Policy options in preparation for the post-hydrocarbon era of Brunei Darussalam

by

Tsue Ing Yap

Master of International Economics and Finance (Advanced)
University of Queensland, Australia

B.Sc. (Honours) Accounting and Finance
University of Southampton, United Kingdom

Centre of Policy Studies, Victoria University

Melbourne, Australia

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Abstract

Brunei Darussalam, a highly hydrocarbon-dependent economy, is facing the inevitable fate of depletion of its oil and gas resources. With limited success in diversification efforts over the past decades, the future appears bleak if no urgent and effective policies are undertaken. This thesis seeks to elucidate a post-hydrocarbon scenario and various simulated policy options to revive some economic growth. This is proposed through further stimulus of selected industries under current diversification efforts and productivity growth. A recursive dynamic computable general equilibrium (CGE) model was applied, called the Brunei General Equilibrium Model (BRUGEM), which was developed specifically for this thesis.

Before the policy simulation was carried out, the published input-output (IO) database for 2005 was first updated to a more recent year, through an historical simulation technique. The use of decomposition simulation allowed us to decompose the movements in the macroeconomic and selected sectoral variables and attribute them to the different driving forces. This gave us an economic snapshot for the period 2005 to 2011. The economy was characterised by overall low real GDP growth with different attributions of productivity toward the mining and non-mining sectors, as well as high government expenditure and private consumption during the historical period (2005-2011). There was a strong taste preference for imported varieties and an improvement in the terms of trade.

Forecast simulation was used to build the baseline scenario against which the impact of policy shock could be evaluated. The baseline scenario for the period 2012 to 2040 was established from available forecast data. This was based on existing policy directions with some diversification efforts and in the context of depleting oil and gas sectors. Two policy simulations were run to create predictions for more economic growth in the future. One was run through a productivity shock and the other through further expansion of industries selected for diversification. Results from both policy simulations indicated that higher economic growth could be generated in the face of hydrocarbon depletion. However, it was concluded that overall productivity improvement would yield more sustainable long term results than would further expansion of the selected industries. The existing diversification strategy focussed on downstream industries to broaden the industry base and to generate exports, appears not to be sustainable. This is because these industries are dependent on the key inputs of readily available domestic oil and gas, which are depleting.

The thesis findings highlight several issues that policymakers need to consider in order to revive economic growth in Brunei. This calls for a rethinking of the current diversification strategy and the development of well-coordinated microeconomic reforms. This would improve productivity at all levels and thus help grow the economy. At the same time, the government must look into issues of increasing aggregate investment, as investment in the hydrocarbon sector declines. The success of these reforms will much depend on the political will and unwavering commitment of the relevant parties. This will be fundamental in preparing for a smooth transition into the post-hydrocarbon era.

Student declaration

Doctor of Philosophy Declaration

'I, Tsue Ing Yap, declare that the PhD thesis entitled "Policy options in preparation for the post-hydrocarbon era of Brunei Darussalam" is no more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work.'

Signature [redacted] Date 8/12/15

~ With all my love to my parents and my husband for their understanding,

moral support and encouragement ~

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List of abbreviations

ADB	Asian Development Bank
AFC	Asian financial crisis
AMBD	Autoriti Monetari Brunei Darussalam
APEC	Asian-Pacific Economic Cooperation
APO	Asian Productivity Organisation
ASEAN	Association of Southeast Asian Nations
BEDB	Brunei Economic Development Board
BIA	Brunei Investment Agency
BIC	Bio-Innovation Corridor
BMC	Brunei Methanol Company
BOEPD	Barrels of oil equivalent per day
BOP	Balance of payment
BOTE	“Back-of-the-envelope”
BRUGEM	Brunei General Equilibrium Model
BSP	Brunei Darussalam Shell Petroleum Sdn Bhd
CAB	Current account balance
CAD	Current account deficit
CAPEX	Capital expenditure
CES	Constant elasticity of substitution

CET	Constant elasticity of transformation
CF	Consolidated Fund
CGE	Computable General Equilibrium
CIF	Cost, insurance and freight
CoPS	Centre of Policy Studies
CPI	Consumer price index
DEPD	Department of Economic Planning and Development, Brunei
DOS	Department of Statistics under DEPD, Brunei
EPS	Expenditure elasticity of demand
FDI	Foreign direct investments
FOB	Free on board
FSRF	Fiscal Stabilisation Reserve Fund
GAMS	General Algebraic Modelling System
GCC	Gulf Cooperation Council
GDP	Gross domestic product
GEMPACK	General Equilibrium Modelling Package
GNE	Gross national expenditure
GNI	Gross national income
GNP	Gross national product

GST	Goods and services Tax
GTAP	Global Trade Analysis Project
ICT	Information and communication technology
ILO	International Labour Organisation
IMF	International Monetary Fund
IO	Input-Output
IOT	Input-output tables
JV	Joint venture
K/L	Capital/labour ratio
LES	Linear expenditure system
LNG	Liquefied natural gas
LTDP	Long term development plan
MFP	Multi-factor productivity
MMBtu	Millions British thermal units
MoF	Ministry of Finance, Brunei
MIPR	Ministry of Industry and Primary Resources
MNC	Multinational corporations
MPSGE	Mathematical Programming System for General Equilibrium Analysis
NAIRU	Non-accelerating inflation rate of unemployment

NDP	National development plan
NFA	Net foreign assets
NFL	Net foreign liabilities
OBG	Oxford Business Group
OECD	Organisation for Economic Cooperation and Development
OPEC	Organization of Petroleum-Exporting Countries
PMB	Pulau Muara Besar project
RF	Reserve Fund
SCP	Supplementary contributory pension
SDCF	Strategic Development Capital Fund
SF	Sustainability Fund
SME	Small and medium enterprise
SUT	Supply and use tables
SWF	Sovereign wealth fund
SWFI	Sovereign Wealth Fund Institute
TAP	Tabung Amanah Pekerja (employees trust fund)
TFP	Total factor productivity
TOT	Terms of trade
UAE	United Arab Emirates
UN	United Nations

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It has been a long journey full of ups and downs but all I can say is that I did it and it was all worth it in the end! I owe so much to many people who have touched my life in one way or another, whether in small or big ways, I have learnt and grown from this valuable experience.

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Victoria University (VU) on the 30th month of my PhD, but my supervisors remained true to their words … they did not abandon me. I followed them to VU because they are irreplaceable!

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Chapter 1: Introduction

1.1 The issue and research questions addressed

Hydrocarbons have been the backbone of Brunei's[1] economy since the first oil discovery in 1929 (Oxford Business Group [OBG] 2014) and the first gas discovery in 1963. In part, revenues from hydrocarbon production have been invested into a sovereign wealth fund (SWF). However, oil and gas reserves in Brunei are approaching a critical state of depletion. BP Plc (BP 2015) forecasted that reserves have a remaining economic life of between 22 and 24 years, at the current extraction rate.[2]

The Brunei government is aware of this problem. In response, it has been trying to diversify in terms of developing more industries, but without much success. Some studies have identified impeding factors, ranging from resource constraints to bureaucracy. This will be elaborated on in Chapter 2.

Recently, the focus has been on developing downstream energy-related industries. This is following in the footsteps of several Gulf Cooperation Council (GCC)[3] countries. One stark difference is in the life span of resources: GCC countries such as Kuwait, Qatar, Saudi Arabia and United Arab Emirates (UAE) are blessed with abundant oil and gas reserves, which combined could last over 50 years for each country, some even over 100 years (BP 2015). These countries have embarked on diversification programs into downstream industries decades before their hydrocarbons are expected to deplete. Brunei does not have that leeway in terms of time to grow its downstream industries large enough to replace its oil and gas output.

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[1] For brevity, Brunei Darussalam is referred as Brunei in this thesis.
[2] The Brunei authorities do not publish official data nor confirm the third party figure about its remaining reserves level. In a report (OBG 2013), a ministry official indicated that Brunei has to intensify exploration efforts, to open up a number of new blocks for additional operators, to boost production incentives for marginal reserves and to increase the use of new technologies to achieve targets set by the Energy White Paper.
[3] GCC consists of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates.

In terms of literature, there is little discussion of Brunei's economic development and looming problem of hydrocarbon depletion. Empirical data are scarce, which means that there are few quantitative studies related to Brunei. In many regional analyses, Brunei is often left out as the "outlier" or simply not included due to unavailability of data.

The lack of empirical studies of the potential effects of the recommended diversification policies was the motivation for this research. This study aims to quantify the economy-wide impact of current diversification strategies with the help of a dynamic Computable General Equilibrium (CGE) model.

The key research questions addressed within the CGE framework are as follows.

(i) What are the effects on the Brunei economy along a business-as-usual transition path with oil and gas reserves falling?
(ii) Based on the business-as-usual trajectory and current policy directions, what would be the effects if more effort were put into developing downstream energy industries? Will that help Brunei achieve its goal to replace the output generated from the declining primary oil and gas sectors?
(iii) What are the trade-offs that policymakers need to be mindful of in implementing future industrial development policies?

To answer these questions required a methodology that is forward looking and has a detailed depiction of the economy. A dynamic CGE model is best suited to this task.

1.2 CGE model overview

A CGE model is an economy-wide model consisting of a system of equations that depicts the objectives and behaviour of all producers and consumers and the interlinkages between them in the economy. Firms or industries respond to consumers' demands by purchasing intermediate inputs, hiring labour and capital equipment to produce their outputs for both domestic and export markets. The revenues obtained by selling these outputs eventually accrue to households who supply both the labour and capital. The households will in turn spend the income received on goods and services, pay taxes to the government, as well as save some funds. These tax revenues and savings lead to government spending and investments. This completes the model in terms of income and spending in the national economy.

A CGE model will also identify the trade-offs amongst the different economic agents and sectors. It is also able to capture the effects through changes in relative prices of inputs and outputs, brought about by shocks from either the supply or the demand sides of the economy. Most importantly, it can take into account the interdependencies of agents and economic activities to examine the full effects of any policy shock.

CGE modelling is a useful tool and has practical application which enables simulations of policy issues to be run and results analysed to provide insights for policymakers. This can be done at both macroeconomic and sectoral levels.

The CGE model constructed for this thesis, called the Brunei General Equilibrium Model or BRUGEM, is documented in Chapter 3.

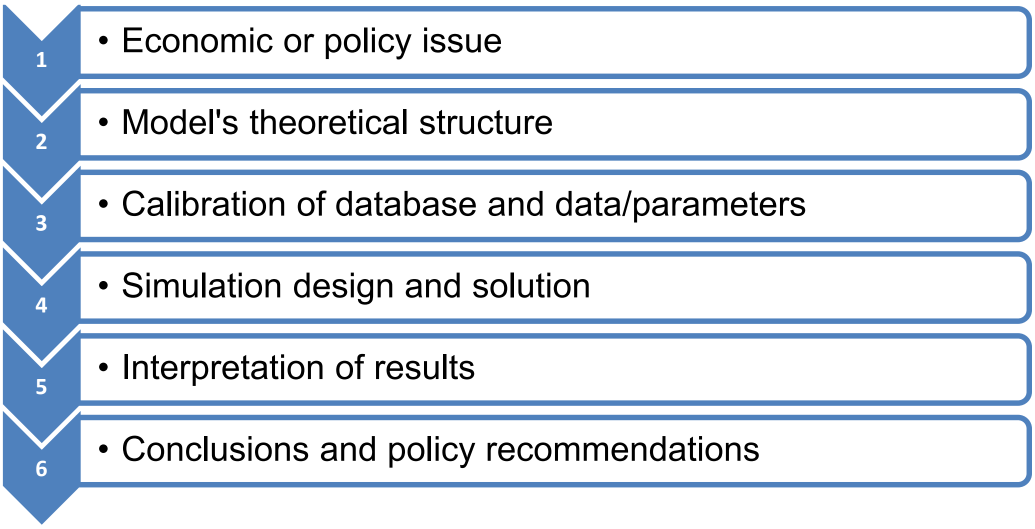
In 2011, Brunei published its first official Input-Output (IO) table for the year 2005. An IO table forms the key database for CGE modelling. In developing a CGE model for Brunei, a key first step is to take the official data and translate into a form required by the model. The collection of statistics for Brunei and collation into a form suited to CGE modelling is discussed in Chapter 4.

In this thesis, BRUGEM is used to showcase four types of dynamic simulations: historical (Chapter 5), decomposition (Chapter 6), forecast (Chapter 7) and policy (Chapter 8), with each serving a different purpose. This will be elaborated on in subsequent chapters.

1.3 CGE analysis

Typically, the process of a CGE analysis involves the following steps (see Figure 1-1).

Figure 1-1: Steps involved in a typical CGE analysis



After identifying the economic or policy issue, the formal theoretical structure needs to be specified (or modified if necessary), followed by construction of the database (or adjustment if there is an existing database to use) and the evaluation of coefficients in order to calibrate the model. The appropriate simulation design is then set up with the closure and solution method specified. The economic issue to be evaluated needs to be expressed in the form of model-compatible variables with the appropriate shock value. The result of the simulation is then interpreted in the context of the economic issue. This helps to verify the check on the correct implementation of the issue within the model and to draw economic insights. The model results help to enhance credibility and enable communication of the underlying mechanism that drives the results to the audience. The final step is to draw conclusions and any policy recommendations.

In the context of this thesis, Step 1 was outlined in Section 1.1 of this chapter and Step 2 is explained in Chapter 3 relating to the theoretical structure in which the economic theory is incorporated into the system of non-linear equations in the model. Step 3 is outlined in Chapter 4, where the model is calibrated using a balanced Brunei IO database of the base year 2005, constructed to fit the format as required by the selected model and the necessary coefficients are evaluated. The choice of behavioural and elasticity parameters determines the responsiveness of agents in their substitution and consumption patterns to relative price changes. Step 4 of the process is to choose a suitable model closure that reflects the appropriate environment under which simulation is to be conducted in order to address the research question. A suitable solution method must be chosen for meaningful interpretation of results. Step 4 and Step 5 are discussed in Chapters 5, 6, 7 and 8, where simulations are carried out and results discussed. Finally, Step 6 is presented in Chapter 9.

It is important to explain the model's projections or results in a logical sequence, in terms of the model's underlying theory, its database, its closure and the shocks. The first-round impacts of the shocks are identified first and then simplified versions of the model, such as "back-of-the-envelope" (BOTE) models, are used to trace the decomposition effects of the variables in the equations. Adams (2005) also highlights that a stylised model, such as a BOTE model, is very useful in identifying the key theoretical mechanisms that underlie the full model, as well as highlighting the main elements of the database. Stylised models can also be used to conduct sensitivity analysis to examine how changes in the data and other inputs can influence the main model.

The macroeconomic results need to be understood first in order to explain the effects. Adams (2005) suggested this strategy for modellers, stating that the bigger picture at the macro level should be considered first before drilling down to details at the micro level. This is because often, a good understanding of what happened to the macro variable, such as the real exchange rate, will lead to an understanding of the way trade-exposed industries have reacted. The sectoral effects at industry level can be traced from the macro effects through the first round impacts of the policy shock and sectoral linkages. It is important to interpret results to ensure that the model was implemented correctly and the scenario under examination is simulated properly. This will provide economic insight to understand how the economy works. Ideally, the interpretation of results has to be kept simple enough to be understood by an economist unfamiliar with the details of the model, but still be able to capture the key mechanisms behind the results. The results can be communicated only through accurate interpretation, so that conclusions are understood and are given credence.

1.4 Some existing CGE studies

There are numerous qualitative articles on the topic of Brunei's economic diversification, highlighting the barriers to that diversification and some suggested areas into which Brunei could diversify. However, there are a limited number of empirical studies on how these strategies can be carried out and what the economy-wide impacts would be if such policies were implemented.

As far as I am aware, there has been only one CGE study of the Brunei economy, documented in Haji Duraman (1998). The model used was comparative-static and based on ORANI, an Australian model developed by Dixon et al. (1982). The author used the model to study the impacts of various policies, such as an increase in government consumption expenditure, a decrease in real wages, an increase in oil and gas exports and a devaluation of the Brunei currency.

In order to carry out these simulations and in the absence of an official IO table, the author developed an IO table for Brunei. The table included 12 industries and 12 commodities. The database represented 1991, although it was constructed primarily using 1986 survey year data.

A limitation of a comparative-static model is that it allows only comparisons between two states of the economy, one prior and one after a policy shock, without much information on the path to how the new state is achieved. Given that the modelling approach is limited to short-run to medium run scenarios, Haji Duraman (1998) suggested the use of a dynamic version of a CGE model which is more suited to addressing long term development issues and in tracing the adjustment process through time.

For the purpose of the research conducted for this thesis, the adjustment process and adjustment costs are important. Hence, the model built is dynamic. In addition, a more up-to-date data set was used, with up-to-date statistics published by the Brunei Department of Economic Planning and Development (DEPD).

In addition to the Haji Duraman study, an internal project was undertaken by the DEPD in 2013 to engage a consultancy firm to build a CGE model for Brunei. This was called BD-CGE. This model employs a modelling platform called GAMS (General Algebraic Modelling System), and has a database based on the official IO tables for 2005. This model, however, is not publicly available.

For this thesis, BRUGEM was built independently using GEMPACK (General Equilibrium Modelling Package) modelling software developed by Harrison and Pearson (1996), with several modifications to suit the purpose of this study. The differences between GEMPACK and GAMS are discussed in Appendix 3-2.

1.5 Main contributions of this thesis

This thesis makes several contributions to the literature. First, it documents an operational, dynamic CGE model of the Brunei economy that captures the government and foreign accounts to track adjustment paths as hydrocarbons deplete.

Second, to implement the CGE model it describes the development of a new CGE database based on the IO tables for the year 2005, with appropriate adjustments and the inclusion of two new sectors: *owners' dwellings* and *methanol and* *petrochemicals.* This database is updated to a more recent year, 2011, via an historical simulation with the CGE model. The same updating method can be used to produce a more up-to-date IO database to work with in the near future without waiting for the official IO tables to be published. In addition, the thesis explores a number of methods to estimate data for the purpose of CGE modelling in case of data non-availability. This can be useful as a reference for other researchers who are facing similar challenges in terms of data.

Third, the study presents quantitative evidence on the future economy-wide impacts of oil and gas depletion in Brunei.

Finally, the study uses the dynamic model to measure the impact of current diversification strategies based on downstream industries and the expansion of construction-related industries.

1.6 Structure of the thesis

There are nine chapters in this thesis, organised as follows. This introductory chapter has outlined the objectives, methodology of the research undertaken, followed by a brief discussion of the existing CGE studies and main contributions of this thesis.

Chapter 2 provides an overview of Brunei, including the economic background and current on-going diversification efforts to set the scene for policy discussion.

Chapter 3 presents the core theoretical framework of BRUGEM, the dynamic CGE model for Brunei. It describes the main behavioural assumptions and relationships between the agents (industries, investors, households, government and the rest of the world) within the economy. It also includes a discussion on the solution method and the dynamic features of BRUGEM.

Chapter 4 details the processes in constructing the core CGE database for BRUGEM from the published IO table for the year 2005, with some adjustments. It includes the creation of a new investment matrix by industries and commodities; the separation of ownership of dwelling and the real estate services industry; the inclusion of a new methanol and petrochemicals industry; and inclusion of additional data, parameters and coefficients to create a dynamic IO database for modelling purposes. This new IO database is the key ingredient for CGE modelling but it needs to be updated to a more recent year for more meaningful analysis.

Chapter 5 outlines the further update of the IO database (created in Chapter 4), from 2005 to 2011, using the historical simulation technique targeting macroeconomic data. The process of historical simulation also uncovers and quantifies the movements of some typically unobservable structural variables, such as technical change and taste change, to achieve the economic outcome for 2011. By using these results, decomposition simulation can be carried out to decompose these movements to understand the contribution of these variables to the movement of the endogenous variables of interest. This decomposition is reported in Chapter 6.

To understand the effects of new policy shock, we need a reference or "business-as-usual" scenario as a comparator. Using the forecast simulation technique, Chapter 7 explains the process of developing this baseline forecast for the period 2012 to 2040. In the baseline, the economy is allowed to go on at its existing pace with the natural progression of population growth and policy direction without any additional shock.

Two baseline scenarios are generated in the face of oil and gas depletion. One scenario has no action to offset the decline in oil and gas sectors. The second contains current diversification efforts in which the government is seen as active in diversifying into downstream industries while continuing to build more infrastructure through construction-related industries. The second baseline forecast scenario was chosen as the reference scenario to run policy simulations in Chapter 8.

Chapter 8 shows the results of two different policy simulations. One is to study the impact of improved productivity and the other is to study the effects of further expansion of the same industries stimulated in the second baseline forecast as part of diversification. The differences in the simulation results between these two policy shocks are compared and discussed in Chapter 8.

The last chapter, Chapter 9, concludes the thesis with a summary of the main findings and limitations of the current research. Possible extensions for future research are also documented.

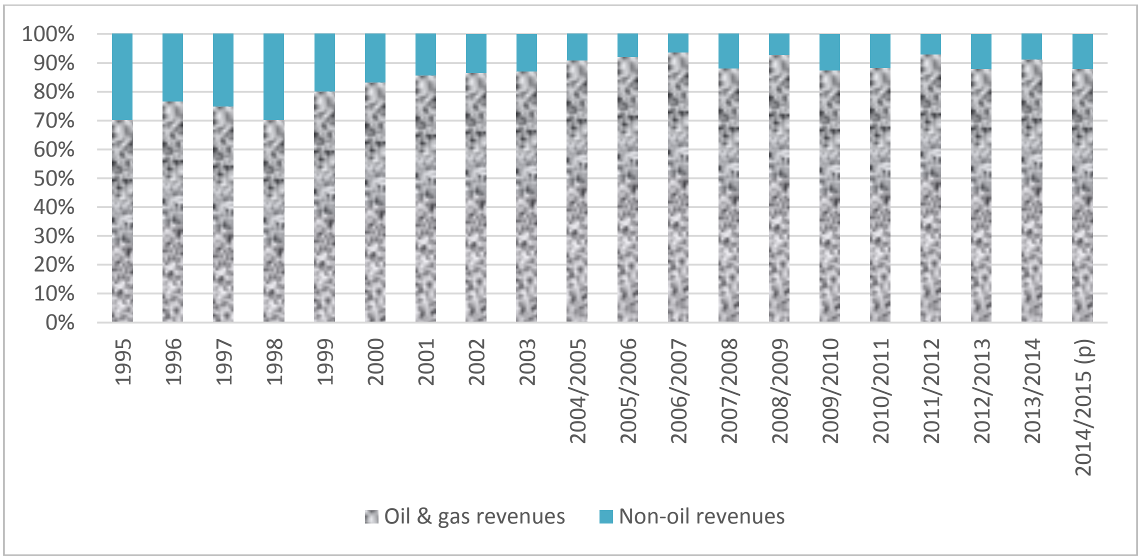
Chapter 2: Overview of the Brunei economy

This chapter provides an overview of Brunei's economy as context for the modelling described in later chapters. Section 2.1 provides some background on Brunei. Section 2.2 lays out the existing issues relating to energy and Section 2.3 on diversification issues. Section 2.4 mainly focuses on diversification efforts and progress to date. Section 2.5 includes a discussion on SWFs and other reserve funds. Section 2.6 relates to problems associated with future fiscal burden. Section 2.7 introduces the current national development plan as a guide to future development and policy directions. Section 2.8 deals with some data concerns. Concluding remarks are provided in Section 2.9.

2.1 Background

Brunei is a small and open economy owning 0.1 per cent and 0.2 per cent of the world's total proven reserves of oil and gas respectively. In the 2013/2014 fiscal year, Brunei derived 91 per cent[4] of its fiscal revenue (see Figure 2-1) from the exports of oil and gas.

Figure 2-1: Sources of government revenue



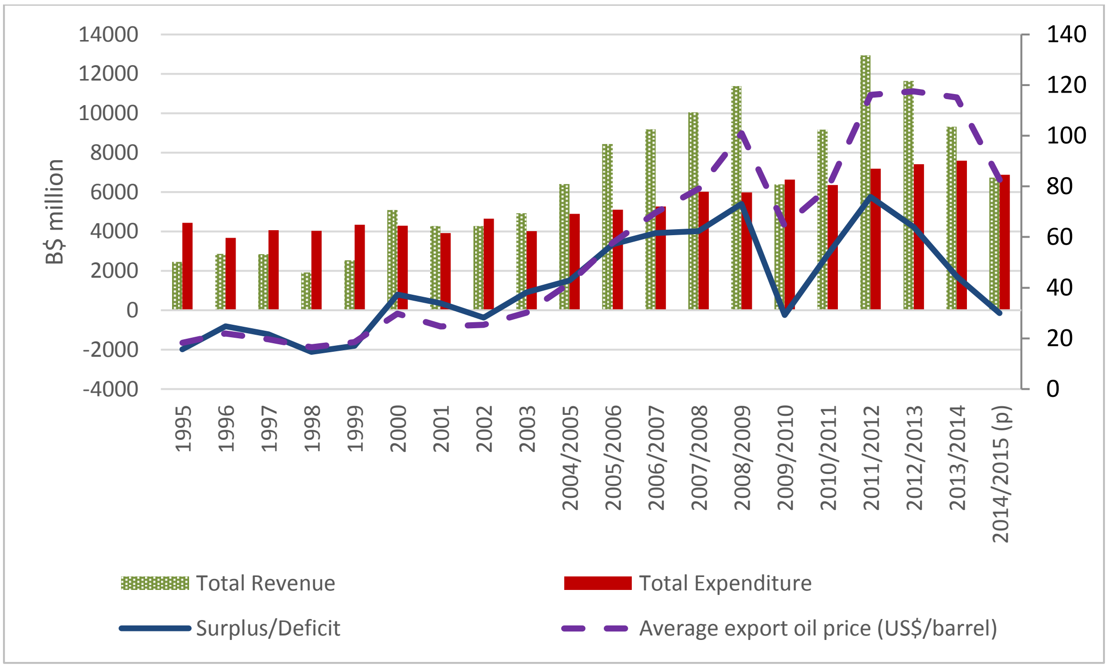
Note: Provisional figures are provided by DOS denoted as (p) for 2014/2015

[4] Unless otherwise stated, all figures on Brunei were obtained from the Department of Statistics (DOS) in Brunei.

