6.18) to arrive at the aggregate budget constraint for the economy.

$$P_t^c\, C_t + \frac{D_t}{RER_t} = \left(\frac{1}{1+R_t}\right)\frac{D_{t+1}}{RER_t} + Y_t^T + P_t^{NT}W_t^{NT}H_t^{NT} + P_t^{NT}Y_t^{NT} - P_t^{NT}W_t^{NT}H_t^{NT}$$

$$-(1-R_{t-1})\theta P_t^{NT}W_t^{NT}H_t^{NT} - I_t^{NT} \qquad 6.24$$

Using (6.24) trade balance to output ratio is defined as output in excess of domestic absorption.

$$\frac{TB_t}{Y_t} = \frac{Y_t^T + P_t^{NT}Y_t^{NT} - P_t^c\, C_t - I_t^{NT}}{Y_t} \qquad 6.25$$

where $Y_t = Y_t^T + P_t^{NT}Y_t^{NT}$. Current account to output ratio therefore will pin down from (6.24) to

$$\frac{CA_t}{Y_t} = \frac{TB_t}{Y_t} - \frac{\left((1-R_{t-1})\theta P_t^{NT}W_t^{NT}H_t^{NT} + \frac{D_{t+1}}{RER_t}\left(\frac{R_t}{1+R_t}\right)\right)}{Y_t} \qquad 6.26$$

The conclusions one can draw from (6.26) has a profound impact on how one should interpret current account to output ratio as a valuation effect that arises due to changes in real exchange rate enters into current account to output ratio. As demonstrated in Notz and Rosenkranz (2021) current account is no longer equal to changes in net foreign asset position. As seen in (6.26) net foreign asset position is adjusted for changes in valuation that arises due to real exchange rate changes.

6.3.8 Closing the model

Finally, the model is subject to the following shocks represented through AR(1) processes.

Technology shock originated in non-traded goods sector:

$$\ln A_t^{NT} = \rho_A \ln A_{t-1}^{NT} + \varepsilon_t^A \qquad \rho_A \in (-1,1);\ \varepsilon_t^A \sim N(0, \sigma_A^2) \qquad 6.27$$

Real exchange rate shock is modelled through foreign composite price index and given by the following AR(1) process :

$$\ln P_t^{c*} = \rho_{PC*} \ln P_{t-1}^{c*} + \varepsilon_t^{PC*} \qquad \rho_{PC*} \in (-1,1);\ \varepsilon_t^{PC*} \sim N(0, \sigma_{PC*}^2) \qquad 6.28$$

Evolution of endowment in tradable sector:

$$\ln Y_t^T = \rho_T \ln Y_{t-1}^T + \varepsilon_t^A \qquad \rho_T \in (-1,1);\ \varepsilon_t^T \sim N(0, \sigma_T^2) \qquad 6.29$$

Stochastic borrowing constraint parameter has the following AR(1) process

$$\ln \eta_t = \rho_\eta \ln \eta_{t-1} + \varepsilon_t^\eta \qquad \rho_\eta \in (-1,1);\ \varepsilon_t^\eta \sim N(0, \sigma_I^2) \qquad 6.30$$

The competitive equilibrium comprises of the first order conditions for the firm and household problem in 6.3.5 and 6.3.6 respectively, along with their budget constraints, borrowing constraint, the law of motion of capital, real interest rate, real exchange rate in (6.8), the external balances in (6.25 & 6.26), expressions on intratemporal substitution problem in (6.2)-(6.6) and the AR(1) process in (6.27)-(6.30). The 24 equations summarising the 24 variables comprise in above equilibrium expressions are coded in Dynare and solved through log linearisation algorithm available in Dynare. The following section summarises the steady state equations of the model that forms part of Dynare coding and relevant calibrated parameters.

6.4 Steady State and Parameterization

6.4.1 Deterministic Steady State

For simplicity, throughout the model we assume that firm has to set aside the entire wage bill, therefore θ is set to 1. Technology in non-traded sector and price of non-traded good at steady state is $A^{NT} = 1$ and $P^{NT} = 1$ respectively.

From (6.21) at steady state we can see that $\lambda^2 = 1$.

From through first order condition in (6.20) the steady state capital to hours worked ratio $\frac{K^{NT}}{H^{NT}}$can be computed as

$$\frac{K^{NT}}{H^{NT}} = \left(\frac{\alpha P^{NT}}{\frac{1}{\beta}-(1-\delta)+\mu\xi}\right)^{\frac{1}{1-\alpha}} \qquad 6.31$$

Taking demand for labour in (6.19), and capital and labour ratio, wages at steady state become

$$W^{NT} = \frac{(1-\alpha)P^{NT}\left(\frac{K^{NT}}{H^{NT}}\right)^{\alpha}}{1+(R-1)+\mu}$$

By substituting (6.31), non-traded wage in the above expression pins down steady state wages as:

$$W^{NT} = \frac{(1-\alpha)P^{NT}\left(\frac{\alpha P^{NT}}{\frac{1}{\beta}-(1-\delta)+\mu\xi}\right)^{\frac{\alpha}{1-\alpha}}}{1+(R-1)+\mu} \qquad 6.32$$

As shown in (6.21), wage is decreasing in μ which determines the effectiveness of collateral constraint. If collateral constraint becomes more binding, μ will increase, causing a decreasing effect on wages. In order to establish the relationship between μ and financial friction parameter η, first (6.23) is re-written as

$$W^{NT} = \frac{\eta}{P^{NT}}\left(\frac{K^{NT}}{H^{NT}}\right) \qquad 6.33$$

Combining (6.19) with (6.33) and substituting $\frac{K^{NT}}{H^{NT}}$ from (6.31), the resulting final expression can be re-arranged for μ to pin down the relationship between financial friction parameter, ξ with shadow price of borrowing constraint (multiplier on collateral constraint), μ. The resulting expression is as follows.

$$\mu = \frac{(1-\alpha)}{\xi}\left(\frac{1}{\beta}-(1-\delta)\right)-\alpha R \qquad 6.34$$

As shown in (6.34) the multiplier μ is decreasing in ξ, the fraction of capital against which firm can borrow. The bigger the fraction, implies firms can borrow more hence less binding the constraint. Combining labour demand and labour supply condition in (6.19) and (6.13) the steady state hours worked at non-traded sector can be defined as

$$H_t^{NT} = \left[\left(\frac{P^{NT}}{P^C}\right)\left\{\frac{(1-\alpha)\left(\frac{K^{NT}}{H^{NT}}\right)^{\alpha}}{1+(R-1)+\mu}\right\}\right]^{\frac{1}{\rho-1}} \qquad 6.35$$

The steady state trade balance to output ratio and current account to output are pinned down from (6.25) and (6.26) as

$$\frac{TB}{Y} = \frac{Y^T + P^{NT}Y^{NT} - P^C C - I^{NT}}{Y} \qquad 6.36$$

$$\frac{CA}{Y} = \frac{TB}{Y} - \frac{(1-R)P^{NT}W^{NT}H^{NT} + \frac{D}{RER}\left(\frac{R}{1+R}\right)}{Y} \qquad 6.37$$

6.4.2 Calibration of the Model Parameters

The set of calibrated parameters are listed in Table 6.2. The time unit in this model is expressed in annual terms. The parameterization used in this model are drawn from data and literature. Steady state parameters relating to current account to output ratio, trade balance to output ratio debt to output ratio matches their long run unconditional mean in the data as used in the previous chapter.

In terms of preferences and technology parameterization, β is set to match the steady state interest rate to 5%. The value for labour exponent ρ, relative risk aversion σ, the parameter driving elasticity of substitution η, depreciation rate δ, labour share of non-traded output $(1-\alpha)$ and investment adjustment cost are set to standard values in the literature. The capital adjustment cost parameter ϕ_X, cannot be directly identified from the data but are generally set to match the standard deviation of investment. The practice in the literature is to maintain this parameter as a small value to ensure it does not drive the results.

Parameters relating to traded and non-traded good consumption, composite price index, composite consumption are drawn from Medoza and Roja (2017). Finally, the autoregressive parameters for each respective shock relating to technology ρ_A, financial friction ρ_η, foreign prices ρ_η, and endowments ρ_η are set as per the literature ensuring there is some degree of persistence in these shocks.

Preferences and Technology	
Relative Risk Aversion	$\sigma = 2$
Consumption share of traded good	$\omega = 0.205$
Frisch-elasticity parameter	$\rho = 1.455$
Elasticity of substitution – traded and non-traded goods	$\frac{1}{1-\eta} = 1.472$
Labour share of production – non-traded goods sector	$(1-\alpha) = 0.67$
Depreciation Rate	$\delta = 0.10$
Investment adjustment cost	$\phi_X = 0.005$
Steady state debt (based on Maldivian debt to GDP)	D = 0.300
Financial Friction Parameters	
Debt-elastic interest rate premium	$\psi = 0.00742$
Fraction of net worth against which house can borrow	$\eta_t = 0.3208$
Shock Parameters	
Autocorrelation of technology shock	$\rho_A = 0.60$
Autocorrelation of financial friction shock	$\rho_\eta = 0.50$
Autocorrelation of foreign price shock	$\rho_{PC*} = 0.50$
Autocorrelation of traded good sector endowment shock	$\rho_T = 0.60$

Table 6.2: Calibrated Parameter Values

6.5 Results of simulation

In this section I will describe the impulse responses. The impulse responses help to describe transmission and propagation mechanism of shocks along with impulse responses of the theoretical model. As this model features four shock, how these four shocks transmit into the real economy with relevant rationale are provided. Before I focus on impact of specific shock, I will first explain the general transmission and propagation mechanism one would expect in a dollarized economy.

6.5.1 Transmission and propagation mechanism in dollarized economies

In this model with real exchange rate, transmission and propagation of shocks begins by affecting the domestic household and firms via different channels.

The first channel is through income effect and substitution effect which alters the consumption between traded and non-traded goods. For instance, if a shock leading to a positive income effect, household will increase its demand for all types of consumption goods – traded and non-traded goods. As shown in (6.5) household demand for non-traded good is a function of relative price of non-traded goods in units of traded goods and tradable good consumption. Given the level of traded good consumption, consumption of non-traded good is an increasing function of price of composite price index. This therefore implies that an increase in absorption of tradable goods will increase demand for non-traded good.

The second transmission channel is via changes in real exchange rate. Any type of shock to the economy is likely to impact real exchange rate by affecting traded and non-traded goods prices. This is due to the market clearing condition where changing consumption of tradable good would result in shift in demand for non-tradable that would impact the composite price index. As covered in exchange rate determination, changes in composite price index would result in either appreciation (increase in price index) or depreciation (decrease in price index) of real exchange rate. A depreciation of real exchange rate would result in a negative change in RER in response to decrease in composite price index at home or rise in the foreign composite price index.

Third, changes in real exchange rate would result in changes in debt burden for both household and firms. A change to household debt burdens can either free or deplete resource available for consumption. In case of increase in available resource, the household as a response will increase tradable good consumption as there is a positive income effect. Higher consumption will expand tradable sector which would results in an increase in non-tradable goods consumption and output. The income effect also can be interpreted in terms of ex-post interest rate changes in units of tradable goods. As shown in section 6.3.4 on determination of interest rate, a real depreciation (appreciation) results in decrease (increase) burden of the debt payment which reduces (increases) the ex-post real interest rate. Such a change would also provide more incentives for firms to borrow encouraging firms to increase its investment and capital to enhance its borrowing capacity.

Fourth, and the final channel will occur as a result of changes in collateral value as a result of any shock to the economy. As shown in first order condition (6.19) and (6.20), any changes in collateral value will trigger a feedback mechanism where the representative firms alter its employment and capital accumulation decision resulting in changes to non-traded output and prices. These changes will further have a downstream effect through changes in composite price index that will result in real exchange rate effect. For instance, a fall in collateral value would force firms to deleverage by reducing its spending on labour, hence reduction in labour demand. In the context of the model, the value of collateral is determined by the level of capital. If capital stock increases more than the payment of labour, the collateral constraint becomes less binding as value of collateral has risen. When collateral constraint binds, the shadow value of the constraint captured by μ increases while when it becomes less binding, the μ falls.

Th impulse responses presented in this section has the following legends:

(CC: composite consumption, CT: consumption of tradable goods, CNT: consumption of non-tradable goods, HNT: hours worked in non-traded good sector, YNT: non-traded output, WNT: wages in nontraded sector, INT: investment in non-traded sector, KNT : capital in non-traded sector, PC: composite price index, PNT: non-traded prices, RR: real interest rate, PINT: profit in non-traded sector, TB_Y: trade balance to output ratio, CA_Y: current account to output ratio: Lambda2: Tobin' Q (price of capital), MIU: shadow price of borrowing).