Globally, Brunei is the 59th largest oil exporter and the 9th largest liquefied natural gas (LNG) exporter in the world (TOGY 2012), generating 0.1 per cent and 0.3 per cent of total world production respectively (BP 2015). With its small population (around 400,000), Brunei ranked 4th in the global ranking of gross domestic product (GDP) per capita measured in purchasing-power-parity current international dollars (International Monetary Fund [IMF] 2015).

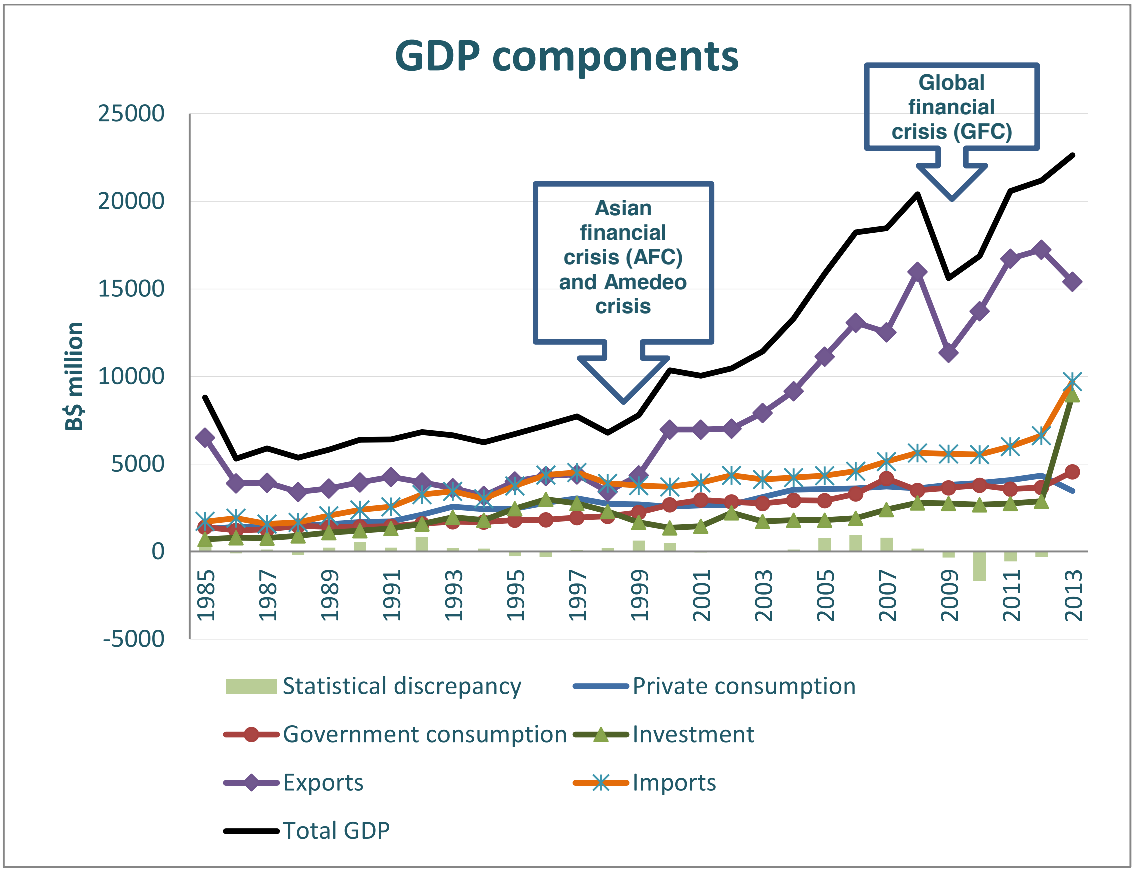
With such heavy reliance on hydrocarbon proceeds, Brunei's economic growth is highly vulnerable to domestic and international forces affecting oil and gas markets (see Figures 2-2 and 2-3). The international forces are the Asian financial crisis (AFC) and the global financial crisis (GFC). The domestic force relates to the Amedeo crisis (Haji Duraman & Opai 2002) which will be discussed later. Figure 2-2 shows that the oil price per barrel is closely linked to the fiscal position. As can be seen, the collapse of oil prices in the late 1990s caused the government's fiscal position to weaken significantly. Appendix 2-1 shows that in Brunei the fiscal break-even price for oil is US$48.6 per barrel and US$5.6 per MMBtu (millions British thermal units) for gas, based on 2014 figures.

Figure 2-2: Relationship between oil prices, government revenue and expenditure



Source: DOS with provisional figures denoted as (p) for 2014/2015

Figure 2-3: Nominal GDP and its components (1985 – 2013)



Source: DOS

Table 2-1 shows annual growth in real GDP in Brunei between 2004 and 2014. Negative growth rates in the final two years were due, in the main, to maintenance shut downs in oil production.

Table 2-1: Real GDP growth rates for Brunei (per cent)

2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
0.5	0.4	4.4	0.2	-1.9	-1.7	2.5	3.4	0.9	-2.1	-2.3

Source: DOS statistical yearbooks

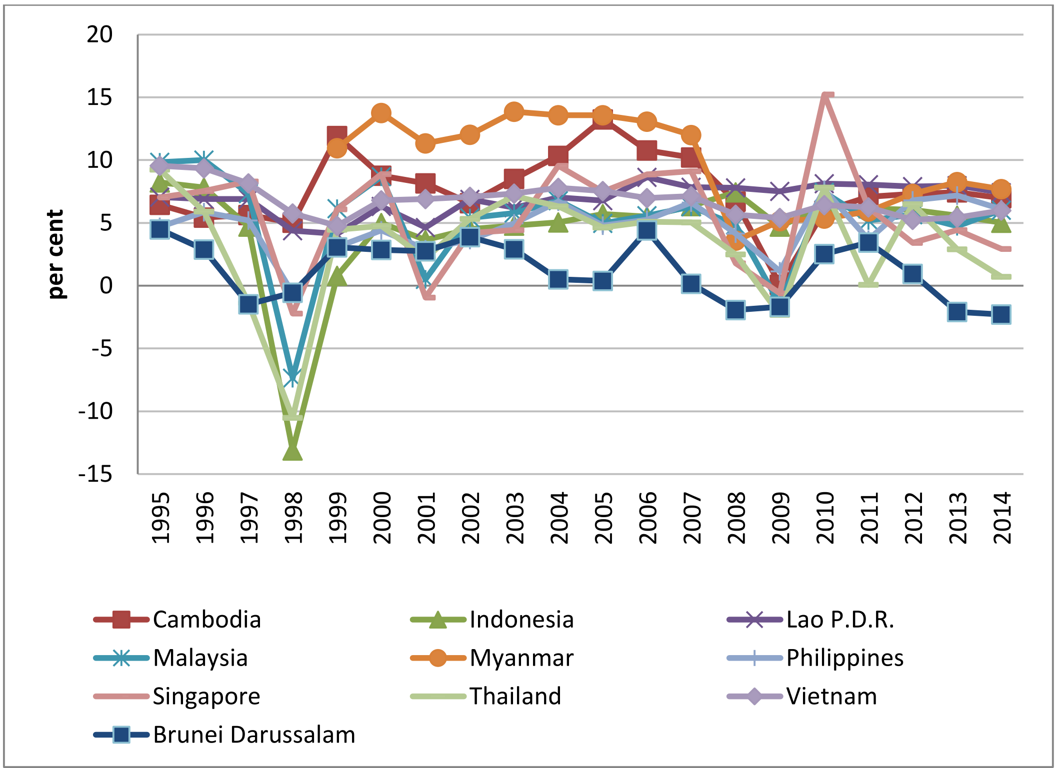
Figure 2-4 compares the growth performance of ASEAN[5] (Association of Southeast Asian Nations) countries between 1994 and 2014. Brunei's economic performance sat mostly at the bottom of the growth chart compared to its ASEAN

[5] ASEAN or the Association of Southeast Asian Nations consists of 10 countries: Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam.

neighbours (with the exception of the AFC period of 1998, when a number of countries faced sharper declines in growth rates).

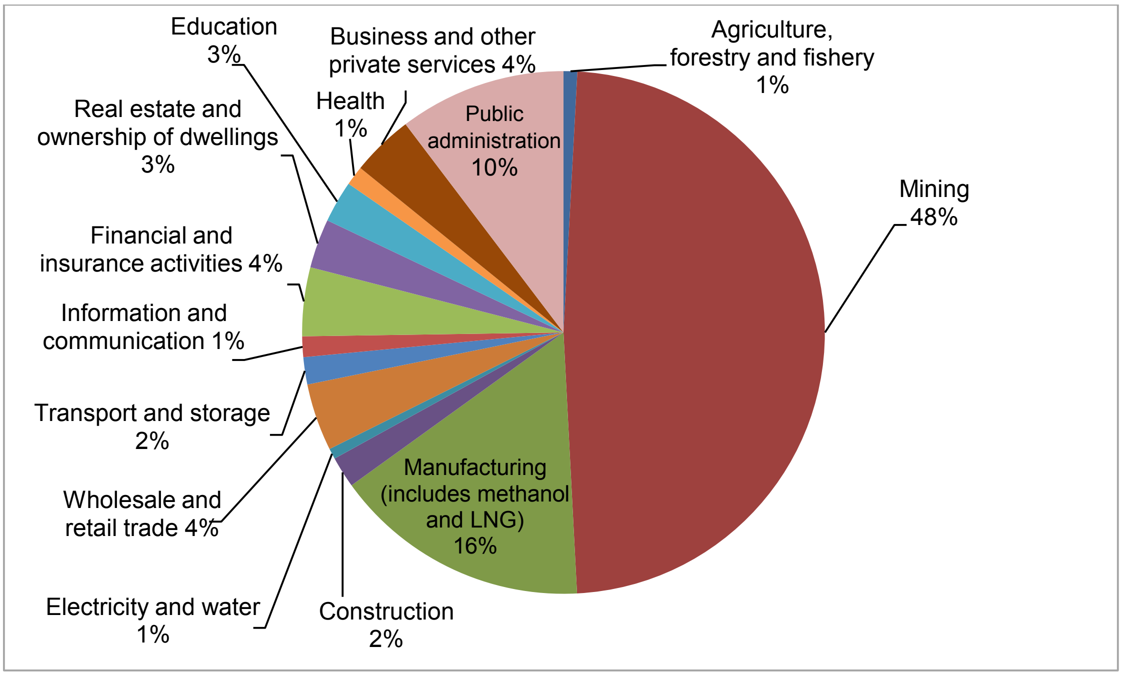
Brunei's non-oil and gas sector remain small and underdeveloped. Industry shares of nominal GDP are shown in Figure 2-5 for the year 2014. The economy is clearly dominated by the oil and gas sectors when we include the manufacture of liquefied natural gas (LNG). The second largest contributor to GDP is government services, which contributes about 10 per cent. All other industries are relatively small. These include sectors such as the wholesale and retail trade (4 per cent), business and other private services (4 per cent), finance (4 per cent), construction (2 per cent), and real estate and ownership of dwellings (3 per cent).

Figure 2-4: Real GDP growth rates of ASEAN countries



Source: International Monetary Fund (2015)

Figure 2-5: Contribution of economic activities to nominal GDP in 2014



Source: DOS (2015)

An underdeveloped non-oil sector is often associated with "Dutch disease" (Colclough 1985, Cleary & Wong 1993, Duraman et al. 1998, Crosby 2007, Lawrey 2010). The concept of "Dutch disease" emanated from the decline in export competitiveness in the Netherlands with the discovery of the Groningen gas fields in the 1970s. This discovery led to the contraction of the traditional export sectors due to movement of factors of production into the resource extractive activities (Larsen 2006) and caused inflation in the non-tradable sectors as explained below (Benjamin et al. 1989).

Most developing countries need to drive their development process through the expansion of the tradable sector. Since the revenues from the resource export boom are spent on services or non-tradable goods, this leads to the appreciation of the real exchange rate. This hurts the export and import-substitution sectors and therefore brings about unfavourable structural changes in the economy (Corden & Neary 1982). As Auty (1993) posits in his "resource curse thesis", a resource-rich country may fail to benefit from its endowment and perform poorly when compared to a less well-endowed country in terms of economic development. Many countries tend to experience low or negative growth after the discovery of a valuable resource, often coined as the “resource curse” (Larsen 2006).

The “Dutch disease” where the tradable goods sector contracts substantially is avoidable, as shown by the success story of Norway where its tradable sector did not erode away and its competitiveness unaffected. Through Norway’s multi-faceted approach including deliberate macroeconomic policies, political and economic institutional arrangements, fiscal discipline and a well-functioning legal system have led to sustained economic growth and the accumulation of a Petroleum Fund abroad (Larsen 2006). In a comparative study between two developing countries, Indonesia and Mexico, Usui (1997) found that through macroeconomic management of the oil revenues, such as by investing in the tradable sector, Indonesia was able to avoid “Dutch disease”. Brunei has been saving up most of the proceeds from oil and gas since 1983 by putting them in a SWF, managed by the Brunei Investment Agency (BIA).

In terms of macroeconomic performance, Figure 2-3 shows two distinct dips in Brunei’s GDP after 1995. Cleary & Francis (1999) attribute the economic decline of Brunei in 1998 to several factors, both external and internal. These include the fall in oil spot prices and declining investment returns on regional and global markets, which affected the Brunei government revenues.

One internal factor was the collapse of the largest construction-related company in Brunei called the Amedeo group. Amedeo had 27 subsidiaries active in a wide-range of business areas. The collapse of Amedeo caused a lay-off of nearly 2,000 staff, mostly expatriates. The impact on other businesses who dealt with Amedeo was wide-ranging. It was estimated that before being forced to close, Amedeo’s debt was between US$7-$8 billion (Cleary & Francis 1999). This was larger than the entire Brunei nominal GDP in 1998.

2.2 Energy issues

Brunei's oil and gas reserves are, of course, finite. A recent study (BP 2015) found that based on the 2014 figures of proven reserves and reserve-to-production ratios, oil will last 23.8 years and gas will last 23.3 years[6]. This implies that without new oil and gas finds or improvement in technology to extract more out of maturing fields, at the current reserves level and extraction rate Brunei will "run out" of hydrocarbons by the year 2038. Geologically there might still be some oil and gas reserves remaining after 2038, but it is uncertain whether they are economically extractable in terms of costs versus market price.

In 2013, Brunei's oil and gas production amounted to 372,000 barrels of oil equivalent per day (BOEPD). Without further investment or increased recovery from maturing fields, the daily production of oil and gas is expected to drop to 200,000 BOEPD by 2035 (Energy Department 2014). This translates roughly to a fall of 3 per cent per annum over the next 22 years. If current reserve estimates are correct, then after 2035 the production will fall rapidly to zero.

With the very real prospect of a declining oil and gas sector, the government is looking into the issue of energy security. Brunei is a net exporter of oil but due to limited domestic refining capacity, it imports 40 per cent of total refined products, including transportation fuels, to meet domestic consumption (Energy Department 2014). The government is planning to build another refinery to meet the local demand.

The Energy Department at the Brunei Prime Minister's office (Energy Department 2014) prepared an Energy White Paper to outline strategies for sustainable energy production into the future. These strategies are designed to ensure that the energy sector

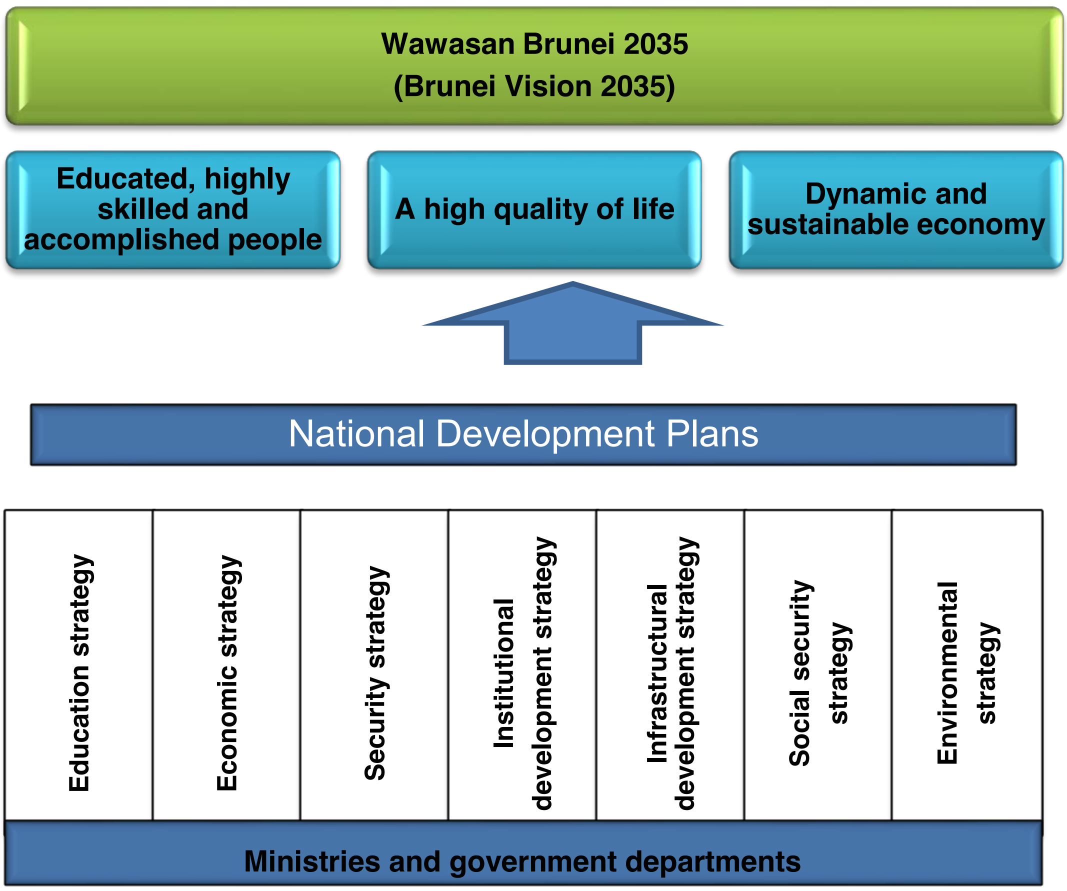
[6] Oil and gas may not run out physically but future extraction can become uneconomical due to high production costs relative to market price or the lack of new technology available to extract marginal reserves.

can continue to contribute towards Brunei's development to help achieve the National Vision 2035 or "Wawasan Brunei 2035".

There are three main goals within the "Wawasan Brunei 2035" (see Figure 2-6) (Department of Economic Planning and Development [DEPD] 2012):

- To make Brunei Darussalam a nation which will be widely recognised for the accomplishment of its educated and highly skilled people as measured by the highest international standards.
- To achieve quality of life that is among the top 10 countries in the world.
- To build a dynamic and sustainable economy with an income per capita among the world's top 10.

Figure 2-6: Wawasan Brunei 2035 (Brunei Vision 2035)



Source: DEPD (2012)

To contribute to economic growth, the Energy White Paper promotes ambitious targets which state that the broader energy sector (including upstream, downstream energy services and power sub-sectors) needs to grow at 6 per cent per annum in real terms in order to achieve GDP contributions from B$10 billion[7] in 2010 to B$42 billion in 2035. This will be done by strengthening and growing both the oil and gas upstream and downstream activities through high value-added industries, not only to diversify the energy sector but also to maximise the value of the upstream oil and gas industries. The downstream industries include refinery, chemical and petrochemicals plants. The government plans to increase output from these sectors from its present value of B$300 million to B$5 billion in 2035, with an intermediate target of B$3 billion in 2017.

The White Paper provides an impressive list of goals, but it can be argued that it is overly optimistic (see Figure 2-7). For example, one medium term goal is to increase daily production of oil and gas by nearly 60 per cent from 408,000 BOEPD to 650,000 BOEPD by 2035. The White Paper bases this expectation on the assumption that new and significant reserves will be discovered over the next twenty years. However, it appears that this target includes overseas production and not just more reserves being discovered in Brunei. Out of the 650,000 BOEPD target, some 2.3 per cent will come from overseas oil output obtained from the 87.25 per cent ownership in an onshore oil field in Myanmar by the national oil company, PetroleumBRUNEI (Thien 2014). Without transparency of data on how these targets are calculated, this expectation of future production is not supported by the external expert forecast, such as that conducted by BP (2015).

Therefore, in the context of modelling, this possible increase in future oil production was not considered viable, for the following reason. From an economic point of view, any oil and gas production outside the Brunei borders, such as in Myanmar, which is not imported into Brunei for domestic use or as intermediate inputs for domestic

[7] B$1.00=USD0.97 as of 15 November 2015 http://www.oanda.com/currency/converter/ (viewed 15/11/15)

production of goods, will not affect GDP directly in any way. This is the case even if production is partially owned by Brunei through some business arrangement. If these outputs are sold in the international markets, then the sale proceeds may contribute financially back into the government's coffers, depending on the financial arrangements of these production sharing contracts. This will then improve Gross National Product (GNP) figures, which measure production based on ownership rather than the geographical location. GNP is defined as GDP plus net incomes received from abroad. These proceeds will be treated in a similar way to income generated from overseas investment or foreign direct investment (FDI) by Brunei. Unless these revenues are pumped back into the economy to generate productive activities and growth, Brunei's GDP is not expected to grow with these foreign investments.

The White Paper also mentions intensifying efforts in upstream activities. Brunei has pursued several other production sharing contracts for exploration and development costs of cross-border oil and gas fields. One such agreement with Petronas of Malaysia, signed in 2010, resulted in a major gas discovery (Shahminan 2013c) at the end of 2013. The cost of developing this new field will be shared between Petronas and the Brunei government since the block straddled the two countries.

On the domestic front, the biggest oil and gas operator, Brunei Shell Petroleum Company Sendirian Berhad (BSP) (a 50:50 joint venture (JV) between the Brunei government and Royal Dutch Shell), is also actively pursuing ways to prolong the life of existing reserves. This is being done through extensive deep-water offshore drilling and significant investments in secondary and tertiary recovery from maturing fields (Oxford Business Group [OBG] 2013).

For an oil firm to consider investing in Brunei, it will need to work out a different break-even price for crude oil that can be sold to cover its costs. If the market oil price falls below this break-even price, the oil firm will lose money for every barrel of oil produced. This is different to the fiscal break-even price discussed earlier for the government to avoid a fiscal deficit. Xu (2015) estimates that the break-even price for

Brunei is US$57.90 per barrel, the most expensive in the Southeast Asia region for a small-medium sized field. This makes it unprofitable to invest within the current climate of low oil prices. However, oil and gas firms may still invest if they have high expectations of the remaining level of reserves underground.

Figure 2-7 The strategic goals and key performance indicators for Brunei's Energy Sector in 2035

	KPI	Definition	Unit	Target		
				2010 Baseline	2017	2035
Strategic Goal 1: Strengthen and Grow Oil and Gas Upstream and Downstream Activities						
1	Oil and Gas Reserve Replacement Ratio	Ratio of expectation reserves added each year and annual production volume (oil and gas)	Ratio	0.5	>1	>1
2	Oil and Gas Production	Gross production of oil and gas	Barrel Oil Equivalent (BOE) per day	408,000	430,000	650,000
3	Downstream Economic Output	Revenue from sales of products	BND Million per year	300	3,000	5,000
Strategic Goal 2: Ensure Safe, Secure, Reliable and Efficient Supply and Use of Energy						
4	Ensure safe operations	Number of major accidents for the energy industry	Number per year	0	0	0
5	Energy Intensity	Ratio of primary energy demand for all sectors and GDP	Ton oil equivalent per USD Million of GDP (2005 baseline)	390	320	215
6	Renewable Energy in Total Power Generation Mix	Power generation from renewable sources of energy	MWh	808	124,000	954,000
7A	Reliable Energy - Power Outage (>1 hour)	Number of incidents of power outages of more than 1 hour duration in a year	Number per year	>300	100	<50
7B	Reliable Energy - Interruption in supply of Transport fuel	Number of incidents where there is a supply interruption for transportation fuel for general public consumption at more than 50% fuel stations at any district in a given day	Number	0	0	0
Strategic Goal 3: Maximise Economic Spin-off from Energy Industry – boost local content and secure high participation of local workforce						
8	Local Content Spending in Energy Industry	Contribution from local industries and workforce in the provision of goods and services supplied to the energy sector in Brunei Darussalam	%	15	50	>80
9	Employment in Energy Industry	Number of employment in the energy industry	Number	20,000	30,000	50,000
		Number of locals working in the energy industry	Number	10,000	20,000	40,000
10	Local Companies Development	Number of local companies that have at least 40% of sales of goods and services generated from overseas market	Number	0	8	30

Source: Brunei Energy White Paper 2014, p. 12

2.3 Diversification issues

Diversification of exports away from primary commodities is argued to offer several benefits, from stabilised export earnings to the provision of sustainable economic growth in the long run. These benefits are discussed in various research studies cited in Hesse (2009).

Like many other hydrocarbon-dependent countries, Brunei is looking to diversify its economy. But what is ‘diversification’ and how is diversity measured?