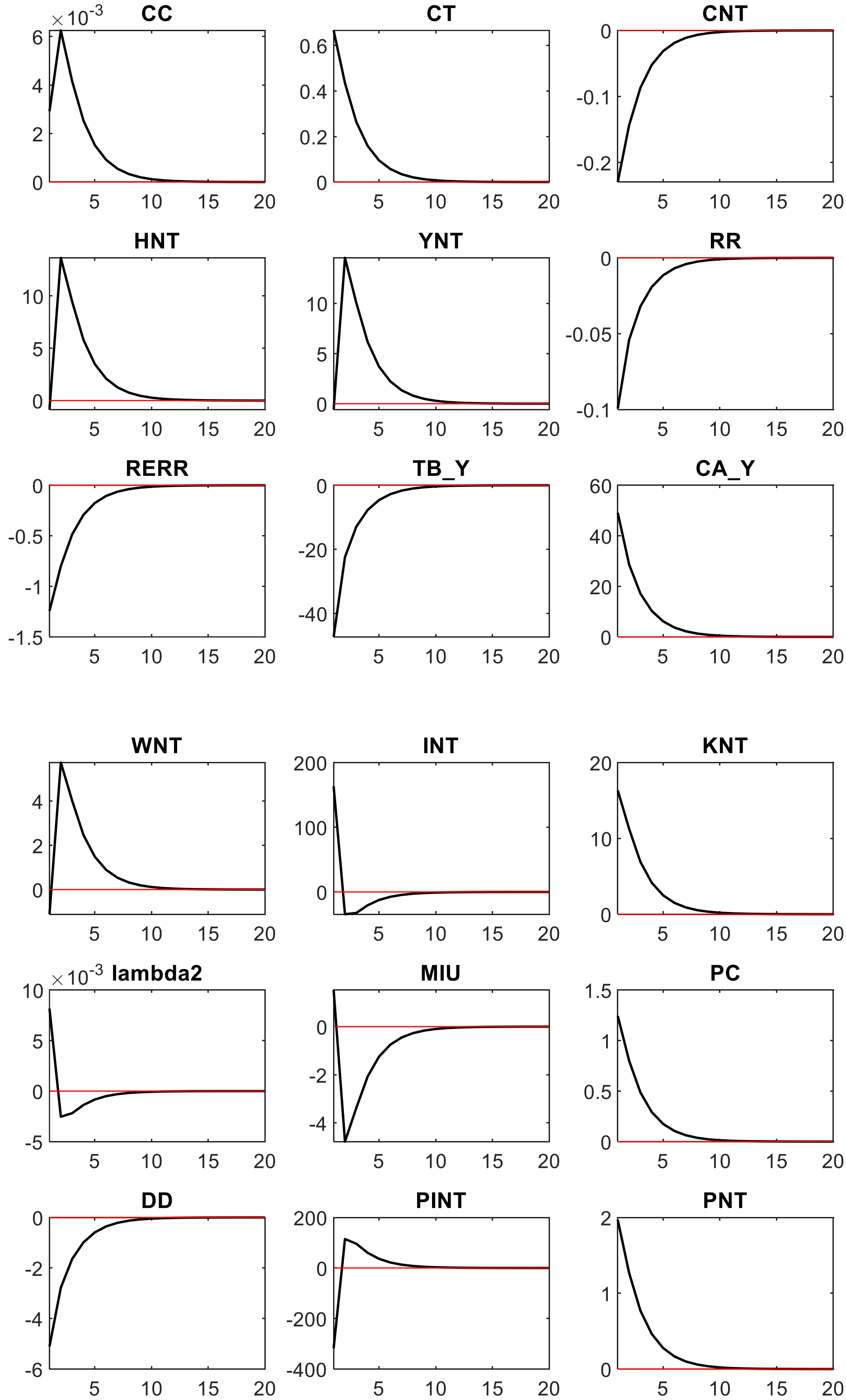


Figure 6.7:Impulse responses following of 1% positive endowment shock

Figure 6.7 represent impulse response following positive 1% shock to tradable endowment. The vertical axis shows percentage deviation from steady state while the horizontal axis shows time. A shock to endowment is equivalent to a terms of trade shock in standard two country models as the representative household experience an increase in income in real term. In this scenario, the source of increase in income (rise in output or a positive term of trade shock) is irrelevant to the household as both sectors are normalized to 1. An endowment shock will have significant macroeconomic implications in small open economies that originates from the household. Such a shock will change relative price of tradable and non-tradable goods due to income effect which would affect real exchange rate (Egert et. al (2006) and Betts and Keohe (2008). This change will impact household and firm's budget constraint. In this model, a positive 1% shock to tradable endowment results in increase in tradable consumption and aggregate consumption upon impact due to positive income effect. Consumption of non-traded goods falls upon impact due substitution of tradable consumption for non-traded consumption and output in non-traded sector contract first before bouncing back. The growth in traded sector in the subsequent periods, however, cause non-traded sector to expand as expected from the theory.

The endowment shock makes price of tradable to fall compared causing an increase in the relative price of non-traded goods hence rising composite price index and appreciation of real exchange rate. The appreciation of exchange rate makes cost of servicing external debt to fall for both the household and firms. While household take advantage of this reduction by paying off debt and increasing their saving to smooth their lifetime consumption, firms invest in its capacity to borrow as cost of borrowing has decreased. While upon impact firms in non-traded sector experience a fall in their output, wage, and hours, more than proportionate increase in price of non-traded goods prices makes collateral constraint more binding. Firms in non-traded sector increases its capital accumulation and investment in anticipation of future rise in output, employment, and hours due to traded sector growth.

As the increase in domestic absorption is larger than the increase in national income following the endowment shock, trade balance deteriorates. This result is consistent with the empirical finding of Lane and Milesi-Ferrett (2002) which shows that trade balance deterioration is linked to appreciation of real exchange rate. When exchange rate appreciates, foreign imports become cheaper to domestic residents resulting in an increase consumption of foreign goods. An important observation to note is that the dynamics of composite consumption with real exchange rate when the shock originates in home country. As impulse responses show, the relationship is inverse. This result is driven from the increase in relative prices of non-tradable in terms of tradable goods.

In this model household starts with an initial net debt position of $D_0 > 0$ (household starts with dollarized debt). The positive wealth effect and fall in cost of servicing of debt leads to reversal of household debt position. As a result of household's repayment of existing debt and expansion of consumption and investment results in a trade balance deficit. Fall in debt level increases current account surplus. This movement in current account is attributed to rise in tradable endowment which increases domestic funds. When tradable endowment increases at t_0 agents borrow less (fall in debt holdings) due to rise in endowments contribution to maintain consumption stream. As the collateral constraint binds, we are in constrained equilibrium which results in increase in non-traded prices, appreciation of real exchange rate and improvement of current account.

After the initial negative impact on non-traded sector's output, consumption and hours, the increased wealth effect starts to benefit non-traded sector when in subsequent periods, these variables improve before converging to its long run level.

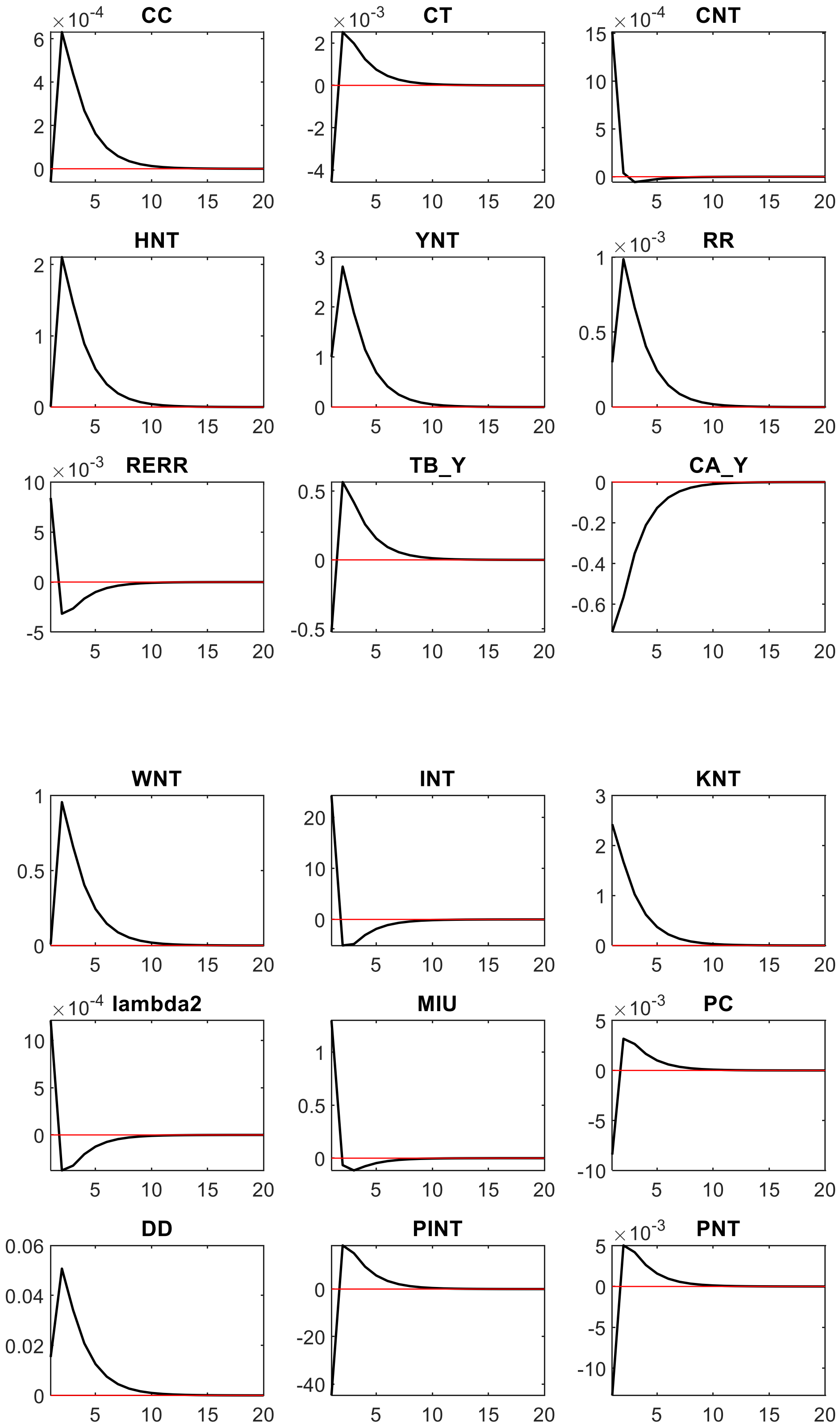


Figure 6.8: Impulse responses following of 1% improvement in technology shock in non-traded sector

Figure 6.8 present the impulse response following a positive technology shock that originates from non-traded good sector. As a result of shock, output and consumption in non-tradable sector increases as one would expect under standard real business cycle setup. At impact, there is no change in wage and hours as labour decisions were made at the start of the period. Firms operating in non-traded good sector would want to increase the employment in subsequent period as positive technology shock increases marginal product of labour. However, the non-traded sector cannot fully exploit this increase in marginal product of labour due to the presence of collateral constraint. As firms seeks to expand the output, the collateral constraint becomes more binding as shown by 'MIU' which reduces the growth in wage rate and hours. As shown by impulse responses, the initial rise in hours and wages are negligible due to lagged impact investment will have on the net worth of the firm represented by the value of the capital. This result is consistent with Jermann and Quadrini (2012) who used a similar framework and to Carlstrom and Fuerst (1997). The dynamics behind impulse responses can be summarised as follows. As collateral constraint became tighter, in order to expand the non-traded output, firms would want to increase the working capital but as capital growth is sluggish it constraints total value against which firm can borrow to meet the desired output expansion. This makes multiplier μ_t (lambda2 in Figure 6.8) to rise. Within the labour demand function in (6.19), μ_t enters directly in the form of a wedge between marginal product of labour and wage rate. As seen in Chapter 5, this is similar to a tax on labour income.

$$W_t = \frac{(1-\alpha)A_t^{NT}\left(K_{t-1}^{NT}\right)^{\alpha}\left(H_t^{NT}\right)^{-\alpha}}{(1+\theta[(1-R_{t-1})+\mu_t])} \qquad 6.38$$

Hence a rise in μ_t, dampens the labour demand which support the initial sluggish growth in wages and hours growth following the jump period. However, as investment growth feeds into more capital accumulation, the output expansion is supported with increase in demand for labour and wages. As shown in Neumeyer and Perri (2005), the presence of borrowing related denominator into labour demand function will dampen the growth in output, wages and hours compared to standard RBC models. This result therefore is consistent with the observed mechanism in Chapter 5 following a positive technology shock.

The increase in supply of non-traded output drives down the prices of non-traded goods which results in fall in composite price index and hence leads to depreciation of real exchange rate due to the presence of a one-to-one relationship between price of non-traded goods and price index. As the real exchange rate has depreciated, the domestic economy has become cheaper for foreigners. At the same time, real interest rate increases making debt more onerous. Therefore, total debt value rises which increases risk premium and real interest rate facing firms. However, as non-traded sector begins to expand following increase in its borrowing capacity, the price of non-traded goods and hence composite price index begins to rise causing reversal of real exchange rate and interest rate. As exchange rate begins to appreciate, cost of servicing debt falls. Household sees this as an opportunity to repay the debt and combined with positive income effect following expansion in the non-traded good sector, household accumulates savings to smooth their consumption, household debt position converging to steady state. Following a productivity shock to non-traded good sector, we observe a positive co-movement between real exchange rate, interest rate and debt

Unlike Chapter 5, with the dollarized debt, the exchange rate significantly affects the risk premium. As real exchange rate and non-traded output moves in the same direction, the reduction in per capita debt through output effect is offset by the rise in RER (depreciation) which becomes the source to influence risk premium. The formulation linking RER to risk premium is therefore a much more realistic setup compared to Chapter 5.

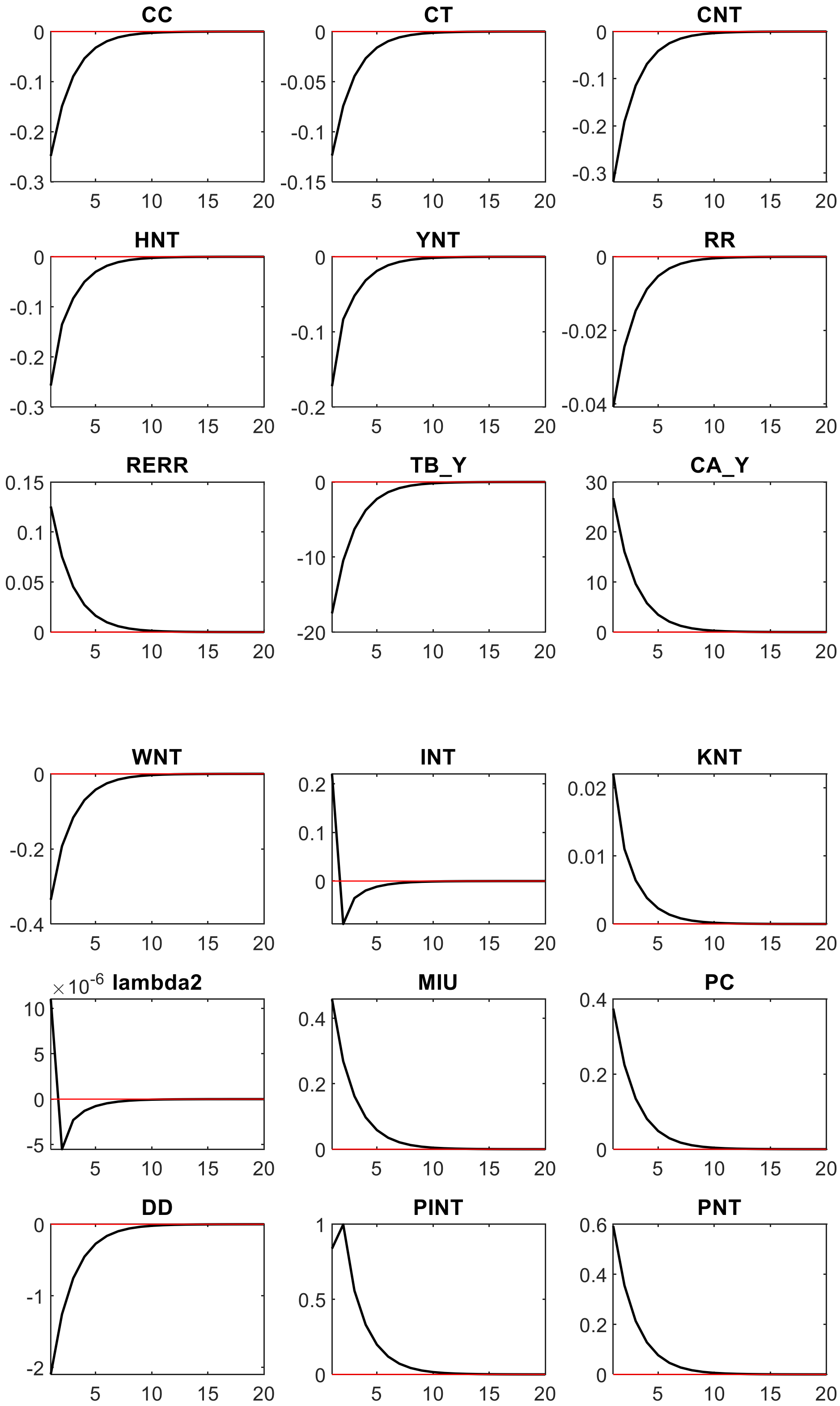


Figure 6.9 : Impulse responses following 1% increase in foreign price shock (foreign composite price index)

In this model, foreign price shock is equivalent to a real exchange rate shock as foreign prices enters into the model economy through real exchange rate channel. Figure 6.9 shows the impulse responses because of foreign price shock. A positive shock to foreign prices makes rest of the world more expensive to domestic agents. This therefore is an equivalent to a real depreciation of home currency as shown by the impulse responses.

A transitory foreign price shock results in negative income effect as foreign economy has become more expensive to domestic agents. This in fall in income in units of traded goods. Therefore, consumption of tradable and non-traded good falls, depressing, output, employment and wages. The price of non-traded good rises triggering an endogenous rise in home composite price index while exchange rate depreciates. As a result of depreciation, household experience a fall in their total net debt value ($\frac{D_t}{RER_t}$) which contributes to a fall in risk premium charged by lenders making cost of servicing debt cheaper for household and firms. Household reduces its debt holding by repaying some of the debt.

The firm's capital and investment rise marginally making constraints more tighter and binding. The feedback mechanism through which a binding and a tighter collateral constraint enters the economy is through the impact non-traded sector which alters the marginal benefit and cost of acquiring additional capital by firms. As consumption of tradable good falls due to relative fall in rest of the world's tradable prices compared to non-traded goods prices, the marginal cost and benefit of acquiring capital alters.

In this model, the price of capital is expressed in units of tradable goods. Using firm's first order condition with respect to capital, one would observe that marginal cost of capital therefore would be its price times its Lagrangian multiplier (shadow price) λ_t^2. Marginal benefit of obtaining extra capital would be $\alpha P_{t+1}^{NT} A_t^{NT} (K_{t-1}^{NT})^{\alpha-1} (H_t^{NT})^{1-\alpha}$ plus its price at which it can be sold λ_{t+1}^2 and impact of additional capital on collateral $\lambda_{t+1}^2 \mu_{t+1} \eta_{t+1}$ as shown in first order condition for capital in (6.20). As the impulse responses show, a foreign price shock depreciates real exchange rate and makes collateral constraint more bind during the transmission process in response to rise in price of capital expressed in units tradable goods.

Furthermore as noted by in Schmitt-Grohe and Uribe (2017), the household's Euler equation shows the marginal cost of an additional unit of debt in period t payable in period $t+1$ is equivalent to the marginal utility derived from composite consumption in period $t+1$ discounted by the subjective discount factor and Lagrange multiplier for the sequential budget constraint ($\beta\lambda_{t+1}^{1}$) compared with marginal benefit of consumption in period t of $\lambda_t^1/(1+R_{t+1})$. Due to fall in cost of servicing of debt, marginal benefit rises whiles marginal cost falls.

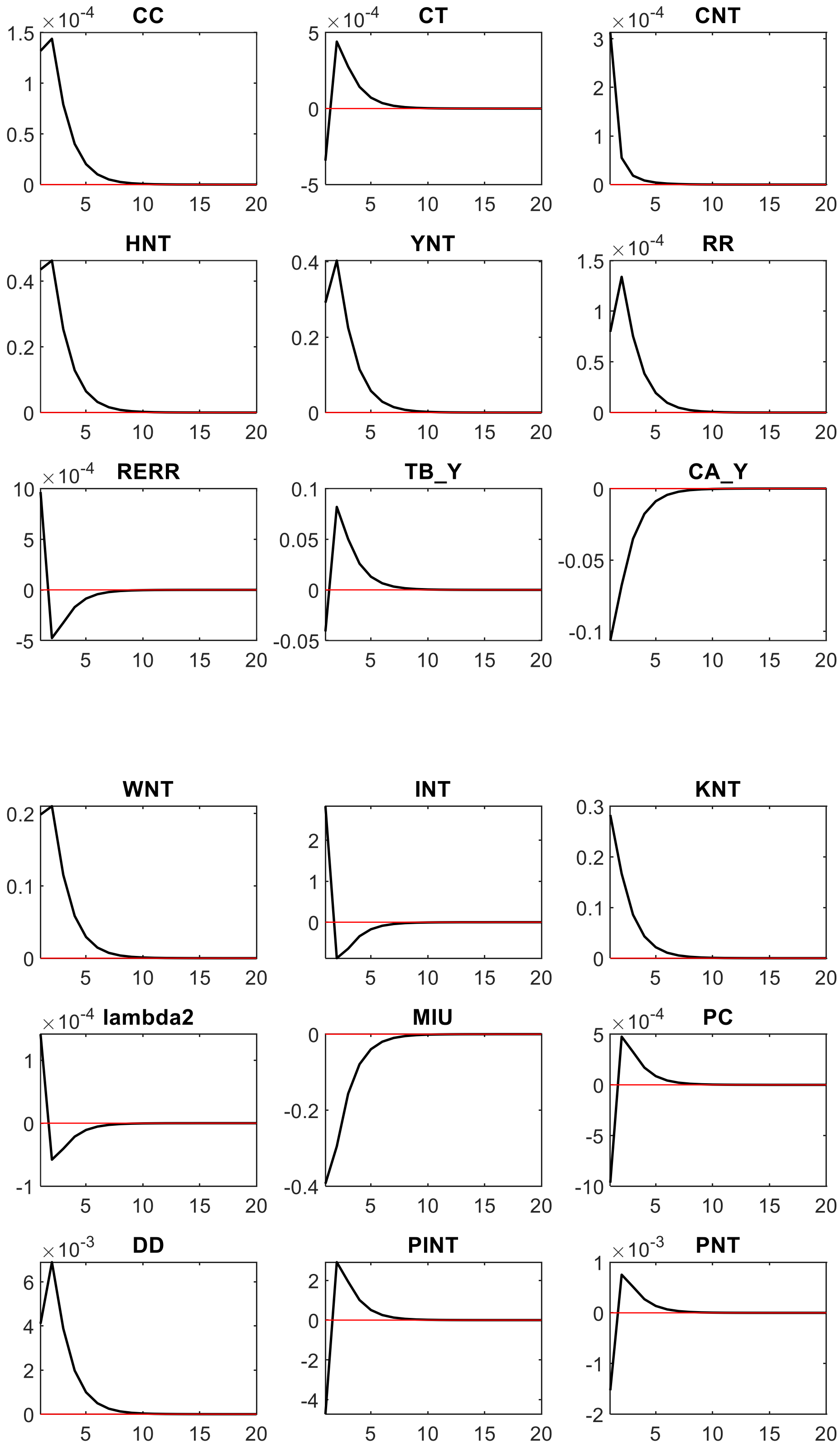


Figure 6.10:Impulse responses following 1% relaxation in borrowing limit

Figure 6.10 represent the effect of positive collateral constraint shock which increases firms borrowing capabilities. An increase in borrowing capacity (also known as loosening of financial conditions) has an expansionary effect on the economy. Such a loosening allows firms to borrow more and this temporarily brings the economy closer to efficient level of production, should there be no constraint. This direct result of borrowing ease is that it makes the collateral constraint less binding as shown by fall in μ_{t+1}. As noted in previous chapter, such a shock can be seen a decrease in discretionary taxes on labour income which allows firms to hire more labour leading to increase in hours and output in non-traded goods sector. Firms increased borrowing capacity also allows it to free more resources to increase its level of investment capital.

The expansionary effect on the economy feedbacks to domestic consumption via increase in demand for labour in non-traded sector which increases its output and profit. The expansionary effect feeds into household budget constraint in the form of higher profit handouts that increases their income. This increase both tradable and non-tradable consumption which increase the composite price index that leads to appreciation of currency and a minor increase in debt level.

6.6 Empirical Estimation

6.6.1 First Look at the Data

As noted in the introduction, this model will be tested using Maldivian data from 1976-2014. In order to estimate the model with the new variables introduced in this chapter, additional data is collected and compiled for the Maldivian economy. As data on these variables are not directly collected by relevant departments in the Maldives, data is computed from the available sources and based on the treatment used in literature.

The real exchange rate is measured as a ratio of foreign consumer price index to domestic consumer price index. As US Dollar dominates the Maldivian economy's foreign currency composition, the consumer price index of United States is used as the foreign price index. The traded and non-traded output share are computed using the Maldives Supply and Use table. In the Maldives, the estimation of GDP is done based on sectoral output presented in the form of a supply and use table. This supply and use table breakdown each sector into distinct subsectors which are then used as the basis to categorise relevant subsector within each sector is either traded goods sector or non-traded sector. The categorization of sectors into traded and non-traded are done based on the classification used in AMECO[27] database. Based on the awarded classification, output share for each sector is calculated for each year. Appendix 6.1 shows the categorization applied to the supply and use table to extract traded and non-traded component of output.

6.6.2 Bayesian Estimation

The baseline model is estimated using Bayesian method in Dynare. An introduction to Bayesian estimation is provided in Chapter 4. For the purpose of estimation, I use Maldivian annual data from 1976-2014 for four observed variables: non-traded sectors output, total factor productivity, composite consumption and foreign composite price index. In this model there are four structural shocks all of which follows AR(1) process. All series are in logarithm. Following literature by Born and Pfeifer (2014) and Jiang (2016) all series are filtered using HP filter to ensure that each series has a zero mean.

6.6.2.1 Calibration and priors

A number of parameters are estimated using Bayesian technique. The choice of parameters to estimate is based on identification test and requirement of the model. More specifically the initial selection of parameters is based on its role in governing the business cycle. The parameters that are not estimated will take the calibrated values in Table 6.2.

The prior distribution of estimated parameters is reported in Table 6.3. The choice of prior distribution are in line with the literature on real business cycle models. More specifically these follow the values used in similar models such as Notz and Rosenkranz

[27] The AMECO database classifies A_E, G_I (agriculture and fishing, mining and utilities, manufacturing, trade, hotels, communications) as traded sector, while sectors listed in F, J_P (construction, finance and business services, market services, other service activities) are considered as non-traded goods sector.

(2021). As a general principal, the prior distributions follows the more establish studies such as Negro and Schorfheide (2012). The persistence coefficient of the AR(1) processes follows a beta distribution with mean of 0.80 and standard deviation of 0.05. The deep parameter for relative risk aversion follows a normal distribution with prior mean of 1.50 and standard deviation of 0.3750.

6.6.2.2 Identification and estimation

Parameter identification is a key requirement prior to model being taken into data. The parameter identification exercise establishes the informativeness of different estimators and their effectiveness when once uses the model for policy recommendation. Identification is important as it enable the researcher to rule out a flat likelihood at the local point. In Dynare model identification using the principles outlined by Iskrev (2010b) and Ratto and Iskrev (2011) are carried out using identification command. The identification results are presented in Figure 6.11 and Figure 6.12. Figure 6.11 shows identification plots for each parameter at their prior mean of the model. The large bars in absolute values indicates the identification strength at respective prior mean. The upper panel depicts the identification strengths normalized for each parameter either at their prior mean (blue bars) or by the standard deviation at the prior mean (red bars). If the identification bar is different from zero, depending on the strength it adds curvature to the likelihood function. The lower panel is the sensitivity plot which further decomposes further the effects shown in top panel. It shows the changes in likelihood with respect to each parameter. As one can see from the figure, the identification of parameters is well placed in its influence on the likelihood function. Figure 6.12 on identification shows the aggregate sensitivity of changes in parameter's prior vector on model moments.