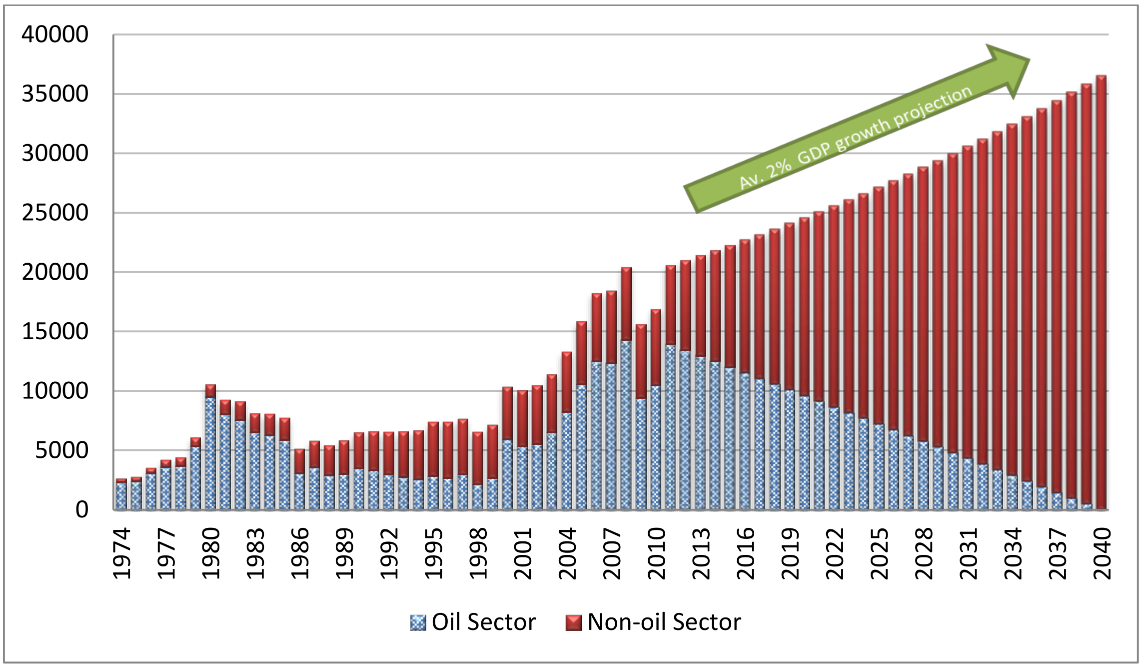
There is a range of definitions of ‘diversity’ from ‘the presence in an area of a great number of different types of industries’ (Rodgers cited in Wagner & Deller 1998), to ‘the extent to which the economic activity of a region is distributed among a number of categories’ (Parr cited in Wagner & Deller 1998), and to balance ‘employment across industry classes’ (Attaran cited in Wagner & Deller 1998). These definitions seem to imply that the more industries an economy has, the better. Does this apply to the case of Brunei? Diversity may not do much to the overall economic growth if the newly-introduced industries are too small in scale to be internationally competitive. Another factor to consider is that if the new industries are correlated to one another, there will be further exposure to risks that can affect these industries collectively in the economy.

Despite the different definitions and measures with regard to diversity and diversification, the objectives are clear in terms of achieving growth and stability of the economy (Wagner 2000).

It is not the intention of this thesis to come up with measures of how much industry diversity is ideal for Brunei’s economy. The objective is to use current development policy directions to determine if they are effective in generating economic growth while replacing the lost output from oil and gas.

The need for industrial diversification in Brunei is highlighted in Figure 2-8, which shows the contribution of oil and non-oil sectors to GDP from 1974 through to the present, as well as a forecast for the future. The contribution of the oil sector has fallen from a peak of 90.3 per cent in 1980 to 64.3 per cent in 2014 in terms of its share of the nominal GDP. This represents a decrease in contribution of about 1.1 per cent per annum on average for the oil sector within the period of 34 years.

Figure 2-8 Contribution of oil and non-oil sectors to nominal GDP (B$ million)



Source: DOS and author's projections (after 2014)

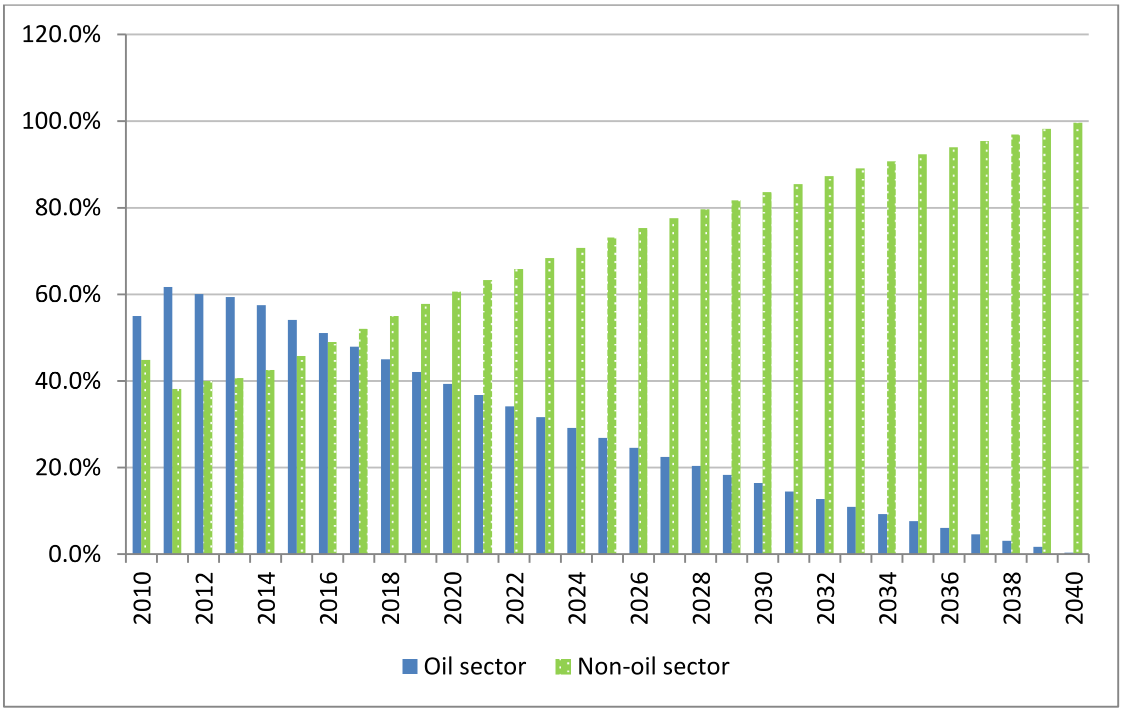
If Brunei were to diversify successfully by the year 2040, and not be dependent on its hydrocarbon sector, based on an average real GDP annual growth of 2 per cent to cater for a population growth of perhaps 2 per cent per annum, the non-oil sector will have to expand by an average of 6.4 per cent per year for 25 years[8] from 2015 onwards (see Figure 2-8).

Figure 2-9 shows the projected contribution of oil and non-oil to Gross National Income (GNI) expressed as a percentage. In the System of National Accounts (United

[8] Based on the calculation of $GDP_E = GDP_B * (1+k)^t$ where subscripts B and E denote the GDP at the beginning and end of the period respectively, k is the steady growth rate per annum and t is the number of years.

Nations [UN] 1993), GNI[9] is defined as GDP less primary incomes payable to non-resident units plus primary incomes receivable from non-resident units. Therefore, GNI at market prices is the sum of gross factor incomes on the capital, labour and natural resources receivable by Brunei resident institutional units or sectors. The shapes of curves in Figure 2-8 are consistent with those in Figure 2-9, in terms of contribution by the oil and non-oil sectors whether in terms of nominal GDP or GNI for the period after 2010.

Figure 2-9 Projected contribution of oil and non-oil sectors to estimated GNI



Source: Author's calculations

If we were to take into account the fact that some of the production factors of the oil sector are foreign-owned, then the future rate of growth of the non-oil sector that is required to replace the depleting oil and gas sector while leaving GNI share of GDP unchanged, might be lower than 6.4 per cent per annum. The income accrued to non-residents must be considered and to work out this portion, information is needed on royalty rates.

[9] GNI was formerly known as Gross National Product, GNP (United Nations 1993) and is a concept of income (primary income). It is used interchangeably with GNP in this thesis.

The World Trade Organisation states that, in Brunei, the petroleum and natural gas companies are subject to taxes of 55 per cent and 50 per cent respectively, and royalty rates range from 8 per cent to 12 per cent of production. Taking foreign ownership into account, it is estimated that 25 per cent of the net returns accrue to foreigners based on the present ratio of shareholding. The contribution of the oil and gas sector in terms of GNI was therefore only around 57.4 per cent in 2014. The GNI was estimated to be B$18,189 million in 2014 or 84 per cent of the GDP. With the same assumption of an average 2 per cent real growth per annum, using the same calculation, the non-oil and gas sector needs to expand by an average of 5.6 per cent for 25 years in order to replace the entire 57.4 per cent contribution from the oil sector. This rate of expansion is lower when compared to the earlier estimation of 6.4 per cent, since GNI is lower than GDP in terms of value due to the payments to non-residents.

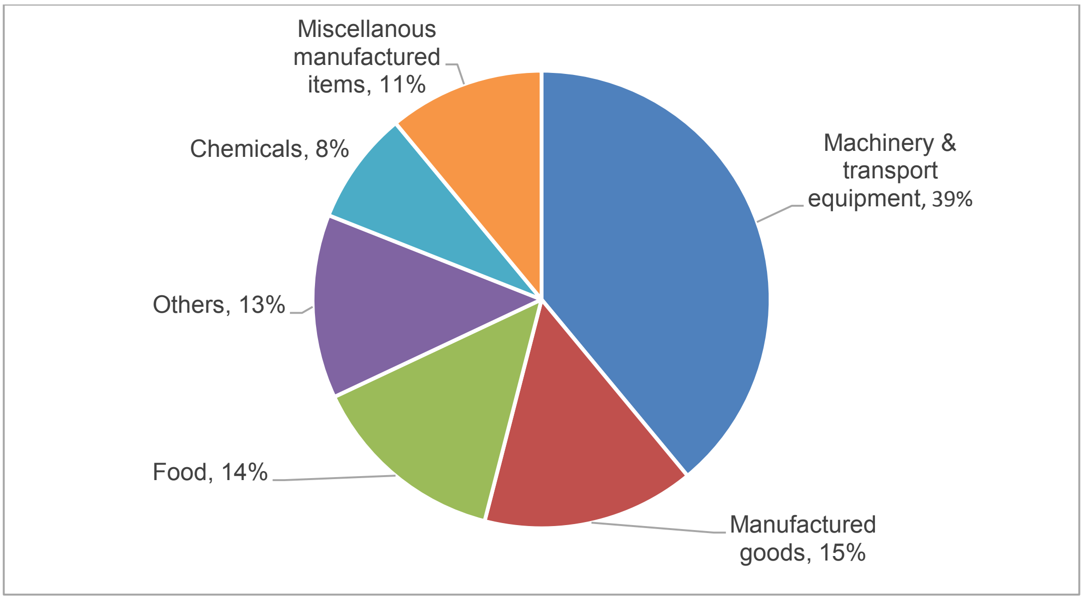
2.4 Initiatives and diversification efforts

Import substitution, export promotion and resource-based processing strategy are amongst the several avenues an economy attempts in order to diversify (Salah 1991). Brunei is attempting all three of these avenues, taking a multi-pronged approach towards diversification.

The immediate diversification approach undertaken to broaden the industrial base is to develop downstream industries, such as methanol, refinery and petrochemicals industries. This represents a resource-based processing strategy. There are also plans for developing an aluminium smelting facility (OBG 2014). These downstream industries and the aluminium smelter are utilising the comparative advantage of low cost and an ample supply of oil and gas. This is vertical diversification, which has little linkage to the rest of the economy with their imported technology and foreign capital investment. In this respect, there are limited productivity gains and spillover effects, similar to that observed by Cherif and Hasanov (2014) of the GCC countries' experience. Another issue is that the long term survival of these industries will depend on the availability of cheap oil and gas as feedstock or intermediate inputs.

Another diversification avenue being explored by Brunei is import substitution. Brunei imports most of its manufactured goods and necessities, such as food, rice and livestock, as shown in Figure 2-10. Import substitution is important to the government, especially on the grounds of food security. Although Brunei is sufficient in fish, vegetables, poultry and eggs, there has been limited success in terms of local rice production, as explained in Section 2.4.2.5.

Figure 2-10: Imports in 2014



Source: DOS (2015)

Brunei currently imports 95 per cent of its staple food, rice from Thailand, Vietnam and Cambodia. There is limited success in agriculture since less than one per cent of Brunei's total land mass is gazetted for agricultural use due to forest conservation (Wong 2014, OBG 2014). Labour is another resource constraint as there is not much interest among local youths to take up agriculture as a career. Consequently, most labour will have to be imported. Brunei is looking at less labour intensive methods and higher-yielding varieties of rice and cash crops.

Another avenue to diversify is through more exports of products other than oil and gas. Brunei needs to increase its production of goods and services and target export markets after meeting domestic demand. At present, Brunei does not have many manufacturing industries outside its oil and gas sectors. There is some success in aquaculture, with blue shrimps being exported to China, Hong Kong, Taiwan, South Korea and Japan (Oi 2014), but there are also challenges, which will be discussed in Section 2.4.2.5.

Besides looking at industrialisation, Brunei is also investing in various business ventures as a way of generating alternative sources of income, both domestically and overseas. The main and consistent diversification effort in terms of getting an alternative source of income is the conversion of the volatile hydrocarbon revenues into investment assets through its SWF by the BIA, as mentioned in Section 2.1. The BIA is tasked with generating a more stable stream of financial income for the country and its future generations.

Diversification efforts in Brunei have shown slow progress despite the various National Development Plans (NDPs) and development initiatives put in place (Tisdell 1998, Bhaskaran 2010, Lawrey 2010) to develop the non-hydrocarbon sectors. The reasons for this are many and are discussed as follows.

Past studies suggest that the lack of clarity in the diversification strategies (Cleary & Wong 1994) have made it impossible to track achievements (Hamzah 1980). Siddiqui et al. (2012) specifically mentioned other factors, such as the issues of land entitlement; lack of a clear immigrant labour policy; the slow decision-making processes of relevant authorities; the corporate tax structure and a possible lack of cohesion on overall development goals and the means to achieve these goals.

It is useful to track the progress of the strategies implemented. Voon (1998) attempted to measure the success of diversification in Brunei's economy for the period

1975 to 1995. Voon used the Herfindahl and entropy indices based on the growth of the primary (for example, agriculture, forestry, fishing, mining and quarrying), secondary (such as manufacturing and construction) and tertiary (including transport, trade, communication, banking, insurance, real estate, business services and public administration) sectors. He discovered that GDP growth was driven mainly by the secondary and tertiary sectors, which accounted for over 46 per cent of total output in 1995. However, the most significant growth came from the tertiary sector, which grew from less than 10 per cent of GDP in 1975 to over 40 per cent of GDP in 1995. This was largely due to the expansion of the government or public administration sector. Despite some growth of the secondary sector, mainly driven by the construction industry from 1970s onwards, there had been little industrialisation. In 1995, 80 per cent of the total GDP was dominated by two sectors: the oil sector and the government sector. Voon concluded that at that point, there was little incentive to diversify due to the oil boom of the 1970s and the vast amount of international foreign reserves accumulated.

2.4.1 Role of the government as a driver of the economy

Brunei's economy is characterised by a large public sector and a small private sector. Brunei shares a similar experience with GCC countries like Kuwait, Qatar and Saudi Arabia. Here, a state-led developmental model is practised with direct ownership of productive assets and large government budgets used to create both the supply and demand of goods and services (Hvidt 2013). Cherif and Hasanov (2014) argued that the failure to diversify away from oil in the case of the GCC is due to market failures stemming from "Dutch disease" rather than government failures. It is, however, the government's role to reform the incentive structure for workers to work in the private sector and incentives for firms to look beyond the domestic market to compete in international markets (Cherif & Hasanov 2014). High value-added industries and innovative sectors will also need to be targeted, besides creating infrastructure, implementing structural reforms, reducing regulations and improving institutions and the business environment.

One study found that the role of government is important in driving Brunei's economy (Anaman 2004). The government sectoral GDP contribution did indeed grow from 26 per cent in 2002 to 32 per cent of the total real GDP in 2011 (see Table 2-2).

Table 2-2: Share of expenditure components in real GDP for the period 2002 to 2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Personal consump-tion	24%	27%	31%	30%	30%	31%	32%	34%	34%	34%
Govt consump-tion	26%	25%	25%	25%	27%	31%	32%	34%	34%	32%
Capital formation	19%	15%	15%	15%	15%	18%	21%	22%	20%	20%
Exports	68%	67%	66%	65%	65%	59%	56%	54%	48%	55%
less: Imports	-39%	-35%	-36%	-37%	-37%	-42%	-47%	-48%	-46%	-51%
Statistical discrepancy	2%	1%	-1%	1%	0%	3%	7%	4%	10%	8%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: DOS various statistical yearbooks

The Brunei government drives the economy by allocation of resources to where they are needed. The private sector relies heavily on the government's financial assistance to develop, whether directly or indirectly. Besides facilitating industrial development, the Ministry of Industry and Primary Resources (MIPR) assists domestic farmers in the cost of production under Agriculture and Agrifood Incentive schemes (OBG 2014). Quasi-government corporate entities also help to facilitate the development of some industries, including the aquaculture industry and food processing (Golden Corporation n.d.).

The government also provides funds indirectly via some entities. Aureos (Brunei) Capital Limited, a private equity fund management company, manages about B$40 million of the Strategic Development Capital Fund (see Section 2.5.1); a trust sub-fund under the Ministry of Finance (MoF) initiative. Aureos has made some investments in

Brunei's small and medium enterprises (SMEs) to help them grow and contribute towards economic diversification (Goh 2011a). One of the investments is in Brunei's first pharmaceutical plant to produce Syariah-compliant products for export to the Muslim markets in Asia (Simpor Pharma 2015), as part of the diversification efforts.

Other organisations, such as the Brunei Economic Development Board (BEDB), run programs and schemes to assist in the development of industrial activities and help local businesses to expand and upgrade (OBG 2014). The Promising Local Enterprise Development Scheme is to help promising SMEs to transform into multinational corporations (MNC), including the provision of equity investment (OBG 2014). Therefore, government expenditure is expected to continue to grow in providing such industrial assistance and programs to develop the non-oil and gas industries.

Being the largest employer, providing around 50 per cent of the total compensation of the labour force based on the IOT 2005, the government has shaped the labour market in such a way that most Bruneians still have a strong preference for entering the public service (Duraman et al. 1998, Blomqvist 2010). This is due to the relatively attractive package of remuneration and benefits. The employment gap between the public and private sectors has been the topic of discussion for many years (Minnis 2000) but the structural issues remain unresolved. Tisdell (1998) proposed subsidising the employment of a Bruneian worker in the private sector through the resource rents received by the government. This, Tisdell argued, would not only bridge the employment gap but also reduce the reliance on guest workers. This idea is outlined further in Section 8.2.2 in the discussion of one of the simulation results.

Realising the need to grow the private sector, the government has provided several initiatives to incentivise private sector employment. These include the Apprentice Training Scheme through which private companies connect with various vocational and technical education institutions to take in selected graduates as local apprentices. These apprentices will receive some allowances for the duration of their apprenticeships, which can range from six to twelve months or beyond (Ng 2007, Thien 2012). The main focus is to develop a skilled workforce through practical placements.

To some extent, this has helped to increase youth employment. Nevertheless, the continuous rise in unemployment of Bruneian workers is not solely due to the preference of public sector over private sector jobs, but due to a mismatch of the skills required by the private sector (Cheong & Lawrey 2009, Koo 2014d). Unfortunately, this mismatch issue cannot be tackled effectively without industry-specific data to know the skills demanded by the market. The authorities are aware of this issue and sought technical assistance from the International Labor Organisation (ILO) in 2014 (Koo 2014d). Hopefully, with more detailed information on the Brunei labour market, better policies can be formulated to address the gaps.

Given such reliance on the government to drive the economy, any delay or inefficiency in the implementation of government development projects can impede not only economic development (Haji Hashim 2010) but also lead to low economic growth. However, a large government can breed bureaucracy and red-tape, cited as one of the hindrances to the slow progress of economic diversification (Bhaskaran 2007, Crosby 2007).

2.4.2 Current policy directions

Brunei appears to have adopted a similar path to the GCC in efforts to diversify its economy through industrialisation. Within the GCC, Bahrain has successfully diversified into the manufacturing sector, accounting for 15 per cent of its GDP, and has, according to Meed (2014), the world's largest aluminium smelter plant, contributing 10 per cent of its GDP. Bahrain has also branched out into finance, real estate and business activities (Asian Productivity Organisation [APO] 2013). Saudi Arabia, Oman, Kuwait and the UAE have installed steel pipes manufacturing facilities to reduce their import dependence and to meet export demand, as well as encourage job creation (Frost & Sullivan n.d.). The GCC is a net importer of iron and steel products mainly driven by their construction activities and development in infrastructure (Frost & Sullivan n.d.). During the period 2000-2010, 60 per cent of the economic growth of Oman originated from the services sector (APO 2013), indicating success in diversifying away from its oil and gas industries.

The following sub-sections summarise Brunei's current efforts to diversify through industrialisation. The sub-sections are organised according to broad industry type.

2.4.2.1 Downstream industries

The government is focusing its efforts in the *medium term* on developing activities downstream from primary oil and gas production. This is to capitalise on Brunei's comparative advantage of readily available resources as inputs for these industries, at least over the next 20 or so years. The BEDB is looking at extending the oil and gas value chain focus on petrochemicals, oil refining and storage facilities (OBG 2011), and is seeking to attract more FDI in pursuit of this aim.

One of the largest downstream projects is the Brunei Methanol Company (BMC), set up in 2006 as a JV between Mitsubishi Gas Chemical Inc., PetroleumBRUNEI and ITOCHU Corporation (Brunei Methanol n.d.) at the Sungai Liang Industrial Park. It started production in 2010 and produces methanol as a higher added value product for export. As of 2014, the export value of methanol was B$256.7 million or around 1.7 per cent of total exports from Brunei. This may have achieved some form of immediate diversification in terms of the variety of industry and exports. However, in order to achieve effective *long term* diversification, downstream industries like these must be complemented by other types of industries that have no direct connection to oil and gas. Methanol started as an industry with a competitive advantage because of Brunei's own production of natural gas, which helped lower intermediate input costs. However, this advantage is not sustainable given the depletion of natural gas, unless Brunei is prepared to import natural gas to maintain the methanol industry.

The BEDB is also facilitating the development of a large island off the Brunei mainland called Pulau Muara Besar (PMB) where there is on-going work to set up a mega-port, a refinery and an aromatic cracker plant. However, as with the methanol project, the refinery and aromatic cracker plant also rely on supplies of oil and gas. The PMB project (Kasim 2014) has been delayed and production will not start until at least 2017.

2.4.2.2 Financial sector

The financial sector is another cluster identified in past studies as having the potential to grow. In terms of total GDP, the financial services sector share of contributions grew from about 3 per cent in 2006 to 4.3 per cent in 2014. Any policies directed at this sector can affect not just the sectoral growth, but also potentially some economic growth. Due to the linkages of the financial sector with other sectors of the economy, some knock-on effects can be expected. The following sections describe one such example of a directive issued by the central bank, the Autoriti Monetari Brunei Darussalam (AMBD), which did affect the financial sector.

In 2013-2014, the financial sector had a set back in terms of profitability due to the introduction of interest rate controls in March 2013. The AMBD imposed the maximum lending rate (for most financing including residential, personal and corporate loans) at 4.5 per cent per annum and the saving deposit rate at a minimum of 0.15 per cent per annum (Too 2013b). The rationale for the caps notices issued in March 2013 was to facilitate credit access, ensure adequate returns to depositors and support long term diversification plans (Autoriti Monetari Brunei Darussalam [AMBD] 2013a). The policy statement declares that the objective of this intervention relating to interest rates is to spur "the growth of productive credit in the economy, thereby supporting the country's economic diversification goals towards Wawasan 2035" (AMDB 2013a, p.2).

In their country assessment in June 2013 the International Monetary Fund (IMF 2013) warned about the potential negative impacts on financial intermediation as profitability is squeezed. The access to credit may be reduced, as banks are less able to adjust loan pricing to reflect risk (Kasim 2013). More than a year after the implementation, the impact of these interest rate controls on the financial sector became apparent with the exit of an international bank from Brunei's financial sector.

Prior to this drastic measure, there were eight banks in Brunei consisting of two local banks and six branches of foreign banks. In March 2014, Citibank, one of the oldest foreign banks, exited Brunei after 41 years of banking business, citing their reasons as the challenge of interest rate caps on lending products (Too 2013c). The exiting of Citibank and possibly other foreign banks from Brunei does not come as a surprise. Big international banks such as Citibank and HSBC have been scaling back their operations in Asia since 2012 (Davies 2012, Arnold & Hall 2014) to focus on profitable and key growth areas. Brunei is not seen as a profitable market, especially with the introduction of interest rate caps, which certainly seemed to hasten their exit. Profitability is a key for the survival of the banking business.

As Brunei implemented Syariah Law in May 2014 (Othman 2014, Bandial 2014b), the push for Islamic banking has become even stronger. This is likely to reduce the market share of conventional banks further unless they adapt. As of 2013, the two Islamic banks in Brunei owned 41 per cent of total banking assets (OBG 2014) and the idea of fully replacing conventional banking with Islamic banking has been mooted at an international Islamic finance conference (Shahminan 2013a).

There are linkages between the financial services sector and other sectors in the Brunei IOT 2005, including the building and construction-related industries. For the banks, as of the end of 2013, the residential loan sector was the second largest lending business, at 22.4 per cent, after the personal loan market share of 30.9 per cent (AMBD 2014a). Banks in Brunei reacted to the interest rate rule by freezing mortgage lending for a period, as they had to restructure their products given the squeeze in profit margins due to the interest rate ceiling (Too 2013a). Some of the banks reduced their financing amount to a maximum of 70 per cent, shortened the repayment period to 10 years and also took away subsidies on land valuation, insurance and associated costs (Too 2013b). Given the significance of residential loans in home ownership, this had a knock-on effect on the construction sector.

Subsequently, in a policy statement released by the AMBD, the interest rate cap on residential loans was lifted, effective from October 2014 (AMBD 2014b) and banks were free to set their own lending rates. Table 2-3 provides an interesting snapshot showing the surge in the finance sector's contributions to GDP in the last quarter of 2014 when this interest rate control was lifted. The construction sector also recovered in the same quarter after three consecutive negative growth rates in 2014. This highlights that a sector-specific policy cannot be implemented in isolation without potential repercussions in other sectors of an economy.