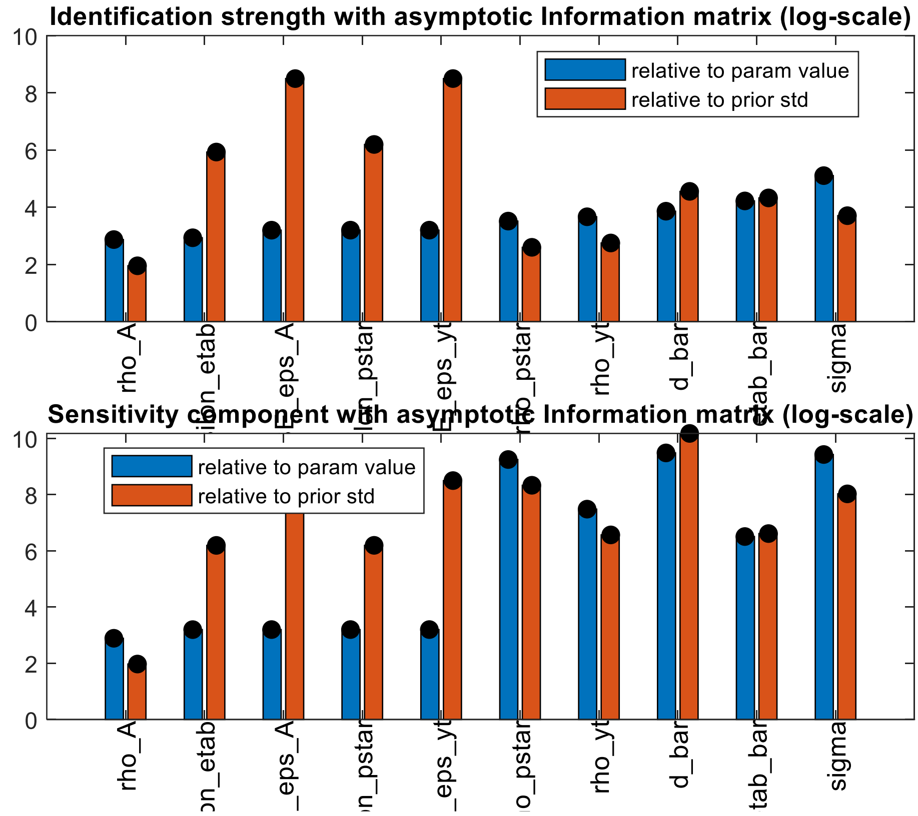


Figure 6.11: Parameter identification

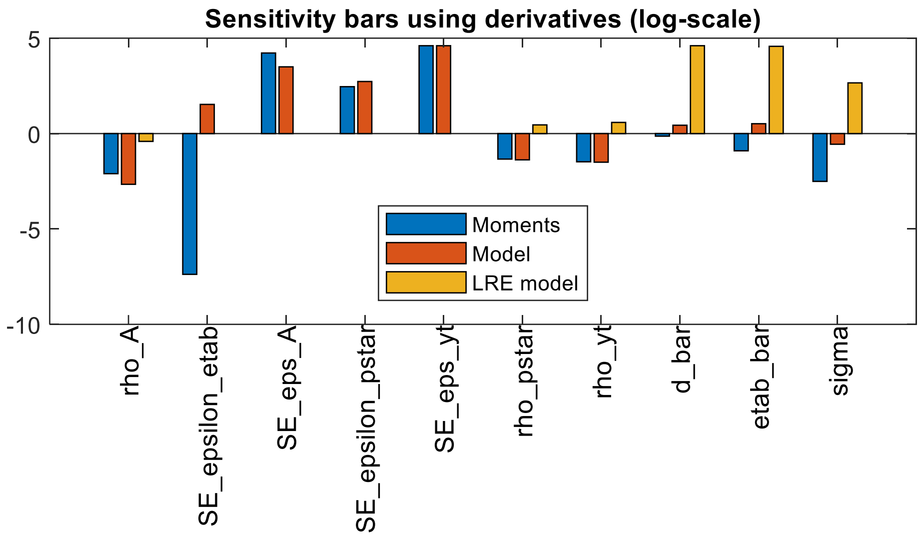


Figure 6.12:Identification: Sensitivity Plots

The posterior modes are generated using Dynare's Monte-Carlo optimization routine. Metropolis-Hastings (MH) algorithm is used to obtain a sample from posterior distribution. The covariance matrix is adjusted using scale parameter in the jump distribution in order to obtain an acceptance ratio of 25%-35%. For MH two parallel Markov chains of 1,000,000 draws are run at run from the posterior kernel with 20% of the draws being discarded.

Appendix 6.3 reports the mode check plots for all parameters estimated in this model. Mode check plot computes log of the posterior kernel and of the log likelihood as a function of each respective parameter, keeping the other parameters constant. This plot therefore allows me to understand the informativeness of priors where if there are differences in shape between likelihood kernel and the posterior likelihood indicates the prior is informative and is able to influence the curvature of the likelihood function. Ideally if the estimated mode should be around the maximum of the posterior likelihood function. As shown in Appendix 6.3, all modes are coincide to the highest peak of the likelihood function.

As part of estimation Brooks and Gelman (1998) convergence diagnostics are produced which is based on the comparison between pooled and within chain variation of MCMC draws through interval statistics around mean, second and third moments. While the univariate convergence diagnostic follows Brooks and Gelman (1998), the multivariate convergence diagnostic applies these principles to range of the posterior likelihood function. Both the univariate and multivariate convergence diagnostics are reported in Appendix 6.2. As noted in Chapter 4, the Brook and Gelman (1998) plots are eyeballing exercise. Therefore, to produce more reliable necessary condition for convergence, I have produced Geweke (1992) Convergence Tests and Raftery and Lewis (1992) convergence diagnostics in Table 6.3 and Table 6.4.

Geweke (1992) Convergence Tests, based on means of draws 200000 to 352000 vs 592000 to 1000000.
(p-values are for Chi2-test for equality of means)

Parameter	Post. Mean	Post. Std	p-val No Taper	p-val 4% Taper	p-val 7% Taper	p-val 15% Taper
σ	2.000	0.318	0.302	0.983	0.850	0.851
ξ	0.280	0.008	0.000	0.564	0.584	0.896
D/Y	1.798	0.270	0.000	0.697	0.692	0.653
ρ_{PC*}	0.982	0.001	0.202	0.839	0.832	0.803
ρ_{YT}	0.957	0.010	0.210	0.925	0.911	0.896
ρ_A	0.894	0.024	0.000	0.769	0.753	0.690
σ_A^2	2.112	0.251	0.000	0.169	0.172	0.149
σ_{PC*}^2	0.040	0.005	0.000	0.247	0.256	0.202
σ_{YT}^2	0.076	0.010	0.000	0.351	0.311	0.208
σ_ξ^2	10.104	1.550	0.000	0.834	0.858	0.879

Table 6.3: Geweke (1992) Convergence Tests

As shown in Table 6.3, at 15% Taper (the highest level of correction for autocorrelation), we cannot reject the null hypothesis indicating all the chains comes from the same distribution. This therefore implies MCMC achieves convergence.

Parameters	M (burn-in)	N (req. draws)	N+M (total draws)	k (thinning)
σ	536	141355	141891	85
ξ	563	149076	149639	101
D/Y	1721	456456	458177	182
ρ_{PC*}	164	42390	42554	30
ρ_{YT}	192	53707	53899	43
ρ_A	1014	252558	253572	162
σ_A^2	131	35351	35482	29
σ_{PC*}^2	48	13200	13248	10
σ_{YT}^2	54	15750	15804	14
σ_ξ^2	272	72600	72872	60
Max	1721	456456	458177	182

(test is based on quantile q=0.025 with precision r=0.010 with probability s=0.950)

Table 6.4: Raftery and Lewis (1992) Convergence Diagnostics

The Raftery and Lewis (1992) shown in Table 6.4 shows that the number of required draws for any variable at maximum is 456,456. As each chain has a draw of 1,000,000 with 20% discarded, the number of draws used in estimation is within the required number of draws set by Raftery and Lewis (1992). All these convergence tests are done on a single chain. Dynare does not report results for multiple chains. If we achieve convergence on a single chain, it is certain the second chain of the same size will result in similar convergence.

The results of Metropolis-Hastings (MH) Monte Carlo algorithm for the full estimation with two chains are reported in Table 6.5. For control and model comparison purposes, I also estimated the dollarization model presented in this chapter after shutting down the collateral constraint. As the control model is nested model, comparison can be easily made to establish the better fit. Koop (2003, p.4) states that two model does not have to nested or have the same parameters for one to be able to make comparison. With Bayesian estimation two models which have different estimated parameters can be compared as there is a natural degrees of freedom correction. Table 6.5 presents the relevant diagnostics for the full model and restricted model without collateral constraint.

Log data density (Laplace approximation) – With borrowing constraint				-29.801212
Log data density (Laplace approximation) – Without borrowing constraint				-43.857317
MCMC Inefficiency Factor Per Block				
	Full model with borrowing constraint		Full model without borrowing constraint	
	Chain 1	Chain 2	Chain 1	Chain 2
Acceptance ratio	29.1473%	29.1376%	32.7579%	32.4820%
	Block 1	Block 2	Block 1	Block 2
σ	351.104	335.194	339.108	351.350
ξ	287.639	303.035	-	-
D/Y	616.572	622.279	658.638	694.639
ρ_{PC*}	72.101	77.472	309.920	277.469
ρ_{YT}	87.646	94.907	18.571	21.142
ρ_A	350.630	335.194	416.208	425.217
σ_A^2	159.315	152.564	278.810	290.171

σ^2_{PC*}	45.343	43.656	243.593	236.557
σ^2_{YT}	46.803	46.335	103.787	111.806
σ^2_{ξ}	278.715	283.338	-	-

Table 6.5: MH algorithm diagnostics

The estimated results for the full model are presented in Table 6.6 in the final column. A full discussion on the results are provided in section 6.63.

Parameters	Prior Distribution	Prior mean (SD)	Posterior mean and 90% highest posterior density interval
Relative Risk Aversion, σ	Normal	1.50 (0.2163)	2.2704 [2.2257 2.3136]
Borrowing limit at steady-state, ξ	Normal	0.01 (0.0074)	0.1357 [0.1330 0.1391]
Steady state debt-output $\frac{D}{Y}$	Gamma	0.20 (0.40)	0.4098 [0.4020 0.4182]
Autocorrelation of technology shock, ρ_A	Beta	0.80 (0.0152)	0.5546[0.5524 0.5566]
Autocorrelation of foreign price shock , ρ_{PC*}	Beta	0.80 (0.0058)	0.6043 [0.6030 0.6059]
Autocorrelation of traded good sector endowment shock, ρ_{YT}	Beta	0.80 (0.0091)	0.6107 [0.6064 0.6163]
SD of technology, σ_A	Inv Gamma	0.01 (0.1988)	0.6130 [0.5302 0.6967]
SD of foreign prices, σ_{PC*}	Inv Gamma	0.01 (0.0530)	0.5006 [0.4978 0.5039]
SD of borrowing, σ_η	Inv Gamma	0.01 (1.9889)	5.8634 [5.4834 0.2566]
SD of endowment, σ_{YT}	Inv Gamma	0.01 (0.0107)	0.4813 [0.4722 0.4898]

Table 6.6: Priors and posteriors

6.6.3 Estimation Results

The fourth column of Table 6.4 reports the results through posterior mean, and corresponding 90% Highest Posterior Density (HPD) intervals using MH algorithm. The results are very informative in terms of shock processes and deep parameters in the model.

Firstly, autocorrelation parameters of all shocks are highly persistent and similar to those reported in RBC models. The persistence of endowment shock ρ_{YT} and foreign price shock ρ_{PC*} are among the highest. This result should not be surprising for the Maldives. As country Maldives economy relies on tourism income and therefore any changes to tourism demand can trigger series of chained macroeconomic events that would impact the economic health of the economy. At the same time, as the Maldives is heavily dependent on imports for its survival, any changes in foreign price level would directly impact the cost of living domestically creating macroeconomic implications. The estimated mean for standard of shocks is at reasonable levels except for the standard deviation of borrowing shock σ_{η}. Among these estimates, the next most volatile estimate is the technology shock. The higher persistence and lower standard deviation for endowment and foreign price shock implies these two over the long horizon drives the business cycle of the Maldives.

The estimates for behavioural parameters relative risk aversion investment adjustment cost, long run debt to output and long run borrowing limit falls within the acceptable estimates in literature. Exception is consumption share of traded good parameter and this may be due to either prior or data not being informative.

6.6.3.1 Models Fit

The goodness of fit of the model is established through two different ways. They are done either by comparing log densities of competing models or by comparing model moments with data. In this section I will be establishing model's fit by comparing theoretical moments with the moments from the data. The results of posterior mean-based moments and the benchmark moments from data are presented in Table 6.7. I have also estimated the model without credit constraint to establish the extent to which a non-binding credit constraint economy's result differ from the one presented here.

x = variable	Maldivian Data (1977-2014)			With Borrowing Constraint $\sigma = 2$; $\emptyset_X = 0.005$; $\omega = 1.7$ $\mu = 0.097$; $\psi = 0.007$			Without Borrowing Constraint $\sigma = 2$; $\emptyset_X = 0.005$; $\omega = 1.7$ $\mu = 0.097$; $\psi = 0.007$		
	$\%\sigma_x$	$\rho_{xt,GDP}$	$\rho_{x,t}, \rho_{x,t-}$	$\%\sigma_x$	$\rho_{xt,GD}$	$\rho_{x,t}, \rho_{x,}$	$\%\sigma_x$	$\rho_{xt,GDP,}$	$\rho_{x,t}, \rho_{x,t-}$
Consumption	0.60	0.53	0.58	0.29	0.60	0.39	0.04	0.72	0.55
Real Exchange Rate	0.07	0.15	0.59	0.32	0.31	0.28	0.10	0.19	0.47
Non-traded Output	0.07	1	0.25	4.45	1	0.60	3.08	1	0.48
CA/Y ratio	0.61	-0.07	0.55	1.52	-0.07	0.33	25.82	-0.39	0.46
TB/Y ratio	0.65	-0.24	0.45	1.20	-0.84	0.61	7.41	-0.04	0.35
Real Interest Rate[28]				0.09	0.90	0.62	0.03	0.36	0.53

Table 6.7: Moments comparison: posterior predictive analysis

As shown in Table 6.7, the posterior moments are less successful in matching the standard deviation observed in data. The final three columns in Table 6.7 shows the moments for the restricted model. In the full model with borrowing constraint, except for composite consumption, all the other standard deviations estimates are higher than what is observed in data. Similar results are arrived for the restricted model without borrowing constraint. Inability to empirically obtain the volatility of the real variables as observed in data is a known problem in DSGE models. The volatility of the variables in estimated model can often be driven by the assumptions made in behavioural parameters. At the same time as quality of the data gathered for the Maldivian economy can be questioned due to approaches used by government agencies in data collection, the data may not be rich enough to capture the true moments. Furthermore, the size of

[28] Real interest data for the Maldives is available from 1996 onwards. As rest of the aggregates are collected from 1977-2014, the available series cannot be used to make comparisons hence are not reported. Table 5.1 provides the correlation between output and real interest rate for the Maldives between 1996-2021.

the data set can lead to inconsistent estimates. In the full model, the cross correlation estimate between consumption and non-traded output and current account and non-traded output matches the data while all the other estimates are significantly different to actual predictions from data. Both models can replicate the observed counter cyclicality of trade balance and current account. The model with borrowing constraint is more successful in matching the persistence of the real variables with data. Except for persistence of non-traded output, all the other estimates are in the neighbourhood of the regularities predicted by the data. Bayesian impulse responses based on the estimated and calibrated values are shown in Appendix 6.4 for each respective shock. The impulse responses are similar to those presented in Section 6.5.

In the model without collateral constraint, the cross correlation is not as closely matched with the data. The model however can match the volatility of real exchange rate with the data and predict the counter cyclical external balances. Despite this success, the model without collateral constraint provides estimates for current account and trade balance to output ratio which are much larger compared with the benchmark model. The reason for over-volatility of the external balance is for technical reasons than model driven reason. As noted in previous chapters, one way to reduce excess volatility of external balances is through friction parameters such as investment adjustment cost parameter or debt-elastic interest rate parameter. The financial friction parameter in this model ξ plays a similar role where in addition translating the financial friction in the economy, ξ governs the volatility of external balances. When the model is estimated without the borrowing constraint where $\xi = 0$, this increases volatility of external balances as other parameters is not adjusted to maintain the volatility of external balances.

The results from the model without borrowing constraint shows that all the volatilities except composite consumption are much higher compared with the model with financial friction. In terms of persistence, the dollarized economy without financial friction can produce a closer match than the original model for most indicators except the non-traded output. It can also be seen that restricted model is able to match the moments for real exchange rate closely with the data. An important finding of this paper is real exchange rate and output has a positive correlation under both the setup. This is consistent with empirical work by Rothert (2020) who found that for a sample of 21 EMEs the correlation between output and real exchange rate is positive. This is however mildly countercyclical for developed countries making the procyclicality of RER and output a specific feature of EMEs. As the non-traded sector growth in EMEs are linked to traded sector, an increase in output will expand non-traded sector and its prices which can result in appreciation of real exchange rate.

The model comparison based on log densities (Laplace) in Table 6.5 shows that the full model with financial friction and dollarization is a better fit to the data than the restricted model. This evidence that dollarization does explain saliant features of Maldivian business cycle. The results from Table 6.4 also signals the importance of financial friction through collateral constraint in explaining business cycle.

6.7. Conclusion

The results presented in this chapter shows that tradable sector and real exchange rate are key drivers of business cycle in the Maldives. The modelling framework shows that a model with liability dollarization (analogous to deposit dollarization) does explain the salient features of the Maldivian business cycle. The specific role of real exchange rate in driving business cycle for the Maldives is a corollary of its fragile economic structure involving limited productive resources. As a result of this, Maldives relies heavily on foreign imports for consumption which increases its exposure to real exchange rate shocks.

The importance of real exchange rate combined with the tourism sector output, as evidence from data drives the Maldivian business cycle. This result therefore can be generalized into other small open economies with similar characteristics as the Maldives. However, one should note as documented by Uribe and Schmitt-Grohe (2017) that due to variation in characteristics of EME, generalisation of results should be done with caution.

In the context of the Maldives, the overreliance of tourism sector for economic growth and rest of the world for consumption makes the country an interesting case study. While the heavy dollarization reduces policy maker's ability to exercise monetary policy in full, the US dollar revenue also ensures the central bank has adequate reserve to maintain the manage floating exchange rate and intervene in the foreign exchange market to ensure international trade remains uninterrupted. The growth in tourism also local residents to utilise their dollarize earning to spend on development of other sectors by investing heavily in infrastructure and local tourism. This therefore creates downstream effects where in addition to increase in employment and income due to expansion of other sectors, it also improves domestic economy's fundamentals which will allow for de-dollarization in the future and establish a fairer foreign currency market which will cater the country's need to use foreign exchange for essential and non-essential consumption from rest of the world. These backward and forward linkages therefore will strengthen the Maldivian economy provided sufficient expansion and diversification of other industries occur.

One of the limitations of this study, including empirical results presented in this thesis is associated with the data limitation. As the data that has been collated from various sources, combined with frequent changes in measurement raises questions on the richness and accuracy of the data. Such issues are prevalent for many economies in South Asia. Nevertheless, the results do point to the relevant patters one would expect from the literature and provide deep insight into economies that have similar characteristics as the Maldives in terms of its business cycle properties.

Appendix 6.1: Classification of Maldivian Industry into traded and non-traded sectors

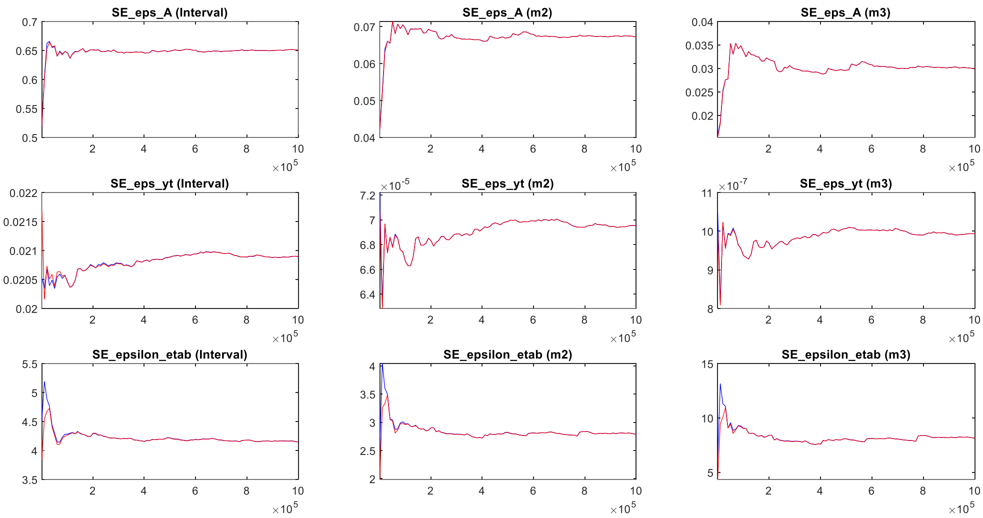
Classification of activities in each sectors of Maldives into traded goods and non-traded goods sector based on conventional AMECO classification.

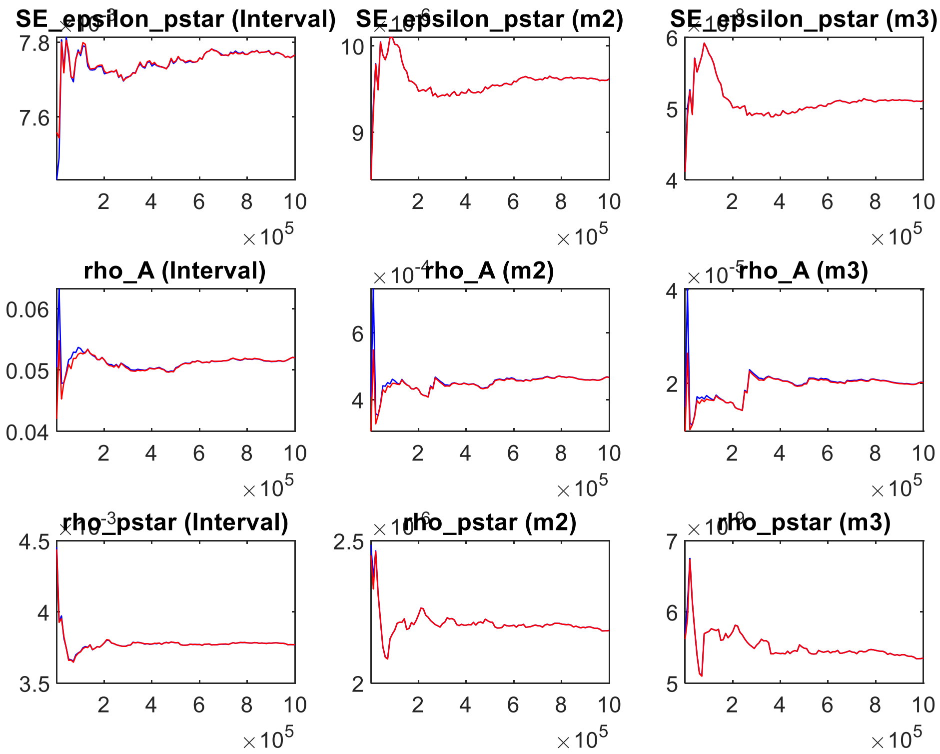
ISIC	Industry / Economic Activity	Sectoral Classification
	Primary	
A	Agriculture	Traded
A	Fisheries	
	Secondary	
C	Manufacturing	
C	Fish preparation	Traded
C	Other manufacturing products	
	Electricity and water	
D	Electricity	Non-traded
E	Water & sewerage	
F	Construction	Non-traded
Tertiary		
G	Wholesale and retail trade	
	Tourism	Traded
I	Resorts	
I	Other accomodation services	
I	Food and beverage services	Non-traded
	Transportation and communication	Non-traded

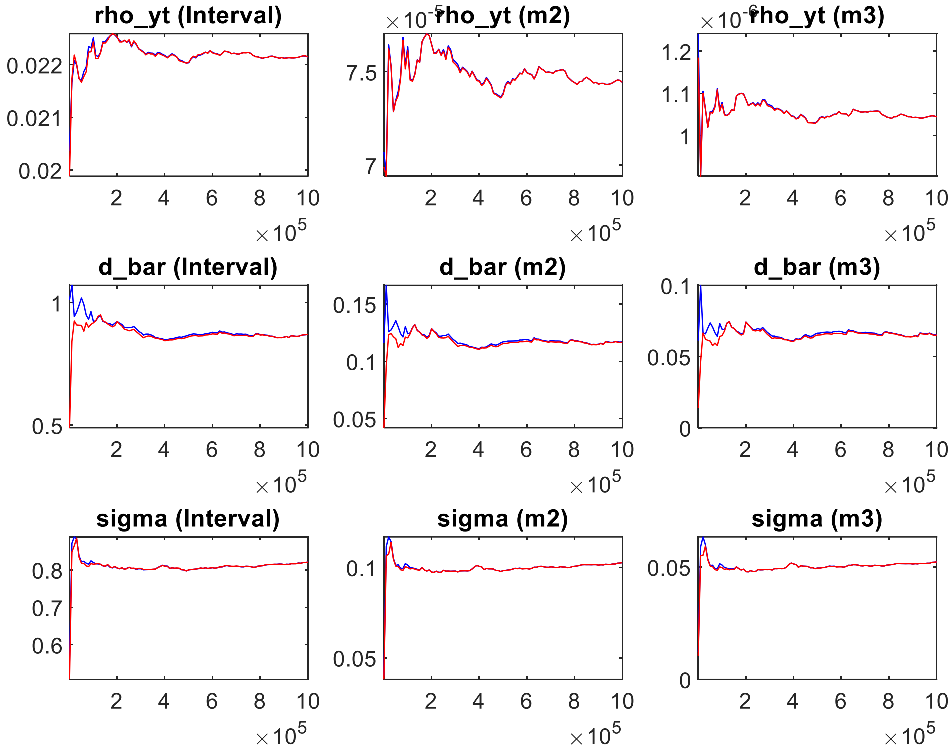
H	Transportation	
N	Travel agencies and support services	
H	Postal and Telecommunication	
	Financial services	
K	Financial intermediation	Non-traded
K	Insurance and auxiliary to financial intermediation	
L	Real Estate	Non-traded
M	Professional, scientific and technical activities	Non-traded
O	Public administration	Non-traded
P	Education	Non-traded
Q	Human health and social work activities	Non-traded
R & S	Entertainment, recreation & Other services	Non-traded