Table 2-3: Quarterly growth rate of finance and construction sectors by GDP contribution measured at constant prices

	Q1_2013	Q2_2013	Q3_2013	Q4_2013	Q1_2014	Q2_2014	Q3_2014	Q4_2014
Finance	4.7	4.7	3.5	7.5	-8.1	5.3	1.6	14.0
Construction	2.7	3.1	2.8	3.3	-23.2	-45.3	-11.4	1.7

Source: DOS (2014d, 2015c)

There is opportunity to grow the financial sector by diversifying away from lending products into investment products. Currently Brunei's financial sector offers limited investment products for consumers and businesses. There is no stock market in Brunei for equity investment. The only types of domestic bonds issued are the government's Islamic short term bonds called 'sukuk' which are not traded and are mainly held by the banks until maturity as part of their liquidity requirements. When a secondary market is established and companies start to raise funds through issuing corporate bonds instead of borrowing from banks, a more vibrant capital market can be created. The AMBD has plans to set up a local stock exchange to boost financial activity and to increase the financial sector's contribution to total GDP (AMBD 2015). There is room for more education and awareness for consumers and businesses in capitalising on the workings of the financial markets.

In terms of ancillary services, the finance industry has a unique role in providing advice on financial management and strategies, as well as giving tailored advice on savings and investment products (Blancher 2006). At the national level, financial education can be part of the economic development strategy (Hogarth 2006) and through financial literacy, economic welfare gains can be achieved (Dixon et al. 2010). Since financial knowledge is a form of human capital (Lusardi & Mitchell 2014), the government has an important role to play in raising the overall financial literacy of its people.

At the household level, despite the high income per capita in Brunei, individual savings levels are low. Household indebtedness remains high and financial literacy is low. A recent survey shows that out of 1,521 households, there is high dependency on personal loans for purchases. Findings revealed that 24 per cent of households needed loans to finance daily necessities, 34 per cent did not plan for their expenditure, 49 per cent did not possess active savings and 32 per cent were not aware of the interest rates applied on their credit cards (Kasim 2015c). Financial literacy is important for keeping families away from poverty. To this end, the AMBD made efforts, through the establishment of the Credit Bureau in 2012, to provide clients with access to credit information for better risk management (AMBD 2013b). The AMBD also utilises ICT (information and communication technology) through the introduction of a smartphone application to disseminate useful information to the public and to promote financial awareness and improve financial literacy (AMBD 2015).

The financial sector also extends corporate lending to businesses. In the context of SMEs, in order for their businesses to thrive and be sustainable it is important for entrepreneurs to be financially savvy and to possess a certain level of financial literary in order to manage their finances. There have been recent drives to build up financial awareness at educational institutions in the country. Eventually, with better financial education and awareness among the general population, the financial sector will be able to grow further to meet demand of the customers in terms of products and services.

The growth of the financial sector can contribute to the overall economic growth of Brunei and the process of economic diversification.

2.4.2.3 Tourism

Past studies also identified tourism as a potential sector for future growth in Brunei (Tisdell 2002, Monitor Group cited in Crosby 2007). However, as an alternative sector for economic diversification, tourism has been performing poorly and there has been little increase in the number of *bona-fide* tourists[10] over the past few years (Thambipillai 2015). Ahmad (2014) conjectures that it is a deliberate government policy to have a reasonably small-scale yet sustainable tourism industry rather than promote mass tourism. This observation is due to the government's commitment to maintain its pristine primary rainforest and preserve the bio-diversity through the Heart of Borneo initiative, where 58 per cent of the forests are to remain protected (Ahmad 2014).

With the implementation of Syariah Law, which may deter some tourists due to the strict Islamic code, Brunei has to look at niche tourism, such as ecotourism and culture, heritage and history. With a small annual budget of under B$1.6 million (Shahminan 2015) or 0.027 per cent of the total budget allocated by the government, this sector is not expected to grow significantly without concerted efforts from both the

[10] There is a large number of international transit passengers passing through Brunei airport on connecting flights and those driving through Brunei enroute to Malaysia on daily basis. They generally do not stay in the country long enough to spend on goods and services.

government and the tourism industry. According to Ahmad (2014), the tourism industry in Brunei appears to be lacking in knowledge and understanding of the concept of ecotourism and environmentally sound practices. This needs to be addressed through education and awareness. Despite the limited budget allocation, the recent change of ministry name in October 2015 from the “Ministry of Industry and Primary Resources” to the “Ministry of Primary Resources and Tourism”, indicates a renewed focus on tourism as an area of potential growth (Wasil 2015).

2.4.2.4 Other manufacturing

Based on the country’s reputation for strict adherence to halal standards, Brunei is actively pursuing a Brunei halal brand to serve the growing global demand for halal-certified products (OBG 2014). A 500-hectare halal industrial park called the Bio-Innovation Corridor (BIC) has been earmarked to pursue halal-certified production of commodities such as food, cosmetics, herbal medicines and pharmaceutical products. Brunei is actively looking for partnerships in the BIC development (OBG 2015).

In 2013, a B$26 million manufacturing facility was set up with plans to produce halal pharmaceutical products for export to Muslim markets in Asia. Simpor Pharma Sdn Bhd is a joint investment between Canadian firm Viva Pharmaceutical Inc, private equity fund Aureos (Brunei) Capital Sdn Bhd and a group of local investors (Abu Bakar 2014). This pharmaceutical company has been certified to comply with Health Canada’s Good Manufacturing Practise requirements for pharmaceutical products and health supplements. Simpor Pharma has manufactured and sold some products for the domestic market (Siti Hajar 2015). At the point of writing, it has not started exporting its products (Kasim 2015e).

2.4.2.5 Agriculture, aquaculture and food production

Recently, the Brunei Government has been working on many projects to develop Brunei’s agriculture, fisheries and aquaculture sectors. These include prawn and grouper farming industries, to meet both domestic demand and for exports. Biomarine was established in 2008 as a JV between the Department of Fisheries at the MIPR and China's Guangdong Provincial Oceanic and Fisheries Administration (Abu Bakar 2012). In October 2012 it began exporting live farmed hybrid grouper to Hong Kong, as well as supplying fresh fish to the domestic market.

Aquaculture is subject to several challenges. One key challenge is to have a stable supply chain to meet export demand continuously, such as that faced by Jindo Sdn Bhd, a Brunei and South Korean JV company that exports shrimps. In 2013, Jindo secured a deal with Lotte Co Ltd, a MNC specialising in the food industry, to export 3,000 tonnes of shrimps to South Korea. However, the owners were concerned about meeting the large order volume of this client and other potential clients. They worked on pulling resources together from neighbouring suppliers, such as Sabah, Johor of Malaysia and Kalimantan of Indonesia, in order to meet export demands (Shahminan 2014b).

The Golden Corporation is a local seafood processing and exporting company. Despite having its own fishing fleets, aquaculture farms and access to supplies from neighbouring Malaysia, it is reported to have issues with the supply of raw materials, limiting its operating capacity to only 20 to 30 percent (Kasim 2015d). The availability of a steady and consistent supply of raw materials appears to be the stumbling block for these industries.

There has been no significant success in agriculture due to resource and capacity constraints. Although sufficient in certain food products, like vegetables, fish, poultry and eggs, the local rice production is still short of meeting the targeted 60 per cent required for self sufficiency (Abu Bakar 2011) by 2015. As of 2011, only 4.4 per cent of annual demand was met by local rice production. This is partly due to lack of available land, reliance on foreign labour and lack of infrastructure (OBG 2014). The MIPR has been working on strengthening institutional structures and maximising agricultural land use while pursuing the adoption of better technology and developing export potential (OBG 2014). The chief executive officer of SME Corporation Malaysia is quoted to say that conventional agriculture “is not the right strategy for economic diversification” for Brunei due to its insignificant contribution to replace oil and gas (Shahminan 2014a).

Aside from primary industries, in 2012, the government began focusing on encouraging the establishment of tertiary institutions, such as the CAE-Brunei Multi-purpose Training Centre. This centre is a B$100 million JV between Canadian-based CAE and Brunei’s MoF, providing helicopter-specific mission training, including offshore oil and gas, search and rescue, and other types of operations. It is also a comprehensive Emergency Management and Crisis Management Centre of Excellence that will support disaster preparedness for Brunei and other ASEAN nations (Koo 2014a). It has some existing customers from BSP, Australia and China (CAE 2015), but it is still too early to tell if this centre can provide a niche growing service industry for Brunei.

The recent activities in the pharmaceuticals industry, with various JV projects, including the BMC, had, up to 2014, not generated any significant revenues for the country. Other activities are in different stages of implementation and are yet to yield reportable results.

Overall, therefore, at present no single industry stands out as the potential replacement to match the income derived from oil and gas exports into the future.

2.5 Sovereign Wealth Funds

As mentioned in Section 2.4, SWFs represent one diversification approach used to generate alternative income streams for Brunei. SWFs are government-owned funds that can be set up for a number of purposes. The IMF (2008) identifies five such purposes: (i) stabilisation funds, where the main objective is to insulate the budget and economy against volatility in commodity revenue flow (usually oil); (ii) saving funds, where a proportion of the non-renewable assets' revenues is saved and invested into a diversified portfolio of assets for future generations; (iii) reserve investment corporations, where the assets are often regarded as reserve assets, established to increase returns; (iv) development funds to help fund socioeconomic projects or to promote industrial policies that might increase the country's output growth; and (v) contingent pension reserve funds, allocated on the government's balance sheet to provide for contingent unspecified pension liabilities.

Although traditionally most SWFs invest in foreign assets, there is a recent trend in resource-rich countries to focus more on domestic investments in infrastructure (Gelb et al. 2014). Gelb et al. (2014) note in this context that it is important to have a system of checks and balances in place to ensure that the SWF does not undermine macroeconomic management or become a vehicle for politically-driven domestic investments.

Unlike traditional reserves, which are typically invested in safe and liquid assets, SWFs seek higher rates of return by investing in a wider range of assets that can increase their risks and provide wider geographical dispersion (Bahgat 2008, IMF 2008a). The source of the foreign exchange funds can come from commodity funds, from commodity exports, either owned or taxed by the government, or from non-commodity funds, transferred from official foreign exchange reserves.

Compared to other nations, Brunei's SWF input is relatively small (Sovereign Wealth Fund Institute [SWFI] 2015a), with little influence on the international financial market. It is, however, significant enough to affect the fate of Brunei. Although the BIA discloses little information on their holdings, it is believed that the portfolio is well-diversified into different asset types, including public and private companies, real estate and currency portfolios (SWFI 2008a). The SWFI estimated that the BIA has about US$40 billion or about US$73,388 per capita (SWFI 2008b). According to the Linaburg-

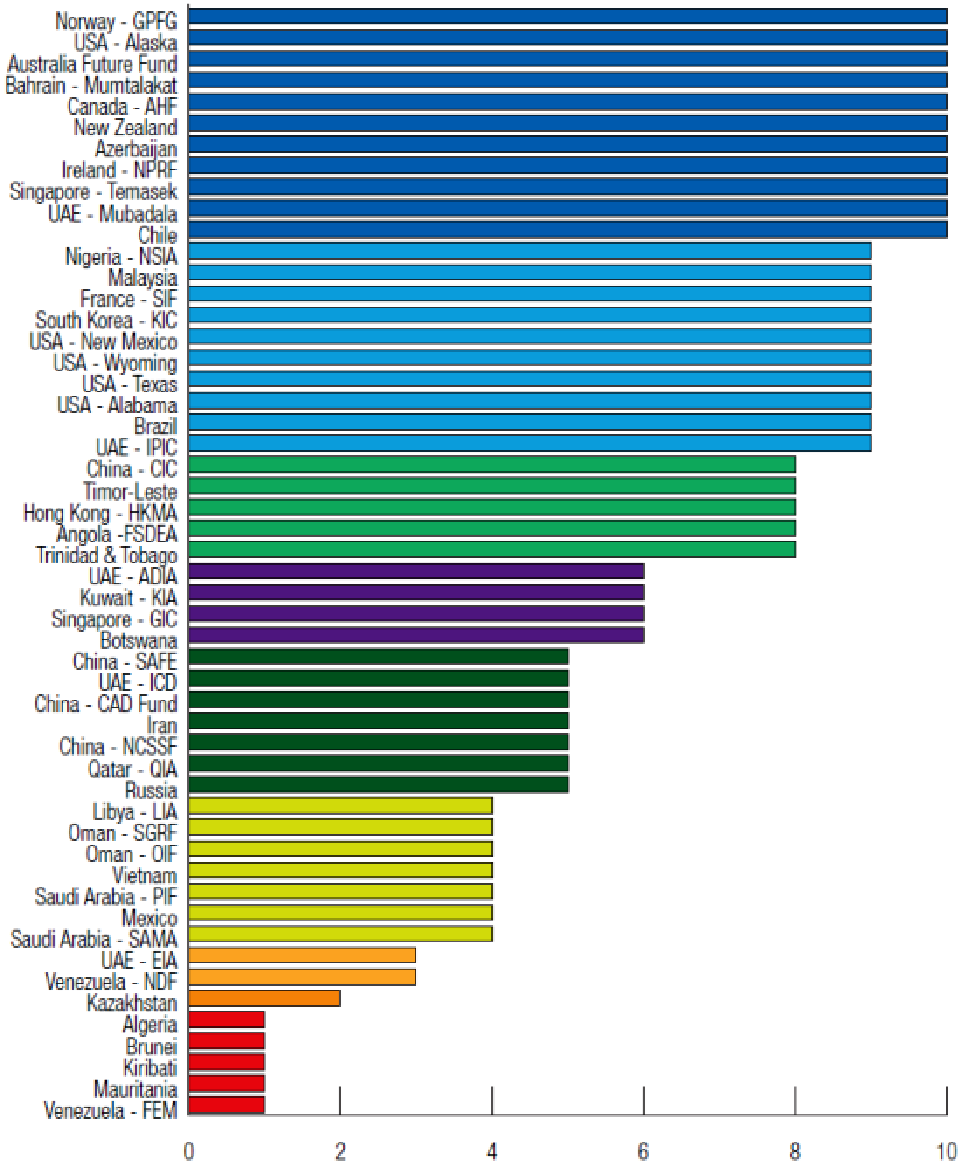
Maduell Transparency Index measuring transparency of SWFs, the BIA is one of the least transparent SWFs, with a rating of one compared to other similar economies in the GCC which have ratings of at least three (see Figure 2-11). To be regarded as adequately transparent, a minimum rating of eight must be achieved (SWFI 2015b).

Brunei's SWFs are estimated to be worth about US$30-$40 billion by different sources other than the SWFI, such as the IMF (2008) and the Investment Management Institute (2012). Gooptu et al. (2008) suggest that a fund size of US$60-$75 billion is more likely with an accumulation rate of US$15-$20 billion per year during high oil prices. De Vienne (2015) suggested that the value of the SWF under BIA's management was between US$170-$200 billion in 2011, based on her projection of market return on capital.

To have some idea of the fund size relative to the population, one can measure SWF on a per capita basis. The SWF size of other GCC countries in relation to the population is shown in Table 2-4. Even with a conservative estimate of US$40 billion, Brunei has a reasonably large fund on a per capita basis. De Vienne (2015) worked out that with an average profitability of 2.5 per cent, Brunei's SWFs would be able to generate 28-30 per cent of Brunei's GDP in 2011.

Into the future, although Brunei's SWFs can continue to generate income for the country and contribute significantly to the growth in GNI, it is unclear if the financial returns will be large enough to replace the lost revenues from oil and gas in entirety. The economy still needs to generate productive activities in providing goods and services from the real sector, both for economic growth and to provide employment.

Figure 2-11: Linaburg-Maduell Transparency Index ratings as of 2nd Quarter 2015 for sovereign wealth funds



Note: Higher number indicates more transparency
Source: Sovereign Wealth Fund Institute (2015b)

Table 2-4: Sovereign wealth funds per capita of GCC countries as of August 2015

Country	Bahrain	Kuwait	Oman	Qatar	Saudi Arabia	UAE (Abu Dhabi, Dubai, Federal)	Brunei*
Fund size (US$billion)	10.5	592	6	256	677.1	1,214.8	40
Population (million)	1.222	4.11	4.227	2.414	31.386	9.581	0.419
Funds per capita (US$)	8,592	144,038	1,419	106,048	21,573	126,792	95,465

Source: Author's calculation based on the SWFI for fund size and the IMF (2015c) for population

2.5.1 Other reserve funds

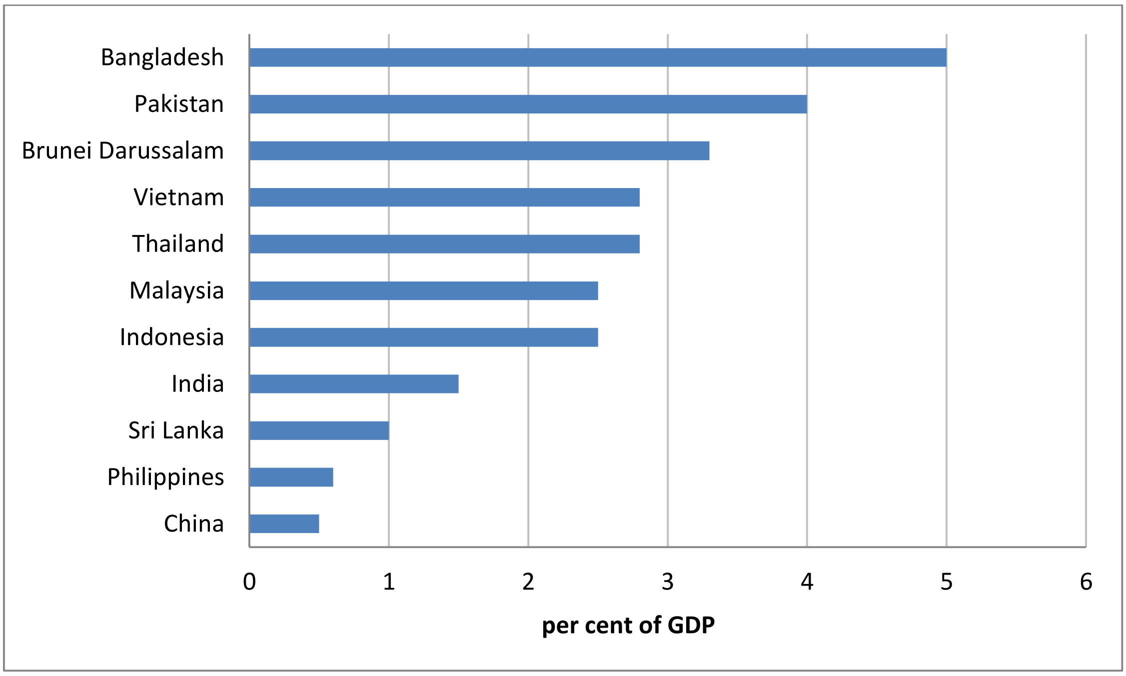
Brunei has other reserve funds in place, besides SWFs, to cater for other purposes. The state of government finances has to be managed in the light of declining oil and gas revenues. To streamline the allocation and usage of funds, in addition to the SWFs, the MoF has set up other funds for ensuring the long term sustainability of government finances (Sustainability Fund Act 2008). These funds include a government trust fund called the Sustainability Fund (SF) and several trust sub-funds: the Fiscal Stabilisation Reserve Fund (FSRF), Retirement Fund (RF) and the Strategic Development Capital Fund (SDCF). The Consolidated Fund (CF) managed by the MoF remains the overarching fund into which all revenues and monies received by government are paid (Constitution of Brunei Darussalam, 1959 revised edition 2011).

The main purpose of the FSRF is to provide monies to the annual budget to eliminate or reduce the shortfall of oil revenues. This is the buffer set up to avoid tapping into SWFs. The RF on the other hand is to fund all pensions and gratuities, and employee provident funds. The SDCF provides risk capital for strategic domestic investment for economic growth and diversification through local development and broadening of the revenue base. Any of the returns on investments made by these trust sub-funds may be transferred back to the CF. Governance of these funds through various boards and committees, is established according to the Sustainability Fund Act and funds must be audited. The Auditor General and the subordinate staff have access to all documentation in order to audit Brunei's accounts. These are then reported to His Majesty the Sultan who may decide to present these reports to the Legislative Council.

2.6 Fiscal burden

The revenues from oil and gas enable the government to provide funds for industrial assistance as described in Section 2.4.1, to finance for government consumption and to provide many generous subsidies to its people. These subsidies are for rice, sugar, water, electricity, fuel, education, healthcare and housing. The subsidies constitute a large fiscal burden on the government. In 2010, the government provided energy subsidies of nearly B$1 billion (Bandial 2012) and electricity subsidies of about B$40 million (Goh 2011b). The Asian Development Bank (ADB 2013) reported that Brunei's fuel subsidy was over 3 per cent of its total GDP in 2010 (see Figure 2-12). This is one of the highest in Asia, and considering Brunei has one of the smallest population in the region, the subsidies per person are relatively large.

Figure 2-12: Fossil fuel consumption subsidies as a percentage of GDP in selected countries (2010)



Source: ADB (2013)

Brunei has limited sources of revenue outside of oil and gas and its SWFs to finance its fiscal expenditure, including these subsidies. There are no personal income taxes and no goods and services tax (GST). The corporate tax rate (18.5 per cent in 2015) and import tariff rates are low and do not raise large alternative revenues. Therefore, with the declining oil and gas revenues, the government may not be able to afford giving out these generous subsidies without alternative sources of income. In turn, the standard of living will be affected as households face higher costs without the support of subsidies.

In January 2012 a new progressive electricity tariff was introduced to influence the behaviour of energy conservation and to redistribute the benefits of electricity subsidies. Under this new tariff scheme, a cheaper rate is charged up to a certain threshold. After that threshold is reached, a higher rate is charged as consumption increases. Koh (2014) evaluated the welfare impact of this policy change on different income deciles of households. He concluded that 80 per cent of all households benefit from this new tariff with the poorer households gaining more with this progressive tariff compared to the old tariff. He found that under the new tariff, the total electricity subsidies remain largely unchanged and the non-poor households continue to enjoy a significant proportion of these subsidies. Koh (2014) suggests that the non-poor households should cross-subsidise the poorer households in order to reduce the fiscal burden of that electricity subsidy by half. In Koh's study, due to data limitations, the assumption of zero price elasticity and unchanged total electricity consumption leads to non-reduction of the fiscal burden.

Besides cutting expenditure, there are other ways to reduce the fiscal burden by broadening the revenue base and reviewing the subsidies (IMF 2010). This may be achieved through a progressive personal income tax[11] or the introduction of a more broad-based consumption tax like GST.

Subsidy reform is another way to reduce the fiscal burden. This has been implemented successfully in several countries, such as India (Verma 2014), Malaysia (Adam & Pakiam 2014, "Malaysia cuts fuel subsidies," 2014) and Indonesia (Wulandari et al. 2014). Subsidy cuts have worked in these countries because of clear communication to the public and due to good timing. Advantage was taken of the small window of opportunity when international oil prices were low, so that households were not hit as hard compared to when the market price was much higher.

More thorough analysis, especially relating to the impact on households, is required before such reforms or taxes are implemented in Brunei.

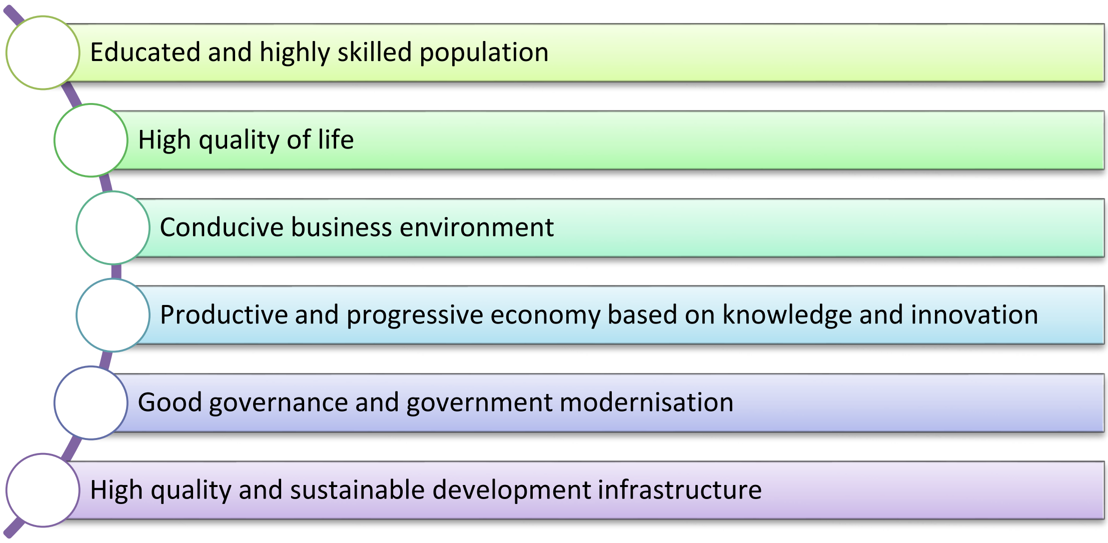
2.7 The Tenth National Development Plan (2012-2017)

This thesis draws upon some of the policy directions stated in the latest NDP (2012-2017), known, in short, as the RKN10. The RKN10 is the second in a series of five-year plans under the Brunei Darussalam Long Term Development Plan (LTDP 2007-2035) set out by the Council for Long Term Development Plan (2007). Each of these five-year plans outlines the programs for national development in the form of physical infrastructure and social development. The latest RKN10 has set a high target of 5 to 6 per cent per annum for real GDP growth to realise the *Wawasan Brunei* 2035 (DEPD 2012). This is a tall order given Brunei's recent low economic growth and with declining oil and gas resources. The RKN10 recognises that significant structural change will be needed and it sets out plans to improve productivity in both the government and private sectors and through existing and new industries.

[11] The personal income tax rate is nil at the moment and is a politically sensitive issue in Brunei.

The six strategic development thrusts listed in the RKN10 are shown in Figure 2-13.