Appendix 6.2: convergence diagnostics

Brooks and Gelman (1998) univariate convergence



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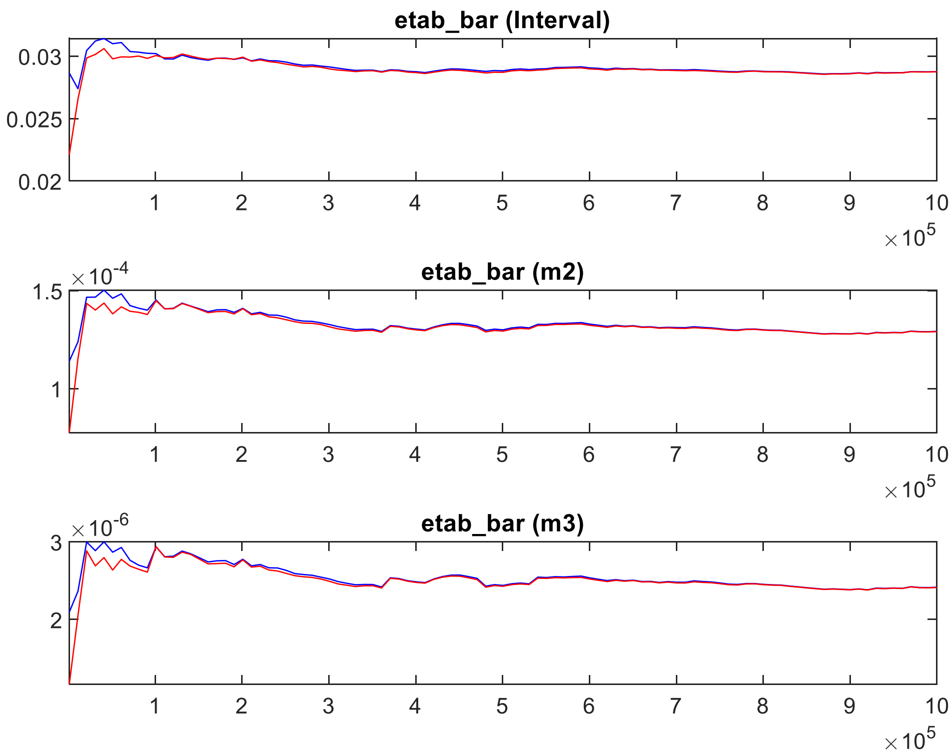
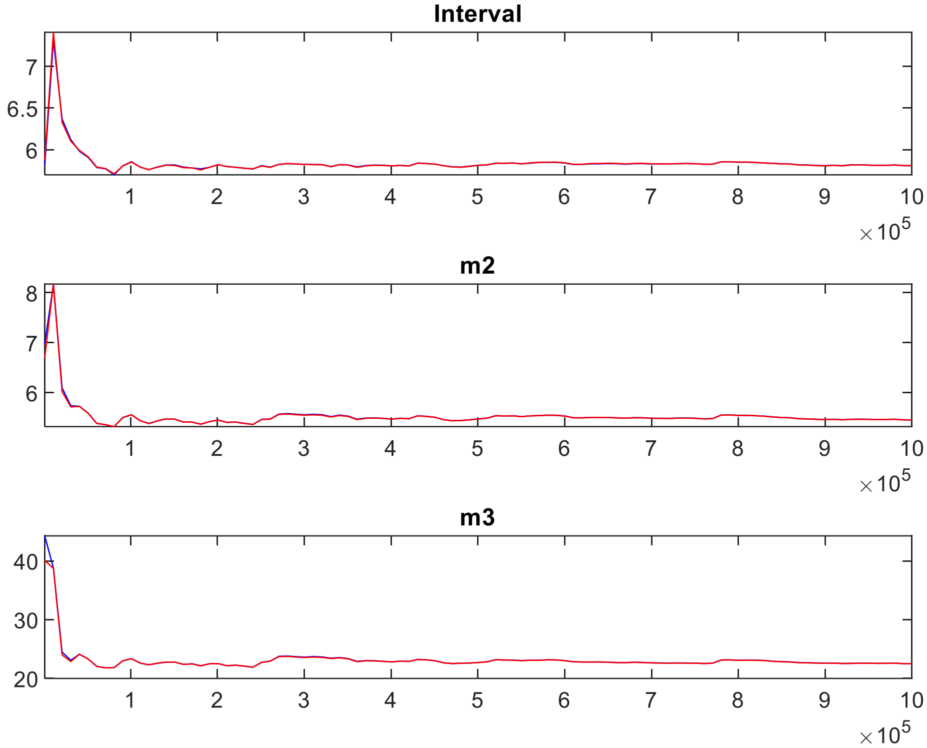
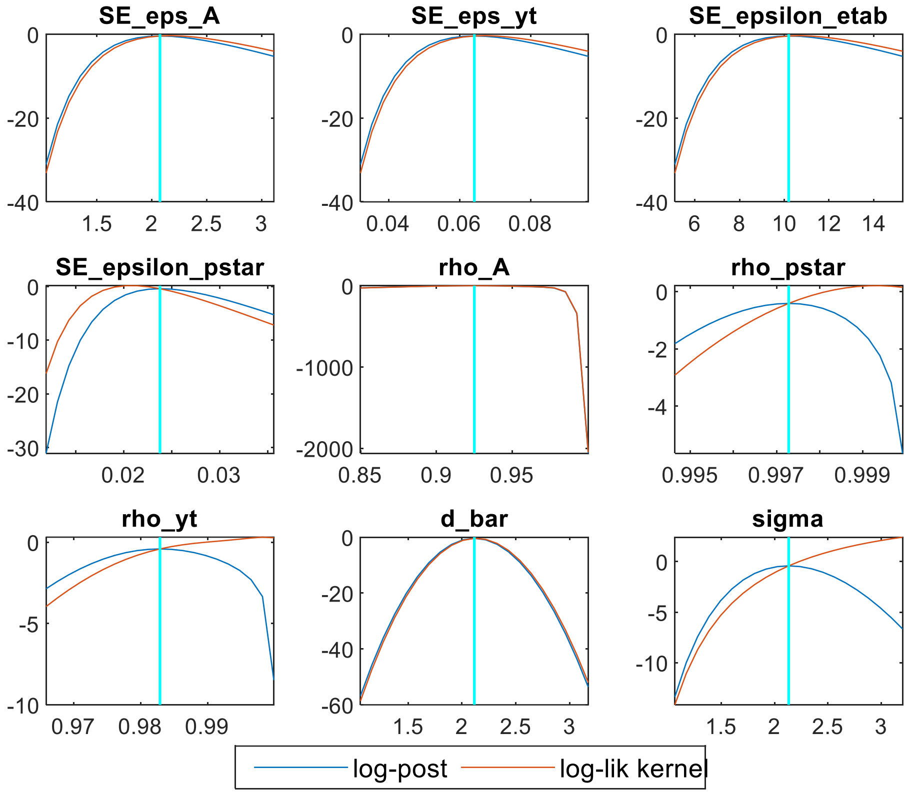
rho_yt (m2)
rho_yt (m3)
d_bar (Interval)
d_bar (m2)
d_bar (m3)
sigma (Interval)
sigma (m2)
sigma (m3)

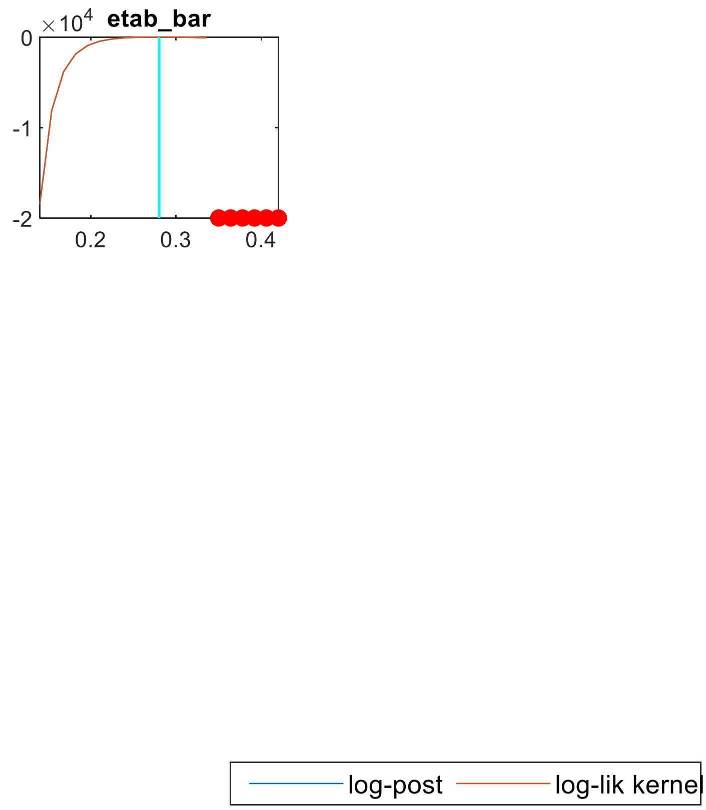

etab_bar (Interval)
etab_bar (m2)
etab_bar (m3)

Brooks and Gelman (1998) multivariate convergence



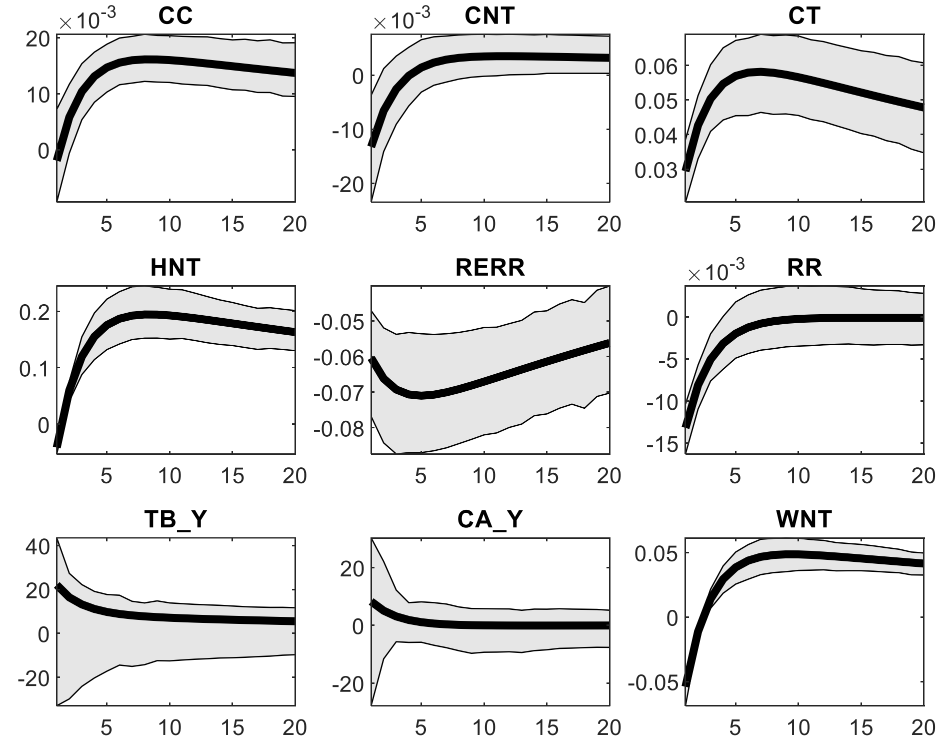
Appendix 6.3: Mode check Plots

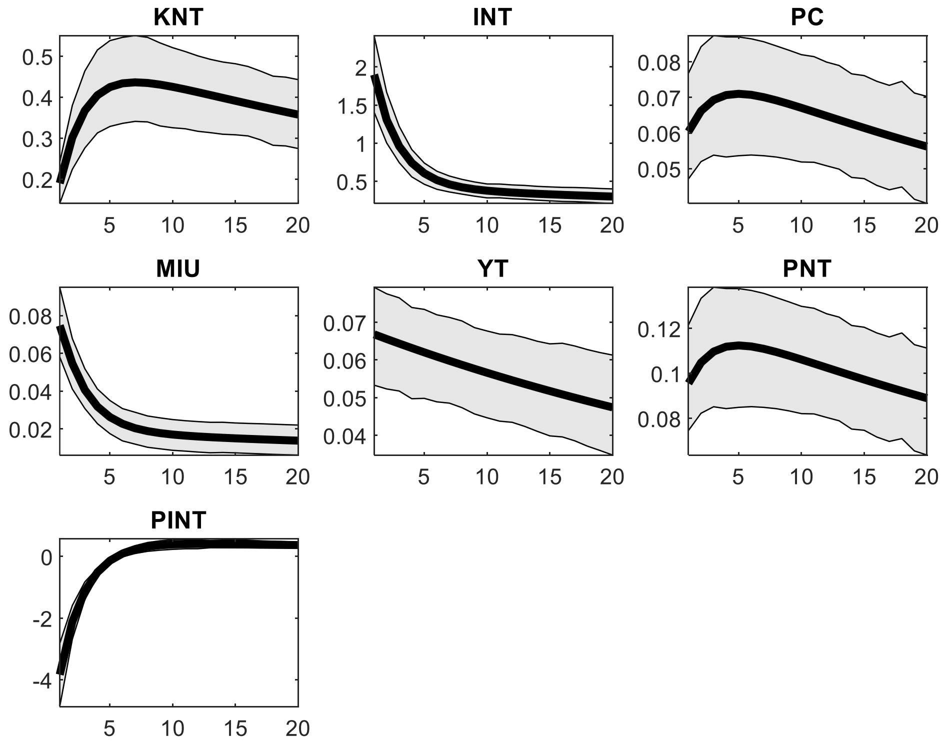




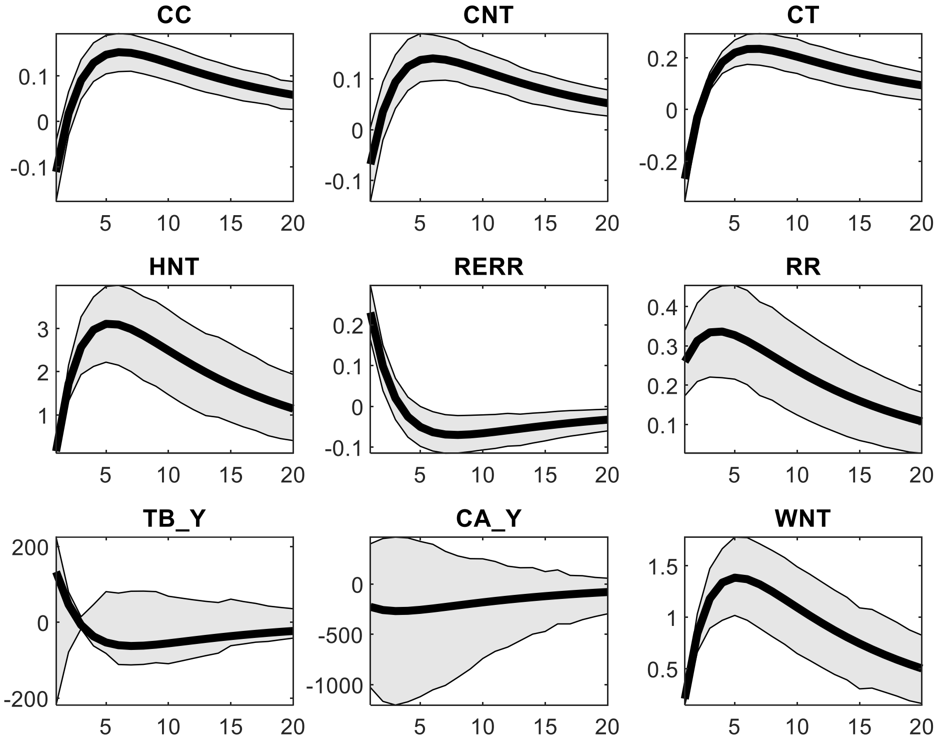
Appendix 6.4: Bayesian Impulse response functions