Figure 2-13: The six strategic development thrusts of the Tenth National Development Plan

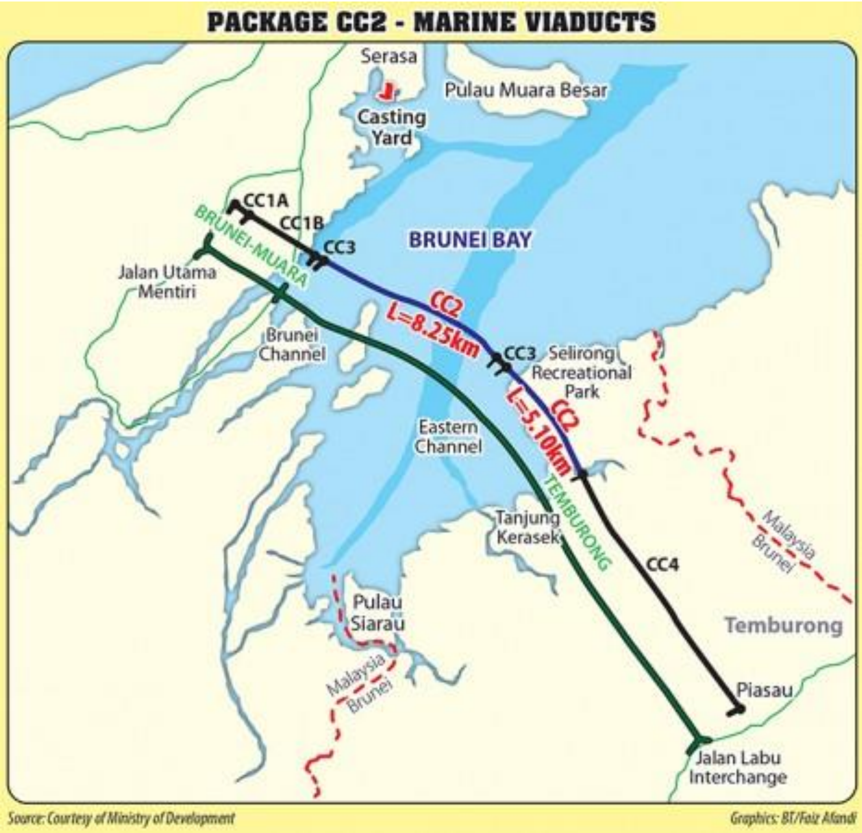


Source: DEPD (2012, p.44)

Some current infrastructure projects include the complete roll-out of the fibre-to-the-home broadband project[12]; the expansion of the international airport; and a bridge connecting across the Brunei Bay to the mainland to cut down commuting time for residents living on the Temburong side (see Figure 2-14). A second bridge that allows an alternative route of traffic to and from Malaysia, the Pandaruan bridge (Malaysia-Brunei Friendship Bridge), was completed at the end of 2013 (Kassim 2013) directly connecting a nearby Malaysian township, Limbang, and Temburong on the Brunei side (see Figure 2-15). Brunei and Malaysia have close trade links and there are also Malaysian guest workers in Brunei.

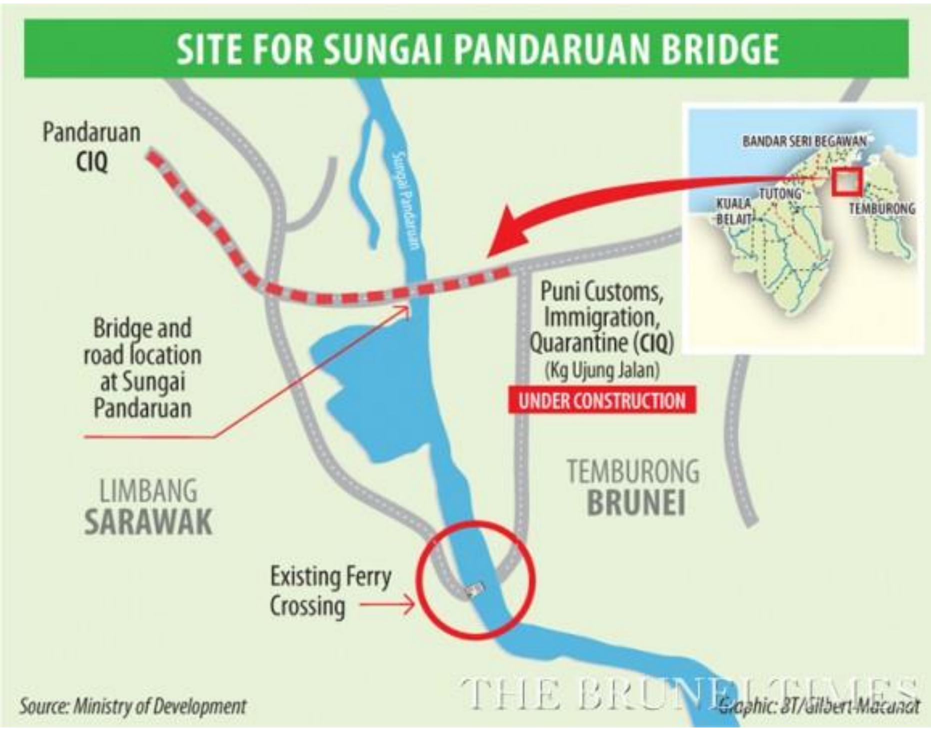
[12] The fibre-to-the-home broadband initiative is one of the largest projects under the Tenth National Development Plan and targets to achieve 85 per cent coverage by 2017 (Too 2012b).

Figure 2-14: Temburong bridge



Source: Koo (2015)

Figure 2-15: Pandaruan bridge connecting Brunei and Malaysia



Source: HAB (2011)

Based on the current developments discussed in Sections 2.4 and above, several industries are identified as having the potential to generate economic growth through diversification efforts. These industries are construction-related, downstream industries and the government sector. This is further discussed in Chapter 7 in the context of modelling.

2.8 Data concerns

An important limitation of any quantitative study of economic issues in Brunei is the availability of data. Despite the government's drive into the field of research and development, most ministries and departments[13] still do not publish statistics and data for research purposes.

The main source of statistics for this study is the DOS under the DEPD. Most of the journal articles relating specifically to Brunei use historic data and there is inadequate data or information about the future. Where expert forecast is not available, some conjecture will be required for building the baseline forecast. Therefore, for the purpose of this thesis, some references are drawn from current affairs based on press releases, newspaper articles, unpublished reports, as well as more current reports by third parties such as the Oxford Business Group (OBG) and the IMF Article IV Mission. These third parties have access to government departments and the private sector in Brunei through which they are able to gather data and information.

2.9 Conclusions

This chapter has provided an overview of Brunei's economy. The country is highly dependent on its oil and gas and provides extensive subsidies to its people. Despite some diversification efforts, there are challenges to develop other industries outside oil and gas. There are insufficient alternative sources of revenue from non-oil tax revenues

[13] Even via personal communication, information is not always made available.

and non-oil exports to replace the declining oil and gas sectors. The current focus is on downstream industries, which may not be sustainable in the long term.

Brunei does have its SWF, but it is unclear if the returns generated from the fund will be sufficient to last for many generations should Brunei “run out” of oil and gas. Brunei cannot rely on the SWF returns and needs to generate productive activities to create export earnings and sustainable income for its economy.

Despite the heavy fiscal burden shouldered by the government, there is some reluctance to introduce reforms to reduce subsidies due to uncertainties about the impact on lower income households. Some measures, such as progressive electricity tariffs, have been introduced recently but their impact on reducing fiscal expenditure may not be significant.

One of the main aims of this study is to assess the effectiveness of the existing diversification efforts in generating economic growth. Evaluation of the policy impact, however, requires a functional database (Chapter 3) and a model (Chapter 4).

Chapter 3: Theoretical structure of BRUGEM

A CGE model consists of two components: the theoretical structure and a database. This chapter aims to describe the theoretical structure of BRUGEM, the core economic model used in this thesis; Chapter 4 will elaborate on the database. The first section of this chapter provides a brief overview of BRUGEM and its relevance to this study. Section 3.2 gives an overview of the model's core theory covering the main behavioural assumptions and relationships in the model. Section 3.3 details the model theory, including the specifications of each economic agent, how decisions are made, and how demands for factors of production, intermediate inputs and outputs are formed. Section 3.4 describes dynamic aspects of the model. Some requirements that need to be considered in closing a model are explained in Section 3.5. Section 3.6 completes the chapter with some concluding remarks.

3.1 Introduction

BRUGEM is the dynamic CGE model used in this thesis. This model traces its roots back to the legacy of Leif Johansen who developed the first CGE model in 1960. Unlike the Leontief's IO model, which depicts industries in complementary relationships where good news in one industry will positively affect other industries, Johansen's model shows, in a more realistic world of resource constraints, that competitive relationships exist and there are trade-offs between resources. Dixon et al. (2013) explained how Australia's first CGE model, ORANI, and its successor, the MONASH model, were developed and improved using Johansen's ideas. The five innovations of the MONASH-style models include the following:

(i) the multi-step solution method to eliminate linearisation errors;

(ii) the adoption of imperfect substitution between domestic and imported varieties of the same commodity and downward sloping foreign demand curves;

(iii) the detailed specification of margins and taxes;

(iv) flexible *closures*[14]; and

(v) the use of complex functional forms to specify production technologies.

A distinguishing feature of a Johansen-style model is that the underlying non-linear set of equations in the levels of variables are solved as a system of linear equations in the changes (percentage or absolute) of variables. A change representation can be more transparent compared to a levels representation.

To cope with the enormous volume of results generated, MONASH modellers use stylised BOTE models in interpreting the macro results by locating the main mechanisms underlying the dynamic models.

To ensure that simulation results are sensible, a validation test is often performed. Dixon and Rimmer (2013) suggested the use of validation tests to check that the mechanisms built into the model adequately represent how the relevant parts of the economy behave, as well as to demonstrate that the results obtained have been computed by the model correctly and consistently with the model theory and data.

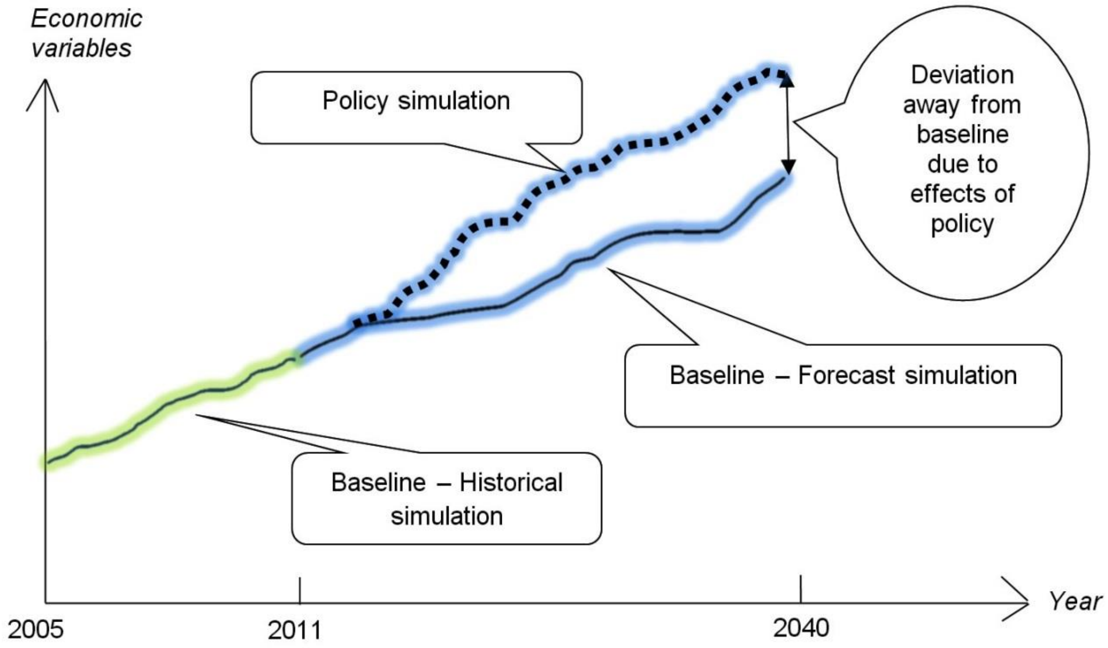
Flexibility of *closure* is one of the strengths of MONASH-style models, offering the user a choice to allocate variables between endogenous and exogenous settings depending on the research question. To meet the growing demand of policy analysis, MONASH modellers have developed four techniques of analysis: historical, decomposition, forecast and policy.

Historical simulations are used to update IO data and to estimate the historical trends of certain unobservable variables such as technologies, preferences and other typically exogenous variables. With the use of these estimates, decomposition

[14] A typical CGE model has more variables than the number of equations. In order to solve the model, we need to choose a suitable *closure* to *close* the model. The modeller needs to choose which variables are to be exogenous and which endogenous. The number of endogenous variables must equal the number of equations.

simulations are used to explain historical episodes and the impacts of policy in an historical context (Dixon et al. 2013). Forecast simulations project forward from historical simulations using specialist forecasts to extrapolate future trends. These then form a business-as-usual scenario or the baseline for subsequent comparison of alternative scenarios. Policy simulations deviate from a given baseline in response to an exogenous imposed shock. The effects of that shock are computed as deviations away from baseline values. Figure 3-1 depicts how the historical, forecast and policy simulations put trajectories for the economy in place that start in some historical year, pass through the present year, and proceed forward under different assumptions for the key economic variables under investigation.

Figure 3-1: Baseline history, baseline forecast and policy simulation



3.1.1 Construction of CGE models and the process of analysis

In general, construction of a Johansen-style CGE model involves four main steps. The first step involves the specification of the economic theory, which involves many non-linear equations. The second step is to linearise the resulting system of non-linear equations. The third step is to use official statistics (principally IO data) to evaluate the coefficients and parameters of the model. The final step is to solve the model for values of the endogenous variables in terms of the values imposed on the exogenous variables.

Depending on the research question, the CGE model can be a comparative-static or dynamic model. A comparative-static model is used when the modeller is interested in the impact of the policy shock by comparing two states of the economy: pre-simulation and post-simulation. Sometimes, however, the adjustment process or time path on how the variables move is of relevance to the research question and this is where a dynamic CGE model will be most useful. A comparative-static model is simpler but a dynamic model can provide more information, particularly on adjustment issues.

3.2 Overview of the BRUGEM core theory

BRUGEM retains the key features of the well-documented comparative static ORANI-G model (Dixon et al. 1982, Horridge 2003) and is extended to include additional dynamic equations to produce a recursive dynamic model. BRUGEM is largely based on ORANIG-RD (Horridge 2002), which is a simplified version of the MONASH model, the successor of the ORANI-G model as described in Dixon and Rimmer (2002).

A recursive dynamic model is a multi-period model that is solved sequentially year-to-year. For each year, the starting data utilise information from the previous period's simulation. It is assumed that the behaviour of economic agents depends only on past and current states of the economy (static expectations).

Section 3.2.1 outlines the main behavioural assumptions and relationships in BRUGEM. The solution method is described in Section 3.2.2. Section 3.2.3 describes the nature of dynamic solution methods and Section 3.2.4 lists the conventions and notations used in TABLO[15] language of the model.

[15] TABLO is the GEMPACK program which translates the algebraic specification of an economic model into a form that is suitable for carrying out simulations with the model (Harrison et al. 2013).

3.2.1 Main behavioural assumptions and relationships

In terms of the underlying theory, BRUGEM is a Johansen-style model in which the key behavioural assumptions of the economic agents identified in the model (producers, investors, households, government and the rest of the world) are drawn from neoclassical microeconomic theory. BRUGEM allows for detailed treatment of margins, taxes, technology and preferences or tastes allowing flexibility and further analysis.

Producers and households are assumed to make decisions based on their optimising behaviour. Each representative industry is assumed to operate under the condition of cost minimisation, subject to its constant returns to scale production function and given input prices and technology. Households maximise their utility subject to their budget constraints, prices and tastes, and their demands are modelled via a single representative household in the economy. Investors will allocate new capital to industries based on expected rates of return.

Imported and domestic varieties of each commodity are assumed to be imperfect substitutes and are modelled using Armington's Constant elasticity of substitution (CES) assumption, which follows the approach adopted by Dixon et al. (1982). Appendix 3-3 explains more about the CES functional form and its properties.

Export demand is inversely related to the export price denominated in foreign currency. Therefore the higher the export price, the lower the export demand.

Unlike other agents, the government is not an optimiser in this model. Its consumption and investment are modelled in such a way that they can be set as exogenous or assumed to change via a simple relationship with other relevant variables. For example, it is commonly assumed that government consumption is proportional to private consumption in a welfare-enhancing policy change (Dixon & Rimmer 2002), and industry-specific government investment is proportional to total investment in each industry.

Unlike IO models, relative prices play an active role in the determination of economic outcomes in this type of model (Parmenter & Meagher 1985). There are different valuations of prices for the domestically produced goods and services: basic prices, producers' prices and purchasers' prices. Basic prices are the prices received by the producers rather than the prices paid by the users. The basic price of an import is the landed-duty-paid price or the CIF (cost, insurance and freight) price plus any tariff. For domestic products, the basic price is the factory-door price, which includes the production taxes but not sales taxes. Basic prices are assumed to be uniform across producing industries and across users, and also across importers in the case of imported goods.

Producer prices are prices that include the indirect sales taxes but exclude margins (Dixon et al. 1992). Margin flows represent quantities of retail and wholesale services or transport needed to deliver each basic flow of goods to the user.

The difference between the basic prices and purchasers' prices is due to sales taxes and margin flows, such as wholesale, retail and transport costs. Each commodity has a single basic price but potentially has many purchaser prices.

Markets are assumed to be competitive with no pure profits in any economic activity. Markets will clear with demand equals supply for all domestically produced goods and services. All agents will take input and output prices as given for their decision-making.

In summary, BRUGEM consists of a system of simultaneous equations, many of which are non-linear. These can be classified into several blocks, as described in Dixon et al. (1982):

1. Equations describing industry demands for primary factors and intermediate inputs;
2. Equations describing household and other final demands for commodities;

3. Pricing equations setting pure profits from all activities to zero;
4. Market clearing equations for primary factors and commodities;
5. Miscellaneous definitional equations, for example equations defining GDP, aggregate employment, and the consumer price index;
6. Dynamic equations linking the stocks and flows of capital stock, foreign assets and foreign liabilities, and adjustment in the labour market in terms of real wages and employment; and
7. Specific equations for the facilitation of forecasting and policy simulations.

The above equation blocks will be explained further in Section 3.3, which expands on the model's representation of the issues faced by each economic agent. With this complex system, containing many non-linear equations, we need a way to solve this model in an efficient and effective manner. This is discussed in the following section.

3.2.2 The percentage-change approach and solution method

There are two main approaches to solve large CGE models. One way is to solve by non-linear programming (mainly used by modellers in North America) and the other is to use linear derivative methods (widely used in Australia). Appendix 3-2 provides a brief overview of these two solution methods. BRUGEM is solved using the Johansen/Euler solution method.

Johansen's method begins with *linearisation* (Appendix 3-1 provides some examples); approximating the original system of non-linear equations in the levels of variables by a linear system in the changes of variables. The initial solution to the model in its levels representation is assumed to be provided by the IOT. The linear equation represents changes (typically percentage changes) away from this initial solution. A set of exogenous variables is then chosen, and values for the exogenous variables are specified by the user. The model is run to solve for changes in the endogenous variables away from their initial values.

We can represent BRUGEM as a system of equations describing the economic activities at year t in vector form, as follows:

$$F[V_t] = 0 \qquad (3.1)$$

where F is a vector of length m of differentiable functions and V_t is a vector of length n of prices, quantities and other variables for year t. The number of variables n is larger than m, the number of equations, because in an economy represented by a typical CGE model, there are more unknown or endogenous variables than the identifiable relationships between the variables or the number of equations. Therefore, to solve the model, these excess variables $n-m$ are assumed to be exogenous and their values specified. The modeller needs to define a *closure* by identifying which of the variables are exogenous. This *closure* has to be chosen such that it reflects the purpose or details of the economic issues to be examined.

Under the computation method used by GEMPACK, the non-linear equations in Equation (3.1) are converted into a system of linear equations by taking the total differentials of each equation and then expressing them in percentage change form, as follows:

$$A(\bar{V}_{t-1})v_t = 0 \qquad (3.2)$$

where $A(\bar{V}_{t-1})$ is a m x n matrix of coefficients such as cost and sale shares, evaluated at an initial solution $\bar{V}_{t-1}$ of Equation (3.1) and v_t is the vector of deviations in the model's variables away from $\bar{V}_{t-1}$. From the IO data, we have the initial solution for year $t=1$ (or year 0) where $F[\bar{V}_{t-1}] = 0$.

Equation (3.2) can be rewritten as (3.3) in terms of endogenous and exogenous variables, as follows:

$$A_Y(\overline{V}_{t-1})v_t^y + A_X(\overline{V}_{t-1})v_t^x = 0 \quad (3.3)$$

where,

v_t^y is the m x 1 sub-vector of endogenous components of v_t ;

v_t^x is the $n-m$ sub-vector of exogenous components of v_t ;

$A_Y(\overline{V}_{t-1})$ is the m x m matrix of elasticities (or derivatives if v_t is ordinary change) corresponding to the endogenous variables, evaluated using the solution to the model for previous time period, $t-1$; and

$A_X(\overline{V}_{t-1})$ is the m x $(n-m)$ matrix of elasticities (or derivatives if v_t is ordinary change) corresponding to the exogenous variables, evaluated using the solution to the model for previous time period, $t-1$.

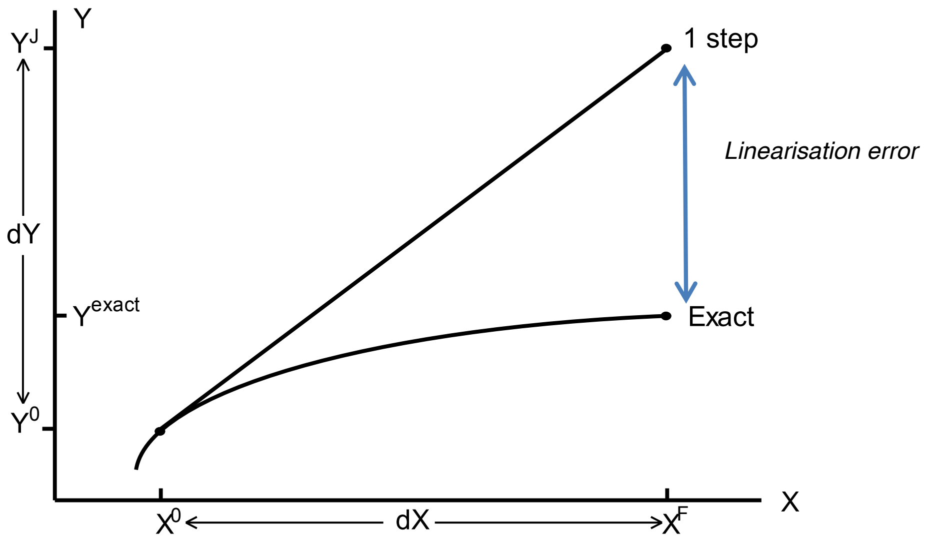
Assuming $A_Y(\overline{V}_{t-1})$ is non-singular, Equation (3.3) can be solved for v_t^y in terms of v_t^x:

$$v_t^y = -A_Y(\overline{V}_{t-1})^{-1} * A_X(\overline{V}_{t-1})v_t^x = B(\overline{V}_{t-1})v_t^x \quad (3.4)$$

Expressing growth rates in endogenous variables y in terms of exogenous variables x, where $y = b * x$, the b matrix will be given by $-A_Y(\overline{V}_{t-1})^{-1} * A_X(\overline{V}_{t-1})$ from (3.4). This is the same b matrix that fascinated Johansen and was discussed extensively in his seminal work (Dixon et al. 2013). This b matrix indicates the sensitivity (usually an elasticity) of every endogenous variable with respect to every exogenous variable in the Equation (3.4) which will provide satisfactory solutions for v_t^y when changes in v_t^x are small. For large changes in exogenous variables, a multi-step Johansen/Euler calculation will be required due to potential linearisation error.

When a non-linear equation is estimated using its linearised form, there is linearisation error. This error occurs the larger the changes are in exogenous variables, as shown in Figure 3-2. This can be resolved through a multi-step solution method.

Figure 3-2: Linearisation with Johansen estimated solution error



Source: Horridge (2003)

The source of linearisation error can be demonstrated in the following example. Using a linear form of equation say,

$$X_0 = Y_0 Z_0$$

Assume the new values for the RHS variables are given by Y_1 and Z_1 where they include the change denoted by Δ for $Y_1 = Y_0 + \Delta Y$ and $Z_1 = Z_0 + \Delta Z$ which will provide a new value for the LHS variable, where $X_1 = X_0 + \Delta X$. Therefore:

$$X_1 = Y_1 Z_1$$

$$(X_0 + \Delta X) = (Y_0 + \Delta Y) + (Z_0 + \Delta Z)$$

$$(X_0 + \Delta X) = Y_0 Z_0 + Y_0 \Delta Z + \Delta Y\, Z_0 + \Delta Y \Delta Z$$

Second-order terms

$$\Delta X = Y_0 \Delta Z + \Delta Y Z_0 + \Delta Y \Delta Z$$ *in change form*

$$x = y + z + [yz/100]$$ *in percentage form*

Percentage change of $X = YZ$ can be approximated to $x \approx y + z$ using product rule (see Appendix 3-1) if we assume y and z are both small so yz is very small. However, we can demonstrate, using a numerical example as shown in Box 3-1, that this is not always the case if we start to increase the size of change.

Box 3-1: Numerical example to remove linearisation error from Johansen solution using Euler's method

For illustration, we assume a small system of two non-linear equations of no particular economic significance:

$$F[V_t] \rightarrow \begin{matrix} X_1^2 X_3 - 1 = 0 \\ X_1 + X_2^2 - 2 = 0 \end{matrix} \rightarrow \begin{matrix} 2x_1 + x_3 = 0 \\ X_1 x_1 + 2X_2^2 x_2 = 0 \end{matrix}$$ in percentage change

Similar to Equation (3.2) format, we can express the above system in matrix algebra expression:

$$\begin{bmatrix} 2 & 0 & 1 \\ X_1 & 2X_2^2 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = 0$$

since we have 2 equations for 3 unknowns, x_3 is exogenous

$$\begin{bmatrix} 2 & 0 \\ X_1 & 2X_2^2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} x_3 = 0$$ which is similar to Equation (3.3) format, or

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = -\begin{bmatrix} 2 & 0 \\ X_1 & 2X_2^2 \end{bmatrix}^{-1} \begin{bmatrix} 1 \\ 0 \end{bmatrix} x_3 = \begin{bmatrix} -1/2 \\ X_1 / 4X_2^2 \end{bmatrix} x_3$$ in the format of Equation (3.4)

If we assume $X_3 = 0.5$ we can solve for X_1 and X_2 from the level form:

$$X_1 = X_3^{-1/2} = (0.5)^{-1/2} = 1.414$$
$$X_2 = (2 - X_3^{-1/2})^{1/2} = (2 - 0.5^{-1/2})^{1/2} = 0.765$$

The initial solution to this small model is now $(X_1^I, X_2^I, X_3^I) = (1.414, 0.765, 0.5)$. Say we shock the model and assume X_3 increases by 100% so the new $X_3 = 1$, then by solving in levels, the solution is $(X_1^{II}, X_2^{II}, X_3^{II}) = (1,1,1)$ which is the true solution, where $x_1 = -29.29\%$ and $x_2 = +30.66\%$. However, the simple Johansen solution yields a different result, where the difference is due to the linearisation error:

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = -\begin{bmatrix} 2 & 0 \\ 1.414 & 2(0.765)^2 \end{bmatrix}^{-1} \begin{bmatrix} 1 \\ 0 \end{bmatrix} x_3 = \begin{bmatrix} -0.500 \\ +0.604 \end{bmatrix} x_3$$

where $x_1 = -50.0\%$, $x_2 = +60.4\%$

Therefore $X_1 = 1.414 * (1 - \frac{50}{100}) = 0.707, X_2 = 0.765(1 + \frac{60.4}{100}) = 1.227$

To improve the accuracy of the solution, we can divide the shock into a number of equal steps (Euler's method), as shown in Figure 3-3. Using two-step Euler computation, we can implement the shock to X_3 as follows, where Step (2,2) is step 2 of the two-steps method.

	Initial value		Step (1,2)		Step (2,2)	
X_3	0.5	→	0.75	→	1.00	level
ΔX_3		0.25		0.25		change
$x_3^{(n,2)}$		50%		33.33%		percentage change

The first step is increasing X_3 from 0.5 to 0.75 or $x_3^{(1,2)} = 50$

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}^{(1,2)} = -\begin{bmatrix} -0.500 \\ 1.414 / 4(0.765)^2 \end{bmatrix} 50 = \begin{bmatrix} -25.00 \\ +30.20 \end{bmatrix}$$

The second step is to calculate the updated values of X_1, X_2, X_3 after Step (1,2):

$$X_1^{(1,2)} = X_1^I * (1 + \frac{x_1^{(1,2)}}{100}) = 1.414 * (1 - \frac{25}{100}) = 1.061$$
$$X_2^{(1,2)} = X_2^I * (1 + \frac{x_2^{(1,2)}}{100}) = 0.765 * (1 + \frac{30.20}{100}) = 0.996$$
$$X_3^{(1,2)} = X_3^I * (1 + \frac{x_3^{(1,2)}}{100}) = 0.5 * (1 + \frac{50}{100}) = 0.750$$

The third step is to increase X_3 from 0.75 to 1.00 or $x_3^{(2,2)} = 33.33$

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}^{(2,2)} = -\begin{bmatrix} -0.500 \\ 1.061 / 4(1.00)^2 \end{bmatrix} 33.33 = \begin{bmatrix} -16.67 \\ +8.84 \end{bmatrix}$$

The fourth step is to calculate the updated values of X_1, X_2, X_3 after Step (2,2):

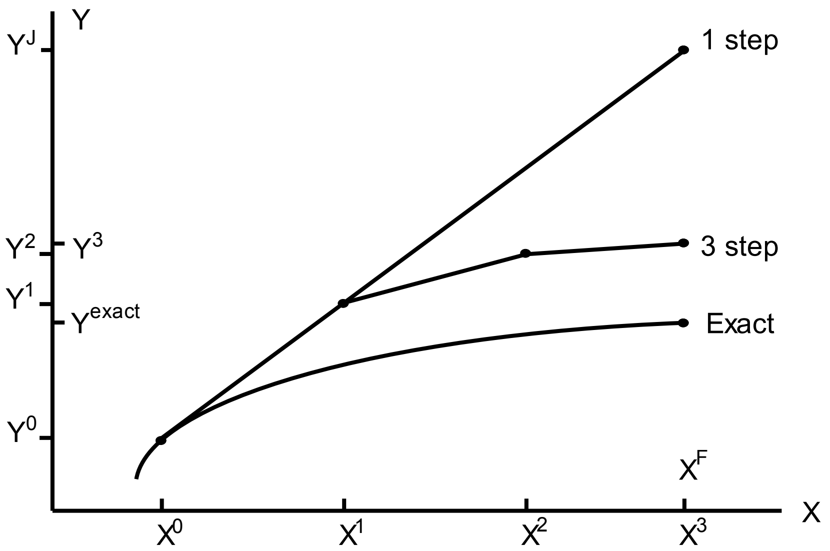
$$X_1^{(2,2)} = X_1^I * (1 + \frac{x_1^{(2,2)}}{100}) = 1.061 * (1 - \frac{16.67}{100}) = 0.884$$
$$X_2^{(2,2)} = X_2^I * (1 + \frac{x_2^{(2,2)}}{100}) = 0.996 * (1 + \frac{8.84}{100}) = 1.084$$
$$X_3^{(2,2)} = X_3^I * (1 + \frac{x_3^{(2,2)}}{100}) = 0.75 * (1 + \frac{33.33}{100}) = 1.000$$

This process can be repeated for more steps, which will generate more accuracy as shown in the following results:

	X_1	X_2
Initial values	1.414	0.765
Increasing X_3 from 0.5 to 1.00, we get:		
True value	1	1
1-step (Johansen) computation	0.707	1.227
2-step (Euler) computation	0.884	1.084
4-step (Euler) computation	0.948	1.036
8-step (Euler) computation	0.975	1.017
16-step (Euler) computation	0.988	1.008

With the Johansen single-step combined with the multi-step Euler method and supplemented with extrapolation, such as the Richardson extrapolation rule[16], linearisation error can be reduced to a negligible level, and highly accurate solutions (closer to true solutions) can be obtained. In BRUGEM, due to the large shocks associated with the depletion of oil and gas resources, an Euler 100-step solution method is used for better accuracy.

Figure 3-3: Multi-step process to reduce linearisation error



Source: Horridge (2003)

This derivative method is found to be convenient and flexible, especially in running simulations under a variety of closures with the help of the GEMPACK modelling software (Harrison & Pearson 1996). A brief background of GEMPACK can be found in Appendix 3-2.

One practical problem is the existence of zero IO flows, which can cause Johansen/Euler computations to fail because the matrix $A_Y(\overline{V}_{t-1})$ in Equation (3.3) will not be invertible due to a row or a column of zeros. Nevertheless, this can be resolved

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[16] We can infer the results for an Euler simulation of an infinite number of steps by using information on the rate at which the gap between simulations of different step size changes as we increase the number of steps. Readers who are interested in the details of this extrapolation method may refer to Dixon et al. (1982), p. 51-61.

by modifying the IO database zero flows with very small numbers or setting an operator function to the relevant denominator in the equations.

There are several variables, such as the balance of trade, *ad valorem* taxes and inventory flows that can be positive or negative numbers, or even zero in values. If these variables are expressed in percentage change form, computational problems may arise; such as a zero-divide issue or non-convergence of model solution when the percentage-change variables cause the sign to change at levels. In such cases, these variables are expressed in ordinary change form.

Horridge (2003) illustrated that the linearised approach is relatively simple compared to the levels form, and convenient at the calibration phase since no units are involved in percentage-changes. There is also potentially less data requirement since some behavioural parameters will be dropped through the linearisation of the equations. Most levels algorithms do not allow flexibility in closing the model (closure). On the other hand in linearised form, the modeller is free to choose which variables to be exogenous and which ones endogenous depending on the variables of interest.

CGE models are large and complex, it is often necessary to reduce them to a manageable size. In linearised form, a substitution process can easily be carried out by GEMPACK via the flexible specification of any variable as the subject of any equation to condense the model. The TABLO program (see Figure 2 in Appendix 3-2) can also be instructed to omit specified variables, which are exogenous and unshocked, besides substituting out specified variables. These functions will help to keep BRUGEM to a manageable size and allow the solving to be done in a more efficient manner.

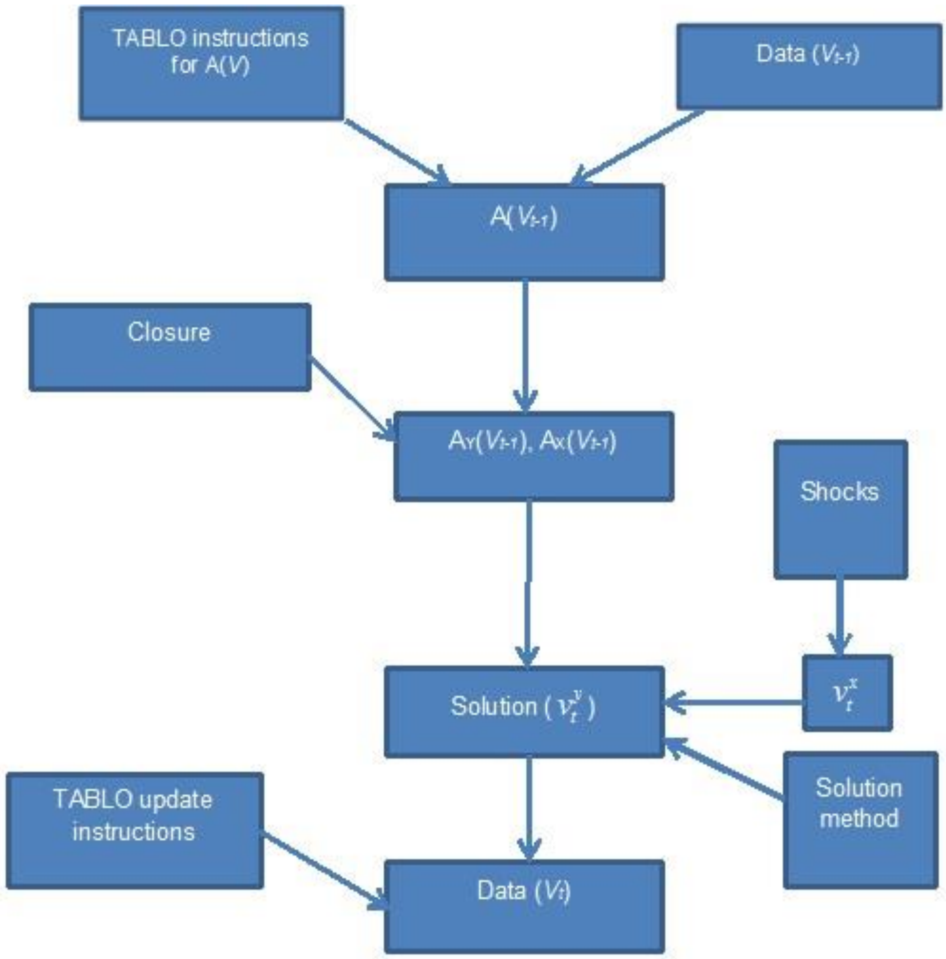
Figure 3-4 illustrates how GEMPACK is used to solve BRUGEM as expressed in a system of equations using instructions related to data, appropriate closure and solution methods to generate the solution or output data.

3.2.3 Nature of the dynamic solution

The dynamic model comprises a sequence of period-to-period simulations. Using the initial solution for year 0, the first computation will create a solution for year 1 via the movement of the exogenous variables from initial (year 0) values to the required values in year 1. This solution represents the changes between one year and the next. This solution for year 1 will in turn become the initial solution for a computation that moves exogenous variables from their values at year 1 to year 2, as shown in Figure 3-5.

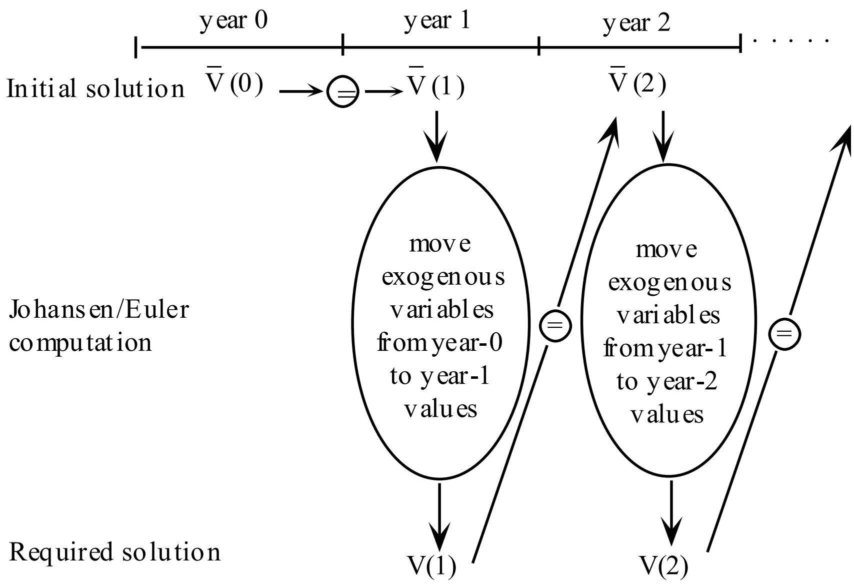
The 'initial' database that is the starting point of each computation represents the state of the economy as it was both at the end of the previous period and at the beginning of the current period. Similarly, the 'updated' database produced by each computation represents the economy as it will be both at the end of the current period and the beginning of the next period (Horridge 2002).

Figure 3-4: Structure of a GEMPACK solution of BRUGEM



Source: Adapted from Dixon et al. 2013

Figure 3-5: Generating a sequence of solutions



Source: Dixon and Rimmer 2002, p. 129

3.2.4 Some conventions and notations used in TABLO

The TABLO input file has a large range of variables and coefficients used in the model's equations. For convenience, a systematic naming system utilised by the base model ORANIG-RD was followed. Although the GEMPACK software does not differentiate between upper and lower case, typically as a convention, lower case is for variable names and set indices; upper case for set and coefficient names. For example, a percentage change of a variable X is represented in lower case x where $x = \frac{dX}{X} * 100$ and for a change variable dX, it is represented by $delX$ as the ordinary change of the variable X.

The notation X usually represents quantity and P the price with V the value as a product of price and quantity. This can be seen in Table 4-1 in Chapter 4. Similarly, the corresponding percentage changes for price and quantity are represented in lower case, as p and x respectively. The agents or users in the model are represented in single digits as follows:

1 - producers
2 – investors
3 – households
4 – export demander
5 - government
6 - inventories
0 - all users, or where user distinction is irrelevant

3.3 Core structure of BRUGEM

This section is largely drawn from the well-documented and established ORANI-G model theory (Dixon & Rimmer 2002, Horridge 2003), as well as materials from the Practical GE Modelling Course (Centre of Policy Studies, 2015), forming the core theory of BRUGEM.

Sections 3.3.1 to 3.3.7 describe all the demands and decisions to be made by different agents in the economy. Section 3.3.8 is the extension on government accounts covering government revenues and expenditures. Section 3.3.9 describes other necessary conditions and associated equations for zero pure profit and market clearing. Section 3.3.10 describes the trade balance, terms of trade and real devaluation. GDP and nominal domestic absorption related equations are described in Section 3.3.11 and Section 3.3.12 includes other price and miscellaneous definitional equations.

3.3.1 Industry input and output decisions

Several stages of decisions need to be made by the producers. Each industry is modelled using a single presentative producer. The producer is a price-taker in both inputs and outputs. These can be illustrated in the nesting structure in Figure 3-6. The producers or firms are modelled as though they make staged decisions. Each nest requires several equations. It is assumed that the input and output decisions are separable. That is, the combination of inputs to production is chosen independently of the composition of the producer's output. Relative prices play an active role in the determination of economic outcomes under this model.

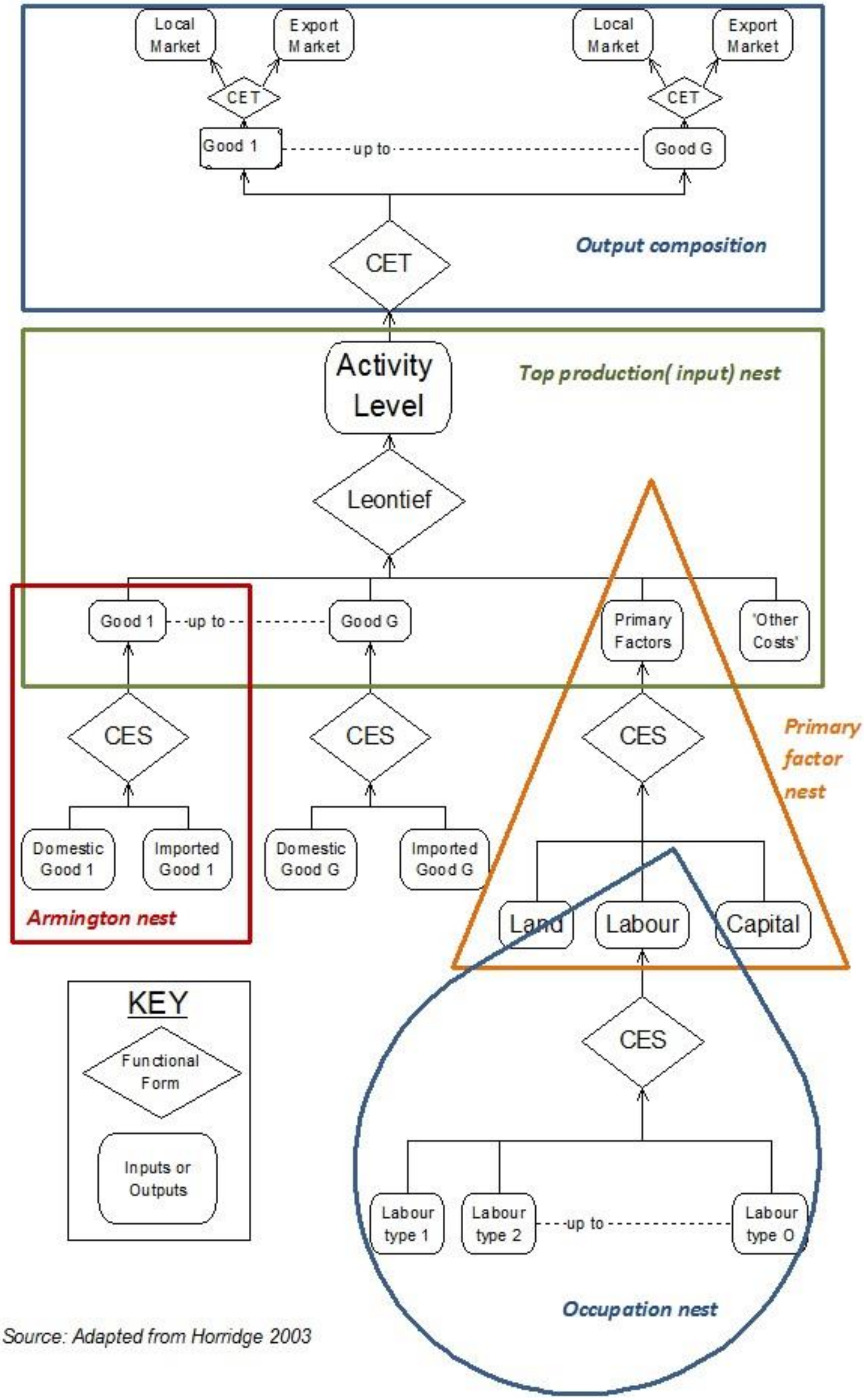
In the structure of production, BRUGEM allows each industry to produce several commodities, using inputs such as domestic and imported commodities, labour of several types, land and capital. The top part of Figure 3-6 shows the composition of output, where commodities destined for exports are distinguished from those for the local market. The multi-input, multi-product production specification is kept manageable by a series of separability assumptions, illustrated by Figure 3-7, where each composite is produced by a CES function (see Appendix 3-3).

In each industry, the output is a function of inputs that can be simplified further into the different components, as shown in Figure 3-6.

Therefore, in this separable production setting, each nest is independent. The marginal rates of substitution, say between the different types of labour (for example between skilled and unskilled labour) within the occupation nest, are independent of the level of capital inputs in the primary factor nest (Dixon et al. 1982) and Horridge 2003).

All industries share a common production structure but input proportions and behavioural parameters vary. It is assumed that all producers are competitive and will take the input and output prices as given in their decision-making process; will choose their primary and intermediate inputs, to minimise their costs for any given level of activity subject to production constraints; and will choose the commodity-composition of their output in order to maximise revenue. An example of a constrained minimisation problem in a CES nest is illustrated in Appendix 3-3.

Figure 3-6: The production structure



Source: Adapted from Horridge 2003

Figure 3-7: Separability assumption of the production structure

Output = f(inputs) = f(labour, capital, land, domestic goods, imported goods)

separability assumptions

Function	Nests in Figure 3-7
Output = f(primary factor composite, composite goods)	Output composition
Primary factor composite = CES (labour, capital, land)	Primary factor nest
Labour = CES (various occupations)	Occupation nest
Composite good i = CES(domestic good i, imported good i)	Armington nest

3.3.1.1 Demand for inputs to production

At the top production nest in Figure 3-6, it can be observed that in order to produce the necessary output or the activity level, there are required inputs from primary factors as well as intermediate goods. Intermediate goods are commodities produced either by the industry itself or by other producers denoted as good 1, good 2 and so on; plus another input called the “other costs”. These other costs include the cost of holding liquidity, cost of holding inventories and other miscellaneous production costs (Dixon & Rimmer 2002). These composite inputs are combined using a Leontief production function where each commodity composite is a CES function of domestic and imported varieties as indicated in the Armington nest for the intermediate goods. The Leontief production function is equivalent to the CES production function with substitution elasticity set to zero. This implies that fixed proportions of the composite inputs are required and that no substitution between the intermediate goods and primary factors takes place. Thus, there is no price substitution term in the demand for the input composites in Equations (3.8) to (3.10).

The technical change term $A1TOT(i)$ in Equation (3.6) is Hicks-neutral and hence affects all inputs equally. If improvement in the use of a specific input is required, this can be implemented via the input-specific technical change term depending on whether the source of efficiency comes from commodity $(a1\_s(c,\mathrm{i}))$, primary factor composite $(a1prim(\mathrm{i}))$ or other cost tickets $(a1oct(i))$ in Equations (3.8)-(3.10). All the commodity composites, primary factor composite and other costs are combined by minimising the total cost of inputs (Equation 3.5):

$$\sum_{c\in COM} P1\_S(c,i)*X1\_S(c,i)+P1PRIM(i)*X1PRIM(i)+P1OCT(i)*X1OCT(i) \tag{3.5}$$

Subject to the Leontief production function given by Equation (3.6).

$$X1TOT\left(i\right) = \frac{1}{A1TOT(\mathrm{i})} MIN\left[all,c,COM : \frac{X1\_S(\mathrm{c},i)}{A1\_S(\mathrm{c,i})}, \frac{X1PRIM(i)}{A1PRIM(i)}, \frac{X1OCT(i)}{A1OCT(i)} \right] \tag{3.6}$$

Cost minimisation implies that:

$$\frac{X1\_S(\mathrm{c},i)}{A1\_S(\mathrm{c,i})} = \frac{X1PRIM(i)}{A1PRIM(i)} = \frac{X1OCT(i)}{A1OCT(i)} = A1TOT(i)*X1TOT(i) \tag{3.7}$$

The activity level or value-add of the industry is given by the outcome to the demands for commodity composites, primary factor composite and other costs in percentage change form in Equations (3.8) to (3.10).

$$\begin{aligned} &E\_x1\_s \text{ \# Demands for commodity composites \#} \\ &\left(all,c,COM\right)\left(all,i,IND\right) x1\_s\left(c,i\right) - \left[a1\_s\left(c,i\right) + a1tot\left(i\right)\right] = x1tot\left(i\right) \end{aligned} \tag{3.8}$$

$$\begin{aligned} &E\_x1prim \text{ \# Demands for primary factor composite \#} \\ &\left(all,i,IND\right) x1prim\left(i\right) - \left[a1prim\left(i\right) + a1tot\left(i\right)\right] = x1tot\left(i\right) \end{aligned} \tag{3.9}$$

$$\begin{aligned} &E\_x1oct \text{ \# Demands for other cost tickets \#} \\ &\left(all,i,IND\right) x1oct\left(i\right) - \left[a1oct\left(i\right) + a1tot\left(i\right)\right] = x1tot\left(i\right) \end{aligned} \tag{3.10}$$

If we wish technical change in intermediate use to be cost neutral, we can require the technical change terms to add to zero via Equation (3.11); where $ac(c)$ is commodity-using technical change, $fa1c(\mathrm{c})$ is the shifter for input-saving technical change and $fa1ci(c,\mathrm{i})$ is the shifter for input-saving technical change in industry *i*'s production.

$$E\_a1\_s \text{ \# Allows equilisation of tech change in intermediate uses of c \#} \quad (All,c,COM)(All,i,IND)\ a1\_s(c,i) = ac(c) + fa1c(c) + fa1ci(c,i) \tag{3.11}$$

Each of the other nests beneath the top production nest in Figure 3-6 are explained in the following sections in terms of the demand for each type of composite.