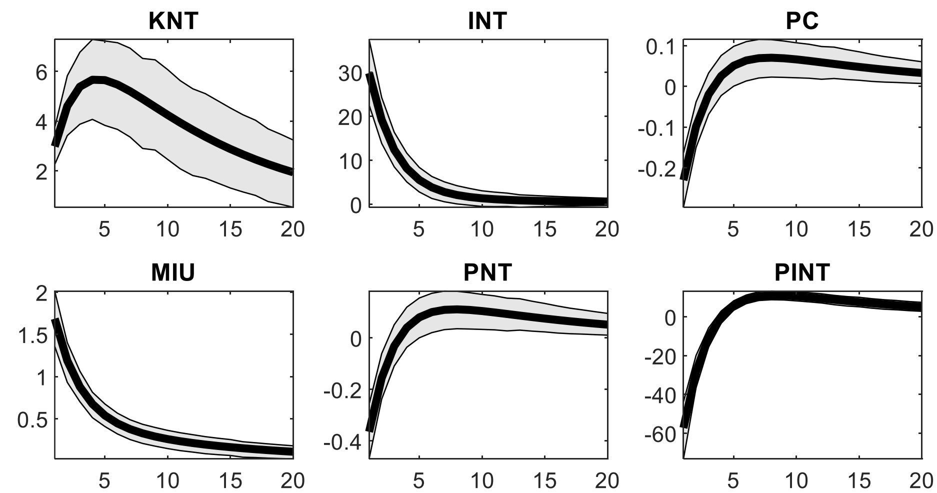
A6.4.1 Impulse responses following endowment shock



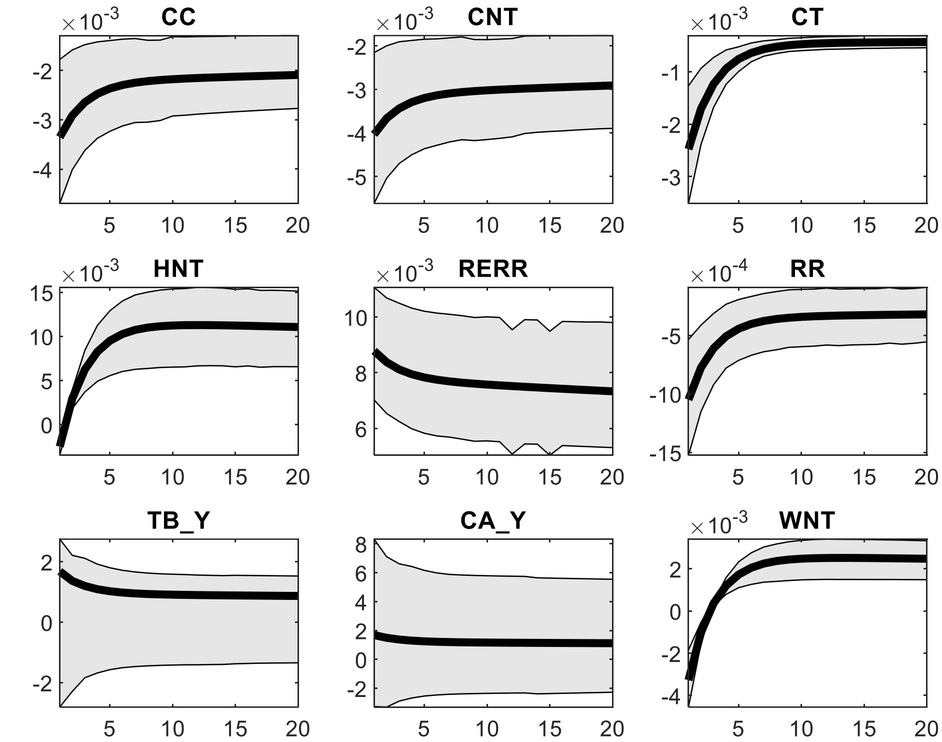


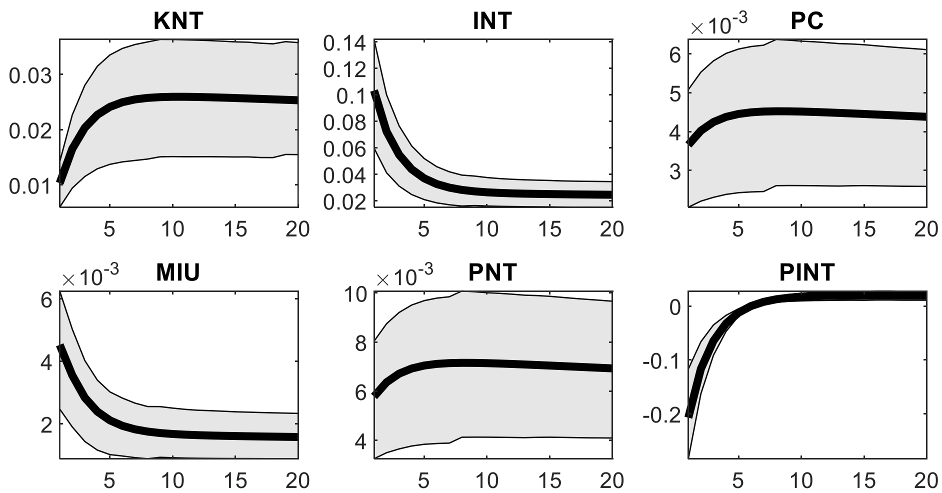
A6.4.2 Impulse responses following technology shock in non-traded sector



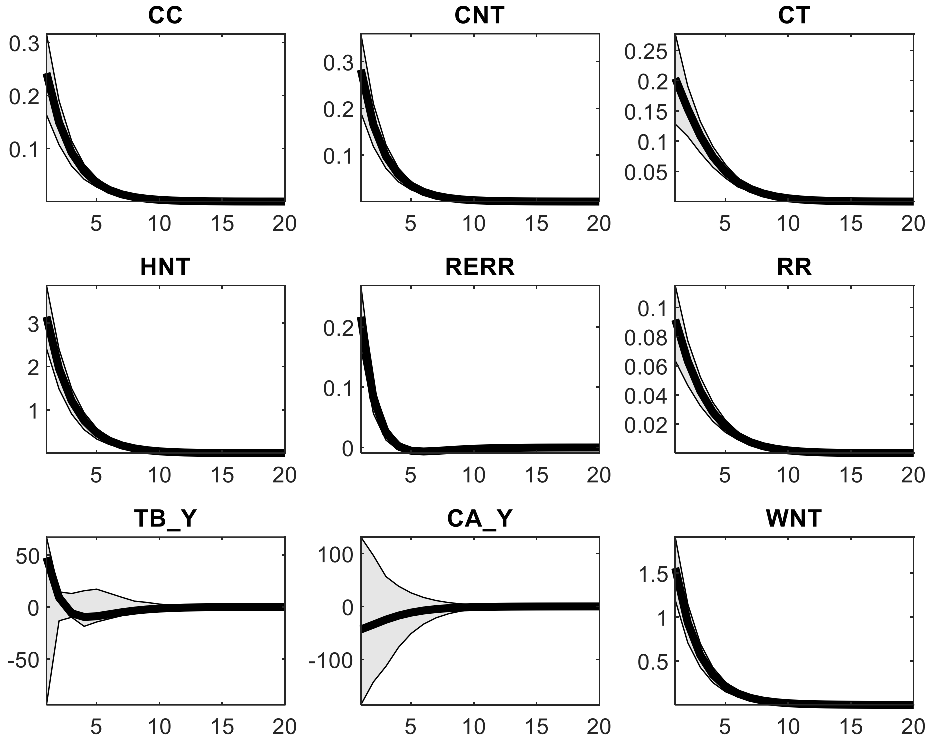


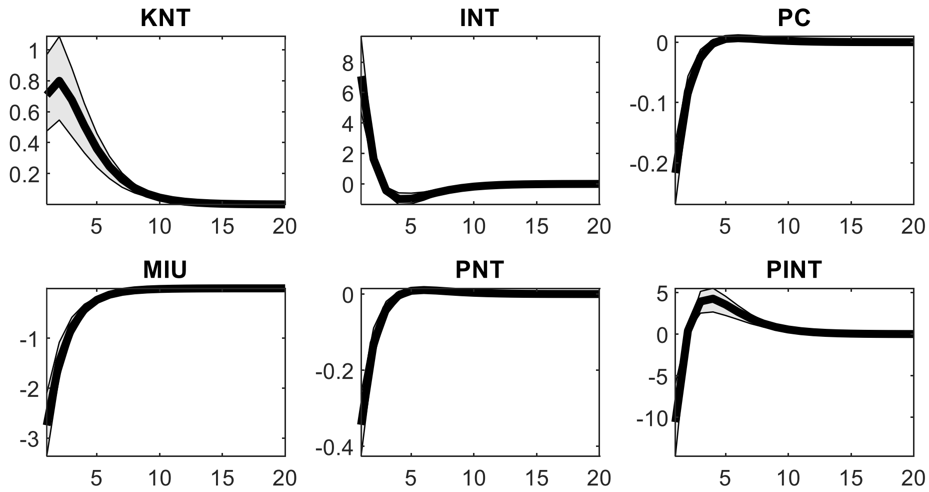
A6.4.3 Impulse responses following foreign price shock





A6.4.4 Impulse responses following financial friction shock





Appendix 6.5: Dynare Code

```
var lambda c hnt wnt pc d r pi_nt pnt Ant knt lambda2 int ynt ct cnt RER pc_star tb_y
ca_y y yt miuu etab DD CC CNT CT HNT YNT RERR RR YY TB_Y CA_Y WNT KNT INT PC
MIU YT PNT PINT;

varexo eps_A epsilon_etab epsilon_pstar eps_yt;

parameters
omegant
sigma
beta
yt_bar
r_star
alpha
delta
phi_x
rhoc
rho_tot
pi %% sensitivity of TOT shock
rho_A
pnt_bar %% steady-state price of NT
tot_bar %%steady-state price tot
ht_bar %% steady-state hours of tradables
hnt_bar %%steady-state hours of non-tradables
d_bar %%steady-state debt
```

```
eta

etab_bar %%fraction of capital that can be borrowed

thetah %% fraction of working capital relambda2uired

rho_etab

sigma_etab

rho_yt

rho_pstar

sigma_pstar

psi;


omegant=1.455;

sigma=2.0;

beta=0;

yt_bar=1;

r_star=0.05;

alpha=0.33;

delta=0.10;

phi_x=0.0005;

rhoc=0.205;

pi=0.5; %% sensitivity of TOT shock

rho_A=0.60;

pnt_bar=0.13472; %% steady-state price of NT 0.248834

tot_bar=1; %%steady-state price tot

ht_bar=0.165;
```

```
hnt_bar=0.165;

d_bar=0.30;

eta=0.3208;

psi=0.00742;

etab_bar = 0.07;

thetah=1;

rho_etab=0.50;

sigma_etab=0.5;

rho_pstar=0.6;

sigma_pstar=0.5;

rho_yt=0.6;


model;


%1. HH Optimality condition c                    Elambda2 1


pc*lambda = (c- (  (hnt^omegant)/omegant ))^(-sigma) ;




%2. HH Optimality condition hours worked in non-tradable sector      Elambda2 2



%3. HH Optimality condition d                    Elambda2 3
```

lambda = beta * (1+r(+1)) * (lambda(+1) * (RER/RER(+1)));

%4. HH Optimality condition wrt lambda Elambda2 4

((d*(1+r))/RER)+pc*c=(d(+1)/RER)+yt+pnt*wnt*hnt+pi_nt;

%5. Firm Optimality condition wrt hnt Elambda2 5

(1-alpha)*Ant*(knt(-1))^(alpha)*hnt^(-alpha)=wnt*(1+thetah*((r(-1)-1)+miuu));