3.3.1.2 Demand for labour composite

At the bottom of Figure 3-6 is the occupation nest, where each industry *i* has to choose the occupation-specific labour inputs $X1LAB(i,o)$ in order to minimise the labour cost $sum\{o,\ OCC,\ P1LAB(i,o)*X1LAB(i,o)$ subject to the constraint:

$$X1LAB\_O(i) = CES(all,o,OCC:\ X1LAB(i,o)) \tag{3.12}$$

The coefficient $SIGMA1LAB(i)$ in Equation (3.13) is the CES substitution elasticity between the different skills denoted by occupations. This controls how readily the occupation can be substituted in response to a change in the ratio of the wage by occupation, relative to the average wage of the labour composite in industry *i*. In percentage change form, the demand of labour is written as:

$$(all,i,IND)(all,o,OCC) \quad x1lab(i,o) = x1lab\_o(i) - SIGMA1LAB(i)*[p1lab(\mathrm{i},o) - p1lab\_o(i)] \tag{3.13}$$

and the percentage change in the price of composite labour given by:

$$(all,i,IND) \quad [TINY + V1LAB\_O(i)]*p1lab\_o(i) = sum\{o,OCC,V1LAB(i,o)*p1lab(i,o)\} \tag{3.14}$$

In TABLO language, a very small number TINY is necessary in the above equation to avoid the zero divide problem that leads to singular matrix, in the case where an industry does not utilise any labour, such as *Dwelling*.

The occupation substitution nest is not activated in BRUGEM. It is, nevertheless, built in for activation if data is available in the future on the different occupations and wage rates.

3.3.1.3 Demand for primary factor composite

The primary factor composite consists of three primary factors: land, labour and capital, as illustrated in the primary factor nest in Figure 3-6. The total primary factor costs are minimised subject to the production function (Equation 3.15), where factor-saving technical changes $A1LAB\_O(i)$, $A1CAP(i)$ and $A1LND(i)$ are explicitly included:

$$X1PRIM(i) = CES\left[\frac{X1LAB\_O(i)}{A1LAB\_O(i)}, \frac{X1CAP(i)}{A1CAP(i)}, \frac{X1LND(i)}{A1LND(i)}\right] \quad (3.15)$$

The solution to the above minimisation problem is given by Equations (3.16) to (3.18) for industry demands for effective labour, capital and land. If the factor-specific technical change or efficiency terms are held constant ($a1lab\_o(i), a1cap(i), a1\text{lnd}(i)$), the right hand side of each of the equation consists of two components explaining the demand for an effective unit of the primary factor. The first component indicates the expansion effect, which moves proportionally to the overall demand for primary factor composite $x1prim(i)$. The second term is the substitution effect consisting of the elasticity of substitution $SIGMA1PRIM(i)$ multiplied by the ratio of each primary factor's effective price to the average cost of the effective (adjusted for technical change) primary factor composite $p1prim(i)$. Equation (3.19) determines the average cost of the effective primary factor composite. This influences the degree to which a primary factor can be substituted for a cheaper primary factor.

$$(all,i,IND) \tag{3.16}$$
$$x1lab\_o(i) - a1lab\_o(i) = x1prim(i) - SIGMA1PRIM(i)*[p1lab\_o(i) + a1lab\_o(i) - p1prim(i)]$$

$$(all,i,IND) \tag{3.17}$$
$$x1cap(i) - a1cap(i) = x1prim(i) - SIGMA1PRIM(i)*[p1cap(i) + a1cap(i) - p1prim(i)]$$

$$(all,i,IND) \tag{3.18}$$
$$x1lnd(i) - a1lnd(i) = x1prim(i) - SIGMA1PRIM(i)*[p1lnd(i) + a1lnd(i) - p1prim(i)]$$

$$(all,i,IND) \tag{3.19}$$
$$V1PRIM(i)*p1prim(i) = V1LAB\_O(i)*[p1lab\_o(i) + a1lab\_o(i)] + V1CAP(i)*[p1cap(i) + a1cap(i)] + V1LND(i)*[p1lnd(i) + a1lnd(i)]$$

3.3.1.4 Demand and sourcing for intermediate goods

Other than primary factors, intermediate goods and services are also required as inputs. The Armington assumption is used here where imports are regarded as imperfect substitutes to the domestic supplies of goods and services (see Appendix 3-3). The import/domestic composition of intermediate commodity demands, shown in the Armington nest, shares a similar pattern to the previous primary factor nest where the total cost of imported and domestic good *c* is minimised subject to the production function in Equation (3.20).

$$X1\_S(c,i) = CES\left[All,s,SRC: \frac{X1(c,s,i)}{A1(c,s,i)}\right] \tag{3.20}$$

The effective commodity demand from each source is proportional to the demand for the composite, $X1\_S(c,\mathrm{i})$ and to a price term. In percentage form, the source-specific commodity demand is given by the following Equations (3.21) and (3.22), where $SIGMA1(c)$ is the Armington elasticity of the intermediate good *c*:

$$(all,c,COM)(all,s,SRC)(all,i,IND)$$
$$x1(c,s,i)-a1(c,s,i) = x1\_s(c,i) - SIGMA1(c)*[p1(c,s,i) + a1(c,s,i) - p1\_s(c,i)] \quad (3.21)$$

$$(all,c,COM)(all,i,IND)$$
$$p1\_s(c,i) = sum\{s,SRC,\ S1(c,s,i)*[p1(c,s,i) + a1(c,s,i)]\} \quad (3.22)$$

The lowering of the source-specific price of a good relative to the effective price of the commodity composite given by the following equation will induce substitution towards the cheapening source.

A change in sourcing preferences for inputs is denoted by a change in the preference term $A1(c,s,i)$.

3.3.1.5 Industry costs and production taxes

The total cost of production $V1TOT(i)$ consists of total industry costs $V1CST(i)$ and an *ad valorem* production tax $V1PTX(i)$ in Equation (3.23). Industry costs are further broken down into the respective costs related to primary factors, other costs and intermediate costs in Equation (3.24). These costs are represented in the form of ordinary change variables $delV1CST(i)$ and $delV1PTX(i)$ in Equations (3.26) to (3.27), where $delPTXRATE(i)$ is the change in the rate of production tax and $PTXRATE(i)$ is the rate of production tax in Equation (3.25).

$$(all,i,IND)V1TOT(i) = V1CST(i) + V1PTX(i) \quad (3.23)$$
$$(all,i,IND)V1CST(i) = V1PRIM(i) + V1OCT(i) + V1MAT(i) \quad (3.24)$$
$$(all,i,IND)PTXRATE(i) = V1PTX(i)/V1CST(i) \quad (3.25)$$

$$E\_delV1CST \ \# \text{ Change in cost of production (tax excluded) } \# \quad (3.26)$$
$$(all,i,IND)\ delV1CST(i) = delV1PRIM(i) +$$
$$sum\{c,COM,sum\{s,SRC,0.01*V1PUR(c,s,i)*[p1(c,s,i) + x1(c,s,i)]\}\}$$
$$+0.01*V1OCT(i)\ *[p1oct(i)+x1oct(i)]$$

$$E\_delV1PTX \ \# \text{ Change in production tax } \# \quad (3.27)$$
$$(all,i,IND)\ delV1PTX(i) = PTXRATE(i)*delV1CST(i) + V1CST(i) * delPTXRATE(i)$$

$$E\_delV1TOT \ \# \text{ Change in tax-inclusive cost of production } \# \quad (3.28)$$
$$(all,i,IND) \ delV1TOT(i) = delV1CST(i) + delV1PTX(i)$$

$$E\_p1tot \ \# \text{ Percentage change in unit cost of production } \# \quad (3.29)$$
$$(all,i,IND) \ V1TOT(i)*\left[p1tot(i) + x1tot(i)\right] = 100*delV1TOT(i)$$

$$(all,i,IND) \ p1cst(i) \ \# \text{ Index of production costs} \#$$
$$E\_p1cst(all,i,IND) \ p1cst(i) = \left[1/V1CST(i)\right]*$$
$$[sum\{c,COM, sum\{s,SRC,V1PUR(c,s,i)*p1(c,s,i)\}\} \quad (3.30)$$
$$+V1OCT(i)*p1oct(i)+V1CAP(i)*p1cap(i)+V1LND(i)*p1lnd(i)$$
$$+ sum\{o,OCC, \ V1LAB(i,o)*p1lab(i,o)\}]$$

The percentage change in the unit cost of production $p1tot(\mathrm{i})$ in Equation (3.29) is equal to the marginal cost of production under constant returns to scale production technology. Under the competitive zero pure profits condition, $p1tot(\mathrm{i})$ will be equal to the average price received by each industry or unit price = marginal cost. To analyse further the total industry costs, Equation (3.30) helps to decompose into the respective cost components.

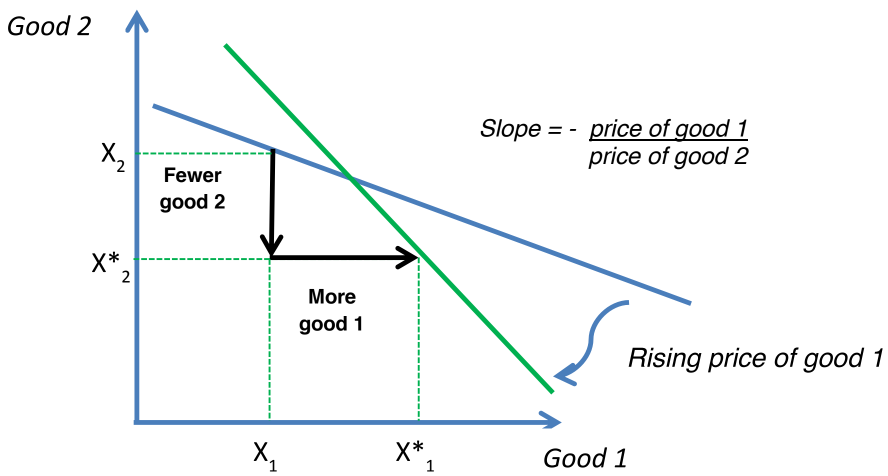
3.3.1.6 Industry output decisions

In the multi-production structure, each industry produces a mixture of commodities according to the relative prices of the commodities. The $MAKE(c,i)$ matrix, which indicates what each industry produces, while it is strongly diagonal, it does have some off-diagonal elements. The producer will choose to maximise the total revenue subject to a constant elasticity of transformation (CET) production constraint:

$$X1TOT(i) = CET\left[All,c,COM: Q1(c,i)\right] \quad (3.31)$$

The CET aggregation function is identical to the CES function, except in the sign of the transformation parameter where it is opposite to CES. CET is a form of production possibility frontier where the elasticity of transformation is constant along the transformation curve (see Figure 3-8). The elasticity of transformation is the elasticity of an industry's output of one good with respect to the output of another good, depending on its relative price, while holding total output constant. For example, industry 1 produces two outputs, good 1 and good 2. The transformation parameter denoted by the negative slope of the two prices indicates that when the price of good 1 rises, the industry will divert production to produce more good 1 and fewer good 2 to sell (see Figure 3-8).

Figure 3-8: CET transformation frontier



The output mix will be given by the following equations with *SIGMA1OUT* as the elasticity of transformation in Equation (3.32):

$$E\_q1 \ \# \text{ Supplies of commodities by industries } \# \quad (3.32)$$
$$(all,c,COM)(all,i,IND)\,q1(c,i) = x1tot(i) + SIGMA1OUT(i)*\left[p0com(c) - p1tot(i)\right]$$

$$E\_pq1 \ \# \text{ Each industry gets the same price for a given commodity } \# \quad (3.33)$$
$$(all,c,COM)(all,i,IND)\ pq1(c,i) = p0com(c)$$

E_x0com # Total output of commodities # (3.34)

$$(all,c,COM)\ x0com(c) = sum\{i,IND,\ [MAKE(c,i)/MAKE\_I(c)]*q1(c,i)\}$$

E_p1tot # Average price received by industries # (3.35)

$$(all,i,IND)\ p1tot(i) = sum\{c,COM,\ [MAKE(c,i)/MAKE\_C(i)]*pq1(c,i)\}$$

Where $(all,\mathrm{i},\mathrm{IND})MAKE\_C(\mathrm{i})$ is the sum of all production by industry *i* and $(all,c,COM)MAKE\_\mathrm{I}(\mathrm{c})$ is the total production of commodity *c*.

3.3.1.7 Local/export mix

As illustrated at the top of Figure 3-6, each industry has to decide on the destination of their outputs. In terms of the local and export mix, BRUGEM allows the possibility that goods destined for export are different to the ones for domestic use. Again, this is governed by the CET frontier.

However, in BRUGEM, we assume that domestic and export varieties are perfect substitutes, leaving the price of export the same as the price for domestic use. Therefore, we require the elasticity of substitution to be infinite. In practice, we rearrange the equation so that $TAU(c)$ represents the inverse of the elasticity in Equation (3.36) where $TAU(c)$ is set to zero. $EXPSHR(c)$ is the share going to exports in Equations (3.37) and (3.38).

Supply of commodities to export market # (3.36)

$$(all,c,COM)\ TAU(c)*[x0dom(c) - x4(c)] = p0dom(c) - pe(c)$$

Supply of commodities to domestic market # (3.37)

$$(all,c,COM)\ x0com(c) = [1.0 - EXPSHR(c)]*x0dom(c) + EXPSHR(c)*x4(c)$$

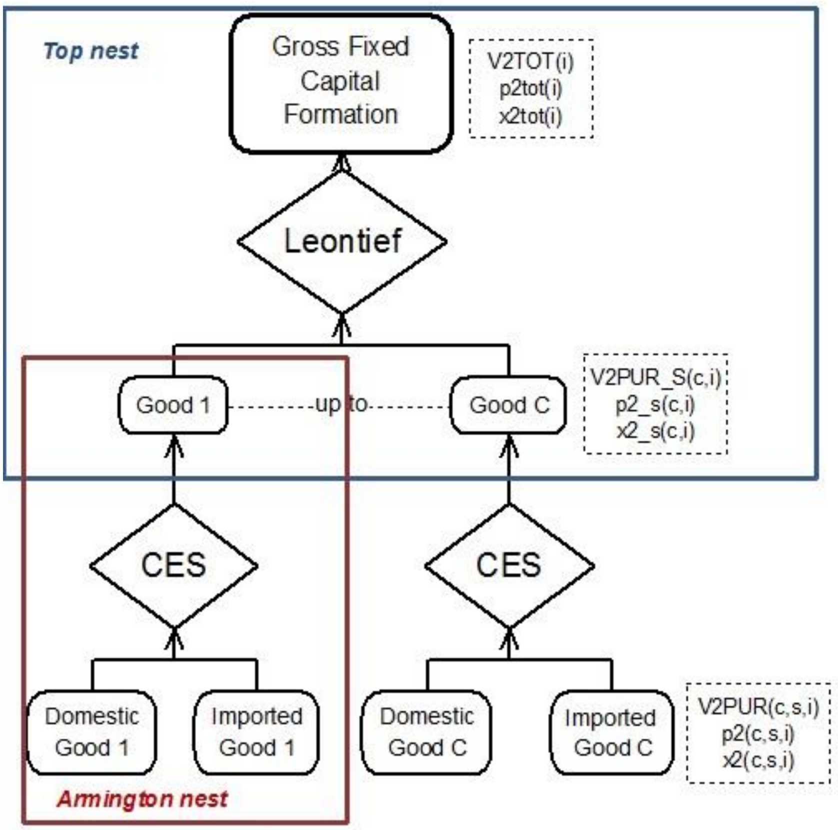
Zero pure profits in transformation # (3.38)

$$(all,c,COM)\ p0com(c) = [1.0 - EXPSHR(c)]*p0dom(c) + EXPSHR(c)*pe(c)$$

3.3.2 Demand for investment goods

In each industry, investment is undertaken by a representative agent. This investor faces a two-part cost minimisation problem. The first problem occurs at the sourcing level and the second relates to the commodity mix used to create the final good of gross fixed capital formation. This is illustrated in Figure 3-9. There is no primary factor being used directly as input to this capital creation process.

Figure 3-9: Structure of investment demand



Source: Adapted from Horridge 2003

For each composite commodity, the capital creators choose from domestically produced or imported varieties using a CES function in order to minimise the total cost in Equation (3.39).

$$X2\_S(c,\ i) \ = CES\left[\ All, s, SRC: \left(\frac{X2(c,s,i)}{A2(c,s,i)}\right)\right] \qquad (3.39)$$

The demand for each source-specific input to investment in percentage change form is given by Equation (3.40). This demand moves in proportion to the demand for the composite investment good and a price effect term that induces substitution towards the cheapening input source. This term comprises the elasticity of substitution, $SIGMA2(c)$, and the effective price ratio of each source-specific input relative to the average price of the composite $p2\_s(c,i)$.

$$\begin{aligned}&E\_x2 \text{ \# Source-specific commodity demands \#}\\&(all,c,COM)(all,s,SRC)(all,i,IND)\\&x2(c,s,i)-a2(c,s,i)=x2\_s(c,i)-SIGMA2(c)*[p2(c,s,i)+a2(c,s,i)-p2\_s(c,i)]\end{aligned} \quad (3.40)$$

The effective price of this composite is given by Equation (3.42), where $S2$ is the commodity and industry-specific source share for investment defined in Equation (3.41). $A2(c,s,i)$ represents the source preference.

$$(all,c,COM)(all,s,SRC)(all,i,IND)S2(c,s,i) = V2PUR(c,s,i) \; / \; V2PUR\_S(c,i) \quad (3.41)$$

$$\begin{aligned}&E\_p2\_s \text{ \# Effective price of commodity composite \#}\\&(all,c,COM)(all,i,IND)\,p2\_s(c,i) = sum\{s,SRC,\; S2(c,s,i)*[p2(c,s,i)+a2(c,s,i)]\}\end{aligned} \quad (3.42)$$

The second stage of the investor's decision, represented by the top nest of Figure 3-9, is determined by minimising the cost of all the required composite goods (each obtained from the above solution in Equation (3.40) at the sourcing level) subject to the Leontief production function in Equation (3.43).

$$X2TOT(i)=\frac{1}{A2TOT(i)}MIN\left[All,c,COM:\frac{X2\_S(c,i)}{A2\_S(c,i)}\right] \quad (3.43)$$

The solution to this Leontief cost minimisation problem is given by Equations (3.44) and (3.45), where the investment demand by industry $x2tot(i)$ is a function of the effective demand for composite input goods with a technical change in investment represented by $a2\_s(c,i)$. If we wish to model an improvement in investment efficiency or technical change, where all capital inputs are used more efficiently by industry, this can be carried out via the shift in the industry-specific variable $a2tot(i)$ in Equations (3.44) and (3.45).

$$E\_x2\_s \ \# \text{ Investment use of imp/dom composite } \# \quad (3.44)$$
$$(all,c,COM)(all,i,IND)\, x2\_s(c,i) \; - \; [a2\_s(c,i) \; + \; a2tot(i)] \; = \; x2tot(i)$$

$$E\_p2tot \ \# \text{ Cost of unit of capital } \# \quad (3.45)$$
$$(all,i,IND) \; p2tot(i) =$$
$$sum\{c,COM, \; (V2PUR\_S(c,i)/ID01[V2TOT(i)])*[p2\_s(c,i) \; + a2\_s(c,i) \; + a2tot(i)]\}$$

If we wish technical change in investment to be cost neutral, we can require the technical change terms to add to zero via Equation (3.46), where $ac(c)$ is commodity-using technical change, $fa2c(\mathrm{c})$ is the shifter for input-saving technical change and $fa2ci(c,\mathrm{i})$ is the shifter for input-saving technical change in industry *i*'s investment.

$$Equation \; E\_a2\_s \ \# \text{ Allows equilisation of tech change in investment uses of c } \# \quad (3.46)$$
$$(All,c,COM)(All,i,IND) \;\; a2\_s(c,i) \; = \; ac(c) + fa2c(c) \; + fa2ci(c,i)$$

3.3.3 Household demands

The household demand theory in BRUGEM is based on the neoclassical economic problem in which a representative household will choose a consumption bundle to maximise its utility, subject to a budget constraint. This problem can be broken down into two stages.

The two-staged nested decision structure of the representative household's utility function (see Figure 3-10) is nearly identical to that for investment demand as shown in Figure 3-9. The lower Armington nest is where the representative household optimises the mix of imperfectly substitutable domestic and imported varieties of each commodity in order to minimise the cost of the composite commodity, where $A3(c,s)$ is the household basic taste change for each source-specific commodity in Equation (3.47).

$$X3\_S(c) = CES\left[All,s,SRC:\left(\frac{X3(c,s)}{A3(c,s)}\right)\right] \quad (3.47)$$

$$V3TOT = \sum X3\_S(c) * P3\_S(c) \quad (3.48)$$

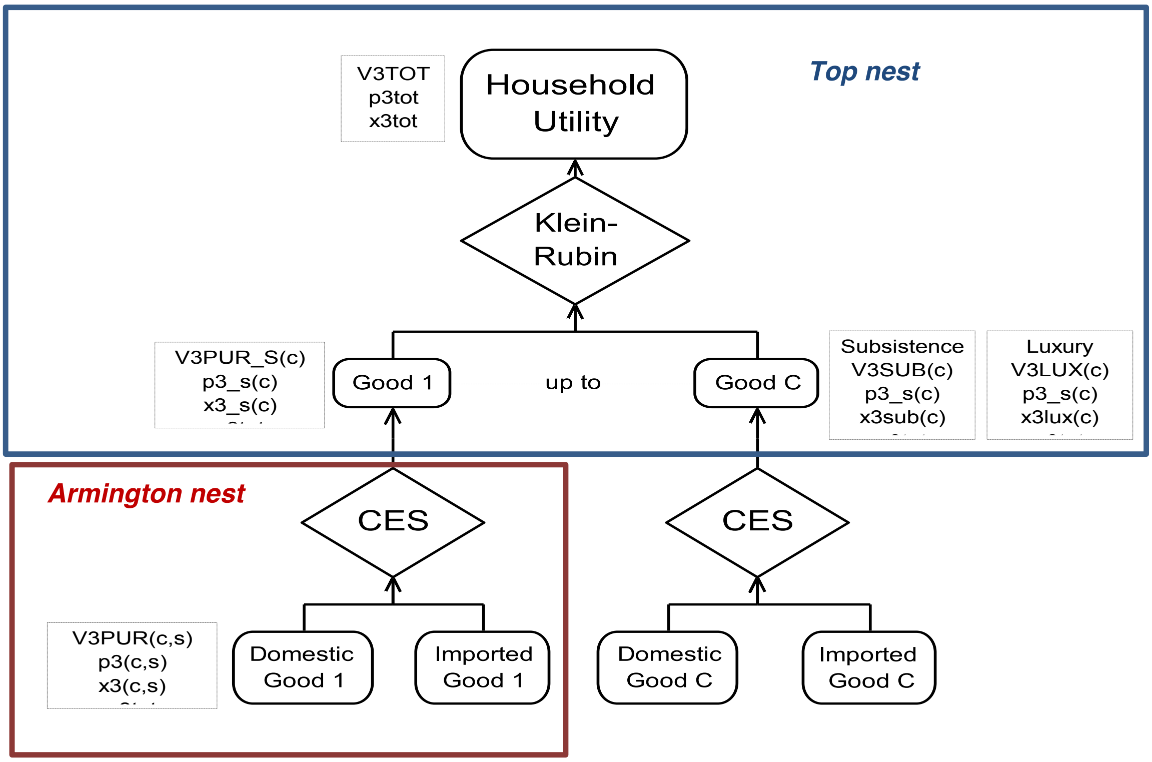
The solution to the above cost minimisation problem is provided in the following Equation (3.49). The effective household demand for each source-specific commodity is a function of the demand for the composite commodity and a price term consisting of the elasticity of substitution $SIGMA3(\text{c})$ and the price ratio of each source-specific commodity relative to the average price of the composite commodity $p3\_s(c)$. Substitution can take place in favour of the cheapening source. The effective price of the composite commodity is given by Equation (3.50) where $S3(c,s)$ are the household source shares.

$$\begin{aligned} &E\_x3 \text{ \# Source-specific commodity demands \#} \\ &(all,c,COM)(all,s,SRC) \\ &x3(c,s) - a3(c,s) = x3\_s(c) - SIGMA3(c)*[\,p3(c,s) + a3(c,s) - p3\_s(c)\,] \end{aligned} \quad (3.49)$$

$$\begin{aligned} &E\_p3\_s \text{ \# Effective price of composite commodity \#} \\ &(all,c,COM)\ p3\_s(c) = sum\{s,SRC,\ S3(c,s)*[p3(c,s) + a3(c,s)]\} \end{aligned} \quad (3.50)$$

The top nest of Figure 3-10 is represented by a linear expenditure system (LES) derived from the Klein-Rubin utility function where the consumption of each good has both subsistence and luxury components. The choice of the Klein-Rubin utility function reduces the parameter requirements, such as the estimation of many elasticities or the elasticities that measure the response of demand for good *i*, in general, to changes in the expenditure level of the average household and changes in the general prices of good *k* (Dixon & Rimmer 2002). A full system requires n x $(n+1)$ elasticities where n is the number of commodities. The parameters required are marginal budget shares and the Frisch parameter in this household demand setting, reducing the parameter requirements to $n+1$.