%6. Firm Optimality condition wrt knt Elambda2 6

lambda2=(beta*lambda(+1)/lambda)*((alpha*pnt*Ant(+1)*(knt)^(alpha-1)*(hnt(+1))^(1-alpha))+lambda2*((1-delta)+(miuu(+1)*etab(+1))+phi_x*((int(+1)/knt)-delta)*((int(+1)/knt))-(phi_x/2)*((int(+1)/knt)-delta)^2));

%% lambda2=(beta*lambda(+1)/lambda)*(rknt(+1)+lambda2(+1)*((1-delta)+phi_x*((int(+1)/knt)-delta)*((int(+1)/knt))-(phi_x/2)*((int(+1)/knt)-delta)^2));

%7. Firm Optimality condition wrt int Elambda2 7

1=lambda2*(1-phi_x*((int/knt(-1))-delta));

%8. Firm Optimality condition wrt lambda2 (motion of capital) Elambda2 8

knt=int+(1-delta)*knt(-1)-(phi_x/2)*((int/knt(-1))-delta)^2*knt(-1);

```
%9. interest rate                    Elambda2 9

    r = r_star + psi*(exp(((d-d_bar)/RER))-1);


%10. production function non-tradable sector        Elambda2 10


    ynt = Ant*knt(-1)^(alpha)*(hnt)^(1-alpha);


%11. composite consumption function        Elambda2 11

   c=(rhoc*ct^(-eta)+(1-rhoc)*cnt^(-eta))^(-1/eta);



%12. Real Exchange rate                        Elambda2 13


    RER = pc_star/pc;




%13. technology shock to NT sector

log(Ant) = log(Ant(-1))*rho_A +eps_A ;


%14. endownment shock

log(yt) = log(yt(-1))*rho_yt +eps_yt;


%15. prince index pc Elambda2. 16
```

```
pc=(rhoc^(1/(1+eta))+(1-rhoc)^(1/(1+eta))*pnt^(eta/(1+eta)))^((1+eta)/eta);

%.16 price of non-tradable goods Elambda2. 17
%%pnt=(rhoc/(1-rhoc))*((ct/cnt)^(eta+1));

%17. consumption of non-tradables Elambda2.18
cnt=(1-rhoc)*((pc/pnt)^eta)*c;

%%18. consumption of tradables goods
ct=yt-(d(+1)/RER)+((d*(1+r(-1)))/RER);


%19. non-tradable sector profit function elambda2.19
pi_nt=pnt*ynt-pnt*wnt*hnt-(r(-1)-1)*thetah*pnt*wnt*hnt-int;

%20. Collateral constraint
thetah*pnt*wnt*hnt=(etab*knt(-1));

%21. trade balance to output ratio
tb_y = 1-(pc*c-pi_nt)/y;

%22. current account to output ratio
ca_y=-((r(-1)*pnt*wnt*hnt)+(d*(1+r)/RER)+(d(+1)/RER))/y+tb_y;
```

%23. borrowing constraint shock

log(etab)=(1-rho_etab)*log(etab_bar)+rho_etab*log(etab(-
1))+sigma_etab*epsilon_etab;

%24. foreign price shock

log(pc_star)=rho_pstar*log(pc_star(-1))+sigma_pstar*epsilon_pstar;

%25. Output

y = yt + pnt*ynt;

CC=c/STEADY_STATE(c);

CNT=cnt/STEADY_STATE(cnt);

CT=ct/STEADY_STATE(ct);

HNT=hnt/STEADY_STATE(hnt);

YNT=ynt/STEADY_STATE(ynt);

RR=r/STEADY_STATE(r);

RERR=RER/STEADY_STATE(RER);

TB_Y=tb_y/STEADY_STATE(tb_y);

CA_Y=ca_y/STEADY_STATE(ca_y);

WNT=wnt/STEADY_STATE(wnt);

KNT=knt/STEADY_STATE(knt);

INT=int/STEADY_STATE(int);

PC=pc/STEADY_STATE(pc);

MIU = miuu/STEADY_STATE(miuu);

```
DD=d/STEADY_STATE(d);

YT=yt/STEADY_STATE(yt);

PINT=pi_nt/STEADY_STATE(pi_nt);

PNT=pnt/STEADY_STATE(pnt);

YY=y/STEADY_STATE(y);


end;


Shocks;

var eps_A; stderr 0.5;

var epsilon_etab; stderr 0.5;

var epsilon_pstar; stderr 0.5;

var eps_yt; stderr 0.5;

end;


steady_state_model;

lambda2=1;

r=r_star;

pnt=pnt_bar;

pc_star=1;

pc=(rhoc^(1/(1+eta))+(1-rhoc)^(1/(1+eta))*pnt^(eta/(1+eta)))^((1+eta)/eta);

beta=1/(1+r_star);

Ant=1;

yt=1;
```

```
RER=pc_star/pc;

etab=etab_bar;

miuu=((1-alpha)/etab)*(1/(beta)-(1-delta))-alpha*(1+(r-1));

wnt=(1/(1+((r-1)+miuu)))*(1-alpha)*Ant*((1/beta-(1-
delta)+miuu*eta)/(alpha*Ant))^(alpha/(alpha-1));

hnt=(wnt*pnt/pc)^(1/(omegant-1));

knt=((1/beta-(1-delta)-(etab*miuu))/(alpha*Ant*pnt))^(1/(alpha-1))*hnt;

int=(delta)*knt;

d=d_bar;

ynt = knt^(alpha)*(hnt)^(1-alpha);

pi_nt=pnt*ynt-pnt*wnt*hnt-(r-1)*thetah*pnt*wnt*hnt-int;

c=((-(d*r)/RER)+wnt*pnt*hnt+pi_nt+yt)/pc;

ct=yt+(d*r)/RER;

cnt=(1-rhoc)*((pc/pnt)^eta)*c;

lambda = ((c- ( (hnt^omegant)/omegant ))^(-sigma))/pc;

y = yt+pnt*ynt;

tb_y = 1-(pc*c-pi_nt)/y;

ca_y=-((r*wnt*hnt)-((d*r)/RER))/y+tb_y;

%%ca_y=-((r*wnt*hnt)+((d*r)/RER))/yt+tb_y;

CC=1;

CNT=1;

CT=1;

HNT=1;

YNT=1;
```

```
RR=1;
TB_Y=1;
CA_Y=1;
WNT=1;
KNT=1;
INT=1;
MIU=1;
DD=1;
RERR=1;
PC=1;
YT=1;
PINT=1;
PNT=1;
YY=1;
end;


resid;
steady(nocheck);
```

```
stoch_simul(order=1, hp_filter=100, irf=20) CC CT CNT HNT YNT RR RERR TB_Y CA_Y
WNT INT KNT lambda2 MIU PC DD PINT PNT YY;



estimated_params;
rho_A, beta_pdf, 0.8, 0.2; //Productivity shock autoregressive parameter
rho_pstar,beta_pdf, 0.8, 0.2; //interest rate shock autoregressive parameter
rho_yt, beta_pdf, 0.8, 0.2; //interest rate shock autoregressive parameter
d_bar,GAMMA_PDF, 0.2, 0.40; //debt to GDP ratio
sigma, NORMAL_PDF, 1.50, 0.37; //elasticity of substitution
etab_bar, beta_pdf, 0.01, 0.05; //elasticity of substitution
stderr eps_A, INV_GAMMA_PDF,0.010, 2.00; //technology
stderr eps_yt, INV_GAMMA_PDF,0.010, 2.00; //interest rate
stderr epsilon_etab, INV_GAMMA_PDF,0.10, 2.00; //financial friction
stderr epsilon_pstar, INV_GAMMA_PDF,0.10, 2.00; //financial friction

end;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% OBSERVABLE VARIABLES
%%%%%%%%%%%%%%%%%%%%%%%%%%%%
varobs YT Ant pc_star DD ;
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% sample periods 1976-2014
% 2 years for initialisation
% this estimates the original model (with the rule) with 2000 MH
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

estimated_params_init(use_calibration);
end;



options_.plot_priors=0;
identification(advanced=1,max_dim_cova_group=3);
estimation(datafile=Consumption,presample=4,prefilter=0,diffuse_filter,
mh_replic=1000000,mh_drop=.2,mode_check,
mode_compute=6,mh_nblocks=2,mh_jscale=0.4,geweke_interval = [0.19 0.49],
taper_steps = [4 7 15], raftery_lewis_diagnostics, raftery_lewis_qrs=[0.025 0.01 0.95],
bayesian_irf) CC CNT CT HNT RERR RR TB_Y CA_Y WNT KNT INT PC MIU YT PNT PINT;

if ~isequal(options_.convergence.geweke.taper_steps,[4 7 15]') ||
~isequal(options_.convergence.geweke.geweke_interval,[0.19 0.49])
   error('Interface for Geweke diagnostics not working')
end

if ~isequal(options_.convergence.rafterylewis.qrs,[0.025 0.01 0.95]) ||
~isequal(options_.convergence.rafterylewis.indicator,1)
```

```
    error('Interface for Raftery/Lewis diagnostics not working')
end

steady;// recompute ss with post. means or modes

stoch_simul(order=1,irf=40) CC CNT CT HNT YY RERR RR TB_Y CA_Y WNT KNT INT PC
MIU YNT PNT PINT;
shock_decomposition (parameter_set=posterior_mode) yt Ant RER;
```

Chapter 7: Conclusion

7.1 Summary of Conclusions

This thesis oriented towards understanding the role of interest rate, financial market friction and dollarization in explaining business cycle in small and emerging economies. The thesis selects to empirically investigate the objects to the Maldives. To this end, I started by establishing the real business properties of the Maldives and then developed various models to explore how interest rate, financial market frictions and dollarization business cycle in small and emerging economies. The methodological developments and empirical investigations in Chapter 3-6 has contributed to the literature on real business cycle modelling and understanding of drivers of business cycle in small and emerging economies.

Chapter 2 outlines the methodological innovation in RBC agenda during the last 40 years. The focus was on methodological advances made to extend the RBC framework to account for financial market frictions and structural issues facing small and emerging economies. Chapter 3 embarked on to establish the properties of Maldivian business cycle using a database developed from archives kept in Maldivian Central Bank. A benchmarking exercise against this dataset was undertaken using other established secondary sources. The results reveal stark differences in results owing to issues relating data collection and data generation framework used by different agencies. The Maldivian real business cycle properties captured through data demonstrated that the moments fit well with the expected results from the literature for small and emerging economies. It documented that volatility of investment is higher than all other aggregates of domestic absorption and volatility of consumption is higher than volatility of outcome. Further results were able to produce negative correlation between external balances and output. It also showed that South Asian economies differ in their business cycle properties. A further result from Chapter 3 is that dollarized economies of similar magnitude also share similarities in business cycle moments.

Chapter 4 developed a simple RBC model and estimated the model using data on Maldivian economy. The aims of the chapter are to establish the theoretical business cycle prediction when interest rate shock competes with technology shock; establish the fit of the model to the Maldivian economy by estimating the model with calibrated parameters; and take the model to data and re-estimate the model using Bayesian estimation technique. The results show that the RBC model can match data to a reasonable level. It also signalled that there may be a role for interest rate when the model is expanded to include features of the financial market characteristics observed in small emerging economies.

In Chapter 5, taking the outcomes from the previous chapter and observed fragilities in financial market introduced a new RBC model with financial friction and debt elastic country interest rate. The aims of the chapter are to determine the existence of a financial accelerator mechanism in driving business cycle; role of interest rate and country risk premium in explaining propagation and amplification of shocks to real economy; and to match the moments of the model to those observed for the Maldives. The model developed in Chapter 4 contributes to the literature through methodological innovation and use of the model to understand business cycle properties of the Maldives. The chapter provides weak evidence on the existence of a financial accelerator mechanism. However, the findings provided empirically consistent results on the role of interest rate and risk premium in propagation and amplification of shocks to real economy.

Chapter 6 develops a real dollarization model to understand the business cycle in small and emerging economies. Compared with the other chapters the setup used in Chapter 6 feature a more complete macroeconomic framework we observe in several small and emerging economies. The chapter, in addition to real dollarization incorporates real exchange rate, risk premium and financial market frictions. Methodological contribution from this chapter to the literature is highly significant. First, the chapter contributes to the handful of recent real business cycle models with liabilities dollarization in the literature. Second, the chapter also establishes a framework through which real exchange rate and financial market friction feedback to one another and real economy. The model is empirically estimated to the Maldives. The findings from the empirical estimation shows that liability dollarization and real exchange rate contributes to business cycle in the Maldives.

7.2 Outlook and Limitations

The findings from Chapter 3-6 outlines several new areas of research and limitations associated with methodology and data. In Chapter 3 one can observe the limitation associated with data availability in which obtaining reliable data that is quarterly in frequency and appropriate in length is a challenge. As data becomes available, these models can be re-estimated through quarterly data to understand better the business cycle properties of the Maldives. Further, quality data can also ameliorate the fit of the model with the data and improve the estimation results.

The findings also highlight the need for open economy RBC research to move away from tradition models to incorporate real exchange rate and interest rate premium within the models to explain business cycle in EMEs. EMEs reliance on international financial markets to acquire debt and hence contagion effect following a shock in international financial markets will have an amplified effect on these economies. The turbulence caused by Asian financial crisis and global financial crisis on emerging economies lends sufficient evidence on the importance of this channel. The lack of importance of real exchange rate in Chapter 4 and Chapter 5 therefore is both a limitation of this research and direction for future work.

To fully understand the effect of dollarisation, there is the need to separate assets and liabilities of agents based on currency composition of each respective categories. In the context of the model introduced in Chapter 6 the balance sheet effects are not fully evidenced due to the framework being overly simplified. Therefore, in the future, the real model can be extended to include real assets and liabilities into agents' budget constraint to fully capture the balance sheet effect following shocks.

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