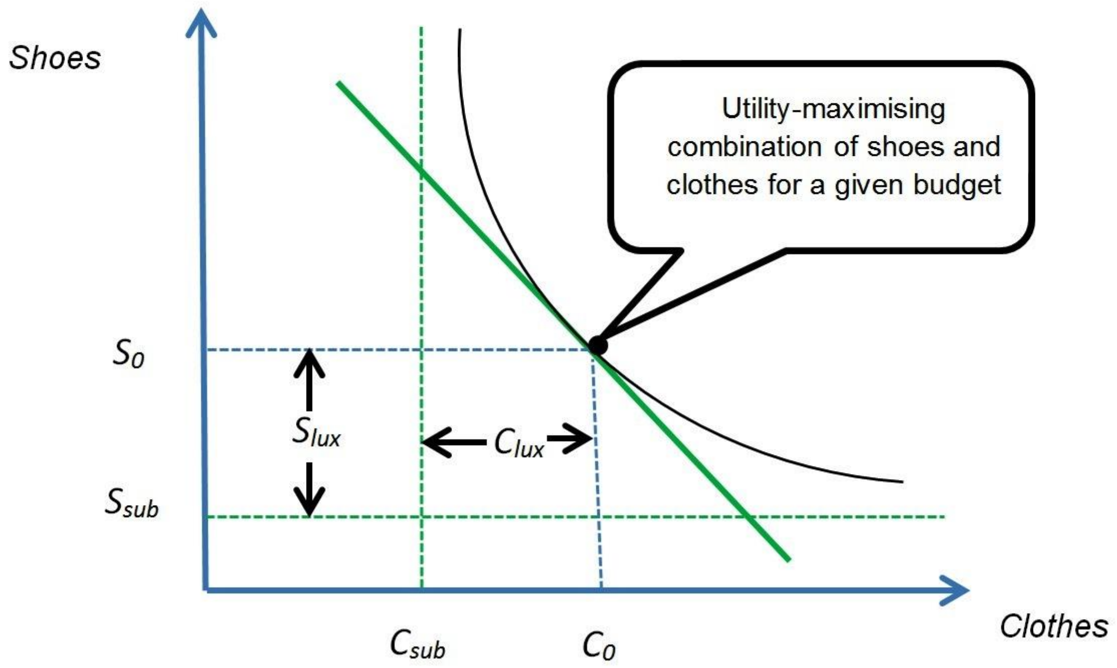
Figure 3-10: Household demand structure



Source: Adapted from Horridge (2003)

As mentioned earlier, total household expenditure consists of subsistence and luxury expenditure on every commodity. Figure 3-11 shows a two-goods example. Subsistence is a quantity of goods that is purchased regardless of price or income. After spending on subsistence (C_{sub}, S_{sub}), the balance of the income will go towards the consumption of the luxury component (C_{lux}, S_{lux}), which generates utility. In this example, it is assumed that there is always enough money in the budget for consuming the subsistence levels of shoes, S_{sub} to protect the feet and clothes C_{sub} to keep warm. The Klein-Rubin function is non-homothetic, which means that a change in income can cause budget shares to change even if the price ratios are fixed. For example, by allowing for non-unitary expenditure elasticities, a 1 per cent increase in income may cause the uneven increase in demand for clothes, say to rise by 1.4 per cent, compared to demand for shoes that rises by 0.8 per cent.

Figure 3-11: Klein-Rubin utility function



The household demand problem is to maximise the utility function in Equation (3.51) subject to a budget constraint in Equation (3.52) for nominal consumption. Although there is a representative household in terms of modelling its behaviour, this utility refers to the actual households themselves.

$$Utility * Q = \prod_c \{X3\_S(c) - X3SUB(c)\}^{S3LUX(c)} \quad (3.51)$$

$$Y = \sum P_c X_c \quad (3.52)$$

Q is the number of households. As Q increases, the size of the representative household increases, meaning that the subsistence expenditure increases in Equation (3.56). Equation (3.53) is the actual household demand or consumption for commodity c from all sources s.

$$X3\_S(c) = X3SUB(c) + X3LUX(c) \quad (3.53)$$

$$X3\_S(c) = X3SUB(c) + S3LUX(c)*\frac{V3LUX\_C}{P3\_S(c)} \quad (3.54)$$

where $$V3LUX\_C = V3TOT - \sum X3SUB(c)*P3\_S(c) \quad (3.55)$$

and $$X3SUB(c) = Q*A3SUB(c) \quad (3.56)$$

The linear percentage change solutions to the household utility maximisation problem are shown in Equations (3.57) to (3.63).

$$\begin{aligned}&E\_x3sub \text{ \# Subsistence demand for composite commodities \#}\\&(all,c,COM)\ x3sub(c) = q + a3sub(c)\end{aligned} \quad (3.57)$$

$$\begin{aligned}&E\_x3lux \text{ \# Luxury demand for composite commodities \#}\\&(all,c,COM)\ x3lux(c) + p3\_s(c) = w3lux + a3lux(c)\end{aligned} \quad (3.58)$$

$$\begin{aligned}&E\_x3\_s \text{ \# Total household demand for composite commodities \#}\\&(all,c,COM)\ x3\_s(c) = B3LUX(c)*x3lux(c) + [1 - B3LUX(c)]*x3sub(c)\end{aligned} \quad (3.59)$$

$$\begin{aligned}&E\_utility \text{ \# Change in utility disregarding taste change terms \#}\\&utility + q = sum\{c,COM,\ S3LUX(c)*x3lux(c)\}\end{aligned} \quad (3.60)$$

$$\begin{aligned}&E\_w3lux \text{ \# Budget constraint \#}\\&x3tot = sum\{c,COM,\ sum\{s,SRC,\ [V3PUR(c,s)/V3TOT]*x3(c,s)\}\}\end{aligned} \quad (3.61)$$

$$\begin{aligned}&E\_p3tot \text{ \# Consumer price index \#}\\&p3tot = sum\{c,COM,\ sum\{s,SRC,\ [V3PUR(c,s)/V3TOT]*p3(c,s)\}\}\end{aligned} \quad (3.62)$$

$$\begin{aligned}&E\_w3tot \text{ \# Household budget constraint\#}\\&w3tot = x3tot + p3tot\end{aligned} \quad (3.63)$$

In Equations (3.53) to (3.56), $X3SUB(c)$ and $S3LUX(c)$ are behavioural coefficients, where $S3LUX(c)$ must add up to unity. The $X3SUB(c)$ is the subsistence requirement of each good c purchased regardless of its price, where $P3\_S(c)$ is the price of the composite commodity c. This subsistence requirement is proportional to the number of households Q and subsistence demand, $A3SUB(c)$ in Equation (3.56). $V3LUX\_C$ is what remains of the consumer budget after subsistence expenditures are deducted—we call this "luxury" or "supernumerary" expenditure in Equation (3.55). The luxury spending on good c is a fixed proportion of supernumerary income, $V3LUX\_C$ in the Cobb-Douglas utility-maximising demand equation in Equation (3.64).

$$P3\_S(c)*X3LUX(c) = S3LUX(c)*V3LUX\_C \tag{3.64}$$

The $S3LUX(c)$ in Equation (3.64) are the shares of this remnant allocated to each good—the marginal budget shares. Though typically unobservable, the luxury shares can be deduced from the expenditure elasticity where:

$$S3LUX(c) = EPS(c)*S3\_S(c) \tag{3.65}$$

Expenditure elasticity of demand (EPS) is defined as the responsiveness for the demand of good c due to a change in the household income. It is the ratio of marginal budget share to the average budget share.

The Frisch parameter is the parameter measuring the sensitivity of the marginal utility of income to total expenditures and establishes the relationship between own price and income elasticities (Jussila et al. 2012). It is the 'money flexibility' (Frisch, cited in Selvanathan 1993), where a lower income elasticity of the marginal utility of income in absolute value is associated with more affluency. It is defined as the negative ratio of total household consumption to luxury consumption in Equation (3.66).

$$FRISCH = -\frac{V3TOT}{V3LUX\_C} \quad (3.66)$$

and $$EPS(c) = -\frac{X3LUX(\mathrm{c})}{X3(c)} * FRISCH \quad (3.67)$$

Hence, the expenditure elasticity for each good c is the product of the absolute value of the Frisch parameter and share of luxury spending on the commodity in the household's total spending on the commodity in Equation (3.67). The luxury expenditure on good c as a share of total expenditure on good c is the ratio of expenditure elasticity to the Frisch parameter, as show in Equation (3.68).

$$B3LUX(c) = -EPS(c) / FRISCH \quad (3.68)$$

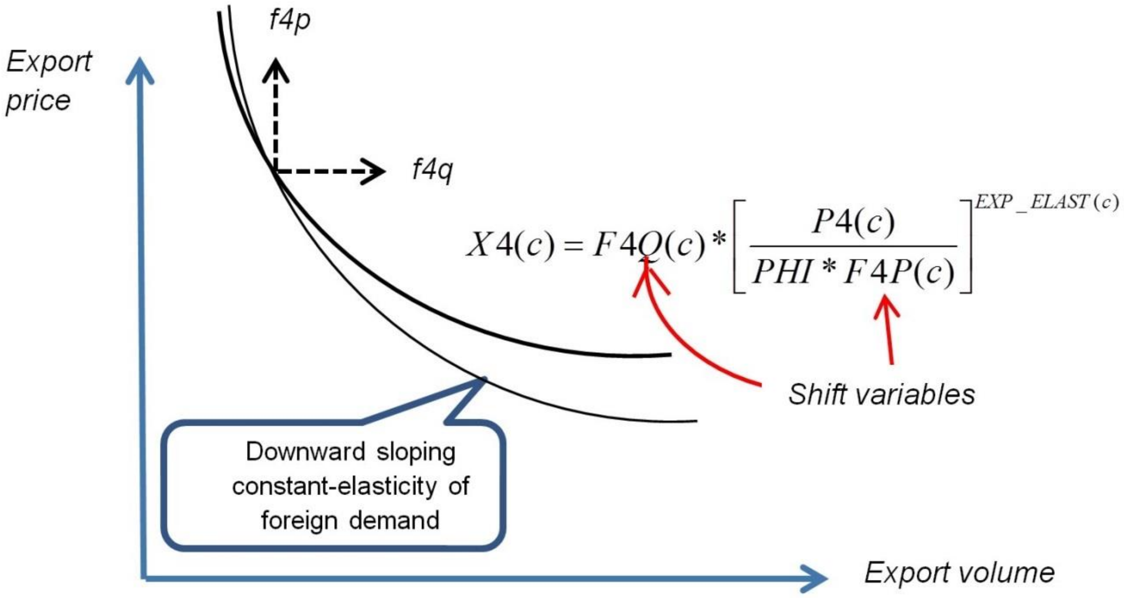
3.3.4 Export demands

In BRUGEM, commodities are divided into two groups: individual export commodities (defined by set TRADEXP) and collective exports (defined by set NTRADEXP). Individual export commodities are the main exports of Brunei, which are modelled individually. For each individual export commodity, foreign demand is inversely related to the foreign currency price of the commodity (see Figure 3-12). The foreign currency price $pf4(c)$ is converted to local currency price $p4(c)$ in Equation (3.69) with the exchange rate phi defined as a trade-weighted index of Brunei dollars to foreign currency.

$$\begin{aligned} &E\_pf4 \text{ \# Foreign currency export prices \#} \\ &(all,c,COM)\ pf4(c)\ =\ p4(c)\ -\ phi; \end{aligned} \quad (3.69)$$

Remaining exports, including service exports, are modelled collectively, where the foreign demand is inversely related to the average price of all collective export commodities.

Figure 3-12: Individual export demands



In BRUGEM, export demand is modelled in two separate demand functions representing the individual (*X4A*) and collective exports (*X4B*) in Equations (3.70) and (3.71).

E_x4A # Individual export demand functions # (3.70)

$$(\text{all,c,TRADEXP})\ x4(c) - f4q(c) = -ABS\left[EXP\_ELAST(c)\right] * \left[p4(c)\ -\ phi\ -\ f4p(c)\right]$$

E_x4B # Collective export demand functions # (3.71)

$$(\text{all,c,NTRADEXP})\ x4(c)\ -\ f4q(c)\ =\ x4\_ntrad$$

E_x4_ntrad # Demand for collective export aggregate # (3.72)

$$x4\_ntrad - f4q\_ntrad = -ABS\left[EXP\_ELAST\_NT\right] * \left[p4\_ntrad - phi - f4p\_ntrad\right]$$

E_p4_ntrad # Average price of collective exports # (3.73)

$$\left[TINY + V4NTRADEXP\right] * p4\_ntrad\ =\ sum\left\{c, NTRADEXP,\ V4PUR(c) * p4(c)\right\}$$

The export demand schedule of a particular commodity can be shocked via the shift variables $f4p(c)$ and $f4q(c)$, representing vertical movement (price) and horizontal movement (quantity) respectively. Similarly, the collective exports can be shocked via the shift variables $f4p\_ntrad$ and $f4q\_ntrad$ for price and quantity shifts respectively.

3.3.5 Government demands

In BRUGEM, there is a simple theory of government demand. There are two modelling choices with the use of shift variables, $f5tot$ or $f5tot2$, to switch on one of two rules: government demands are exogenous or they follow household consumption. These are given in Equations (3.74) and (3.75) respectively.

$$E\_x5 \ \# \text{ Government demands } \# \qquad (3.74)$$
$$(all,c,COM)(all,s,SRC)\ x5(c,s) = f5(c,s) + f5tot$$

$$E\_f5tot \ \# \text{ Overall government demands shift } \# \qquad (3.75)$$
$$f5tot = x3tot + f5tot2$$

The assumption that government demand changes in proportion to aggregate private consumption is activated by exogenising $f5tot2$. This implies that greater household consumption will demand more government services. In this closure, $f5tot$ is endogenous and equal to $x3tot$. With $f5(c,s)$ exogenous for all c and s, any increase in $x3tot$ will lead to an increase in $f5tot$ as well as $x5(c,s)$.

To make government demand overall exogenous, $f5tot$ will be exogenous and $f5tot2$ endogenous. Alternatively, $x5tot$ may be exogenous and $f5tot3$ endogenous in Equation (3.76). Exogenous shocks to $f5(c,s)$ or $x5(c,s)$ are used to target government expenditure on particular commodities.

$$E\_f5tot3 \ \# \text{ Ratio between government consumption to GDP } \#; \qquad (3.76)$$
$$x5tot = x0gdp\exp + f5tot3;$$

3.3.6 Inventory demands

Similarly, there is a simple theory to explain the demand for stocks or inventories. The assumption made in the model is that inventory demands move in proportion to the domestic production. Since inventory demand can change in sign between positive and negative, it is expressed as a change variable $delx6(c,s)$ instead of a percentage change variable in Equations (3.77) and (3.78).

$$E\_delx6 \text{ # Stocks follow domestic output # } \quad (3.77)$$
$$(all,c,COM)(all,s,SRC)$$
$$100*LEVP0(c,s)*delx6(c,s) = V6BAS(c,s)*x0com(c) + fx6(c,s)$$

$$E\_delV6 \text{ # Update formula for stocks # } \quad (3.78)$$
$$(all,c,COM)(all,s,SRC)$$
$$delV6(c,s) = 0.01*V6BAS(c,s)*p0(c,s) + LEVP0(c,s)*delx6(c,s)$$

3.3.7 Margin demands

Margins are required to facilitate the transfer of each source-specific commodity from producers to users. In BRUGEM, it is assumed that inventories do not need margins. In the absence of technical change in margin usage, the demand for margins for other users is modelled to move in proportion to the commodity flows with which the margins are associated. Therefore, an increase in the demand of commodity *c* will lead to an increase in the associated margin demands to move commodity *c* to its users. The following Equations (3.79) to (3.83) are the margin demands in percentage change form for each user:

$$E\_x1mar \text{ # Margins to producers # } \quad (3.79)$$
$$(all,c,COM)(all,s,SRC)(all,i,IND)(all,m,MAR)$$
$$x1mar(c,s,i,m) = x1(c,s,i) + a1mar(c,s,i,m)$$

$$E\_x2mar \text{ # Margins to investment # } \quad (3.80)$$
$$(all,c,COM)(all,s,SRC)(all,i,IND)(all,m,MAR)$$
$$x2mar(c,s,i,m) = x2(c,s,i) + a2mar(c,s,i,m)$$

$$E\_x3mar \text{ # Margins to households # } \quad (3.81)$$
$$(all,c,COM)(all,s,SRC)(all,m,MAR)\, x3mar(c,s,m) = x3(c,s) + a3mar(c,s,m)$$

$$E\_x4mar \text{ # Margins to exports # } \quad (3.82)$$
$$(all,c,COM)(all,m,MAR)\, x4mar(c,m) = x4(c) + a4mar(c,m)$$

$$E\_x5mar \text{ \# Margins to government \# } \quad (3.83)$$
$$(all,c,COM)(all,s,SRC)(all,m,MAR)\; x5mar(c,s,m) = x5(c,s) + a5mar(c,s,m)$$

3.3.8 Government accounts

The inclusion of government accounts in BRUGEM represents a departure from the ORANIG-RD model on which BRUGEM is based. The government accounts cover government income and expenditure by broad categories as defined in DOS (2012a).

3.3.8.1 Government revenues

The Brunei government derives its income from oil and gas companies in the form of taxes, dividends and royalties ("OGR"); income taxes imposed on households ("PIT"), although at present the personal income tax rate is nil; corporate taxes collected from non-oil and gas enterprises ("CIT"); revenues collected from duties ("DUTIES"); fees and charges ("FCR"); and miscellaneous ("OTHERS"). The government also derives revenue from investment and savings ("ROIS"). Income received from the SWF is not included in BRUGEM since it is not shown as part of the government income in the published data. Government revenue items are modelled in BRUGEM based on several rules, as shown in Equations (3.84) to (3.92).

It is assumed that government revenue from the oil and gas sector is indexed to the oil and gas sector's value-add in Equation (3.86). It is also assumed that non-oil and gas corporate tax revenues will grow in proportion to the non-oil and gas producers' total value-add; revenue from duties will grow in line with the tariff revenues collected from imports; and other revenues from fees and rents will move with the size of the economy as measured by GDP. It is assumed that revenue generated from investments and savings (excluding SWF) will grow with oil and gas revenues, as leftovers from windfalls are saved after being used in government expenditure. In Equation (3.92), $ntaxrev$ is a reporting summary variable for total tax revenue. This will be a useful variable for keeping track of the movement of non-oil and gas revenues once oil and gas revenues disappear.

$E\_d\_wgovrev$ # Change in government revenue B$ million # (3.84)
$(all, r, GOVREV)\ 100 * d\_wgovrev(r) = VGOVREV(r) * wgovrev(r)$

$E\_wgovrevA$ # Individual income tax revenue # (3.85)
$wgovrev("PIT") = w1lab\_io + tax\_l\_r + f\_gov\_rev("PIT")$

$E\_wgovrevB$ # Oil and gas revenue # (3.86)
[sum{j,OILSEC,V1CAP(j)}+sum{j,OILSEC,V1LND(j)}+
sum{j,OILSEC,V1PTX(j)}+Sum{j,OILSEC,V1OCT(j)}]$*[wgovrev("OGR") +$
$f\_gov\_rev("OGR")] =$
$[Sum\{j, OILSEC, V1CAP(j) * (x1cap(j) + p1cap(j))\} +$
$Sum\{j, OILSEC, V1LND(j) * (x1\ln d(j) + p1\ln d(j))\}] +$
$[Sum\{j, OILSEC, 100 * (delV1PTX(j))\}] +$
$[Sum\{j, OILSEC, V1OCT(j) * (x1oct(j) + p1oct(j))\}]$

$E\_wgovrevC$ # Corporate income taxes revenue # (3.87)
[Sum{j,NONOIL,V1CAP(j)}+Sum{j,NONOIL,V1LND(j)}+
Sum{j,NONOIL,V1OCT(j)}]$*[wgovrev("CIT") + f\_gov\_rev("CIT")] =$
$[Sum\{j, NONOIL, V1CAP(j) * (x1cap(j) + p1cap(j))\} +$
$Sum\{j, NONOIL, V1LND(j) * (x1\ln d(j) + p1\ln d(j))\} +$
$Sum\{j, NONOIL, V1OCT(j) * (x1oct(j) + p1oct(j))\}]$

$E\_wgovrevD$ # Revenue from duties # (3.88)
$VGOVREV("Duties") * [wgovrev("Duties") + f\_gov\_rev("Duties")] =$
$[Sum(c, COM, V0TAR(c) * \{pf0cif(c) + phi + x0imp(c)\}) +$
$Sum(d, COM, V0IMP(d) * t0imp(d))]$

$E\_wgovrevE$ # Revenues from fees, charges and rent # (3.89)
$wgovrev("FCR") = w0gdp\exp + f\_gov\_rev("FCR")$

$E\_wgovrevF$ # Other revenues # (3.90)
$wgovrev("Others") = w0gdp\exp + f\_gov\_rev("Others")$

$E\_wgovrevG$ # Revenues from investments and savings excluding SWF # (3.91)
$wgovrev("ROIS") = wgovrev("OGR") + f\_gov\_rev("ROIS")$

$$E\_ntaxrev \ \# \text{ Other non-oil tax revenue } \#$$ (3.92)

$$NONTAXREV * ntaxrev \ = \ VGOVREV("Duties") * wgovrev("Duties") +$$
$$VGOVREV("FCR") * wgovrev("FCR") + VGOVREV("Others") * wgovrev("Others")$$
$$+VGOVREV("ROIS") * wgovrev("ROIS")$$

3.3.8.2 Government expenditure

The government total expenditure is made up of charged expenditure ("CHARGED"), which comprises pensions, retirement allowances, gratuities and special allowances; personnel emoluments ("PE"), which include all government salaries, employee provident funds and allowances; other charged annually recurrent expenditure ("OCAR"), which is for annual operations and maintenance; other charges special expenditure ("OCSE"), which is allocated to expenditure on one-off projects; and development expenditure ("DEVEXP"), which includes capital expenditure and expenditure related to national development plans, as classified by the DOS (DOS 2012). The government consumption expenditure, which consists of the compensation of employees and purchase of goods and services, less government receipts from sales of goods and services (reported as government consumption expenditure as one of the GDP components, or $w5tot$), is part of the government total expenditure.

Where detailed information is not available, the government expenditure items are assumed to move with the expansion of the government sector in Equations (3.95) and (3.96). It is also assumed that the special and development expenditure will grow in line with the economic activities, as shown in Equations (3.97) and (3.98).

$$E\_d\_wgov\exp \ \# \text{ Change in government expenditure B\$ million } \#$$ (3.93)

$$(all, e, GOVEXP) \ 100 \ * \ d\_wgov\exp(e) \ = \ VGOVEXP(e) * wgov\exp(e)$$

$$E\_wgov\exp A \ \# \text{ Personnel Emoluments } \#$$ (3.94)

VGOVEXP("PE")*[wgovexp("PE")+f_gov_exp("PE")]=
[Sum{j,GOVSEC,V1LAB_O(j)*w1lab_o(j)}]

$$E\_wgov\exp B \text{ \# Other charges annually recurrent \#} \quad (3.95)$$
$$wgov\exp("OCAR") = w5tot + f\_gov\_\exp("OCAR")$$

$$E\_wgov\exp C \text{ \# Charged expenditure \#} \quad (3.96)$$
$$wgov\exp("CHARGED") = w5tot + f\_gov\_\exp("CHARGED")$$

$$E\_wgov\exp D \text{ \# Other charges special expenditure \#} \quad (3.97)$$
$$wgov\exp("OCSE") = w0gdp\exp + f\_gov\_\exp("OCSE")$$

$$E\_wgov\exp E \text{ \# Development expenditure \#} \quad (3.98)$$
$$wgov\exp("DEVEXP") = w0gdp\exp + f\_gov\_\exp("DEVEXP")$$

The government budget balance is the difference between the government income and expenditure and is expressed in Equation (3.99) as an ordinary change, since it can change sign. A negative balance indicates a budget deficit and a positive balance, a fiscal surplus.

$$E\_d\_budget \text{ \# Ordinary change in government budget balance \#}$$
$$d\_budget = sum\{r, GOVREV, d\_wgovrev(r)\} - sum\{e, GOVEXP, d\_wgov\exp(e)\} \quad (3.99)$$

3.3.9 Zero pure profit and market clearing equations

BRUGEM uses several sets of commodity prices: purchasers' prices, basic values, prices of capital units, FOB (free on board) foreign currency export prices and CIF foreign currency import prices. The key initial assumptions made are: (i) there are no pure profits in any economic activity (producing, importing, exporting, transporting or distribution), and (ii) basic values are uniform across users and across producing industries, in the case of domestic goods, and importers, in the case of imported goods. Differences across users in purchasers' prices are due to the sales tax rates (power of tax represented by *t*) and margins imposed and there are no margins on margins (Dixon et al. 2002). These purchasers' prices for final users are presented in the Equations (3.100) to (3.105), where inventories are excluded because we assume they have no margins or taxes.

$$E\_p1 \ \# \text{ Purchasers prices - producers } \# \quad (3.100)$$
$$(all,c,COM)(all,s,SRC)(all,i,IND)$$
$$[V1PUR(c,s,i)+TINY]*p1(c,s,i) =$$
$$[V1BAS(c,s,i)+V1TAX(c,s,i)]*[p0(c,s)+t1(c,s,i)]$$
$$+ sum\{m,MAR, V1MAR(c,s,i,m)*[p0dom(m)+a1mar(c,s,i,m)]\}$$

$$E\_p2 \ \# \text{ Purchasers prices - capital creators } \# \quad (3.101)$$
$$(all,c,COM)(all,s,SRC)(all,i,IND)$$
$$[V2PUR(c,s,i)+TINY]*p2(c,s,i) =$$
$$[V2BAS(c,s,i)+V2TAX(c,s,i)]*[p0(c,s)+t2(c,s,i)]$$
$$+ sum\{m,MAR, V2MAR(c,s,i,m)*[p0dom(m)+a2mar(c,s,i,m)]\}$$

$$E\_p3 \ \# \text{ Purchasers prices - households } \# \quad (3.102)$$
$$(all,c,COM)(all,s,SRC)$$
$$[V3PUR(c,s)+TINY]*p3(c,s) =$$
$$[V3BAS(c,s)+V3TAX(c,s)]*[p0(c,s)+t3(c,s)]$$
$$+ sum\{m,MAR, V3MAR(c,s,m)*[p0dom(m)+a3mar(c,s,m)]\}$$

$$E\_p4 \ \# \text{ Zero pure profits in exporting } \# \quad (3.103)$$
$$(all,c,COM)$$
$$[V4PUR(c)+TINY]*p4(c) =$$
$$[V4BAS(c)+V4TAX(c)]*[pe(c)+t4(c)]$$
$$+ sum\{m,MAR, V4MAR(c,m)*[p0dom(m)+a4mar(c,m)]\}$$

$$E\_p5 \ \# \text{ Zero pure profits in distribution to government } \# \quad (3.104)$$
$$(all,c,COM)(all,s,SRC)$$
$$[V5PUR(c,s)+TINY]*p5(c,s) =$$
$$[V5BAS(c,s)+V5TAX(c,s)]*[p0(c,s)+t5(c,s)]$$
$$+ sum\{m,MAR, V5MAR(c,s,m)*[p0dom(m)+a5mar(c,s,m)]\}$$

$$E\_p0B \ \# \ \textit{Zero pure profits in importing} \ \# \quad (3.105)$$
$$(all,c,COM) \ p0(c,"imp") = pf0cif(c) + phi + t0imp(c)$$

Under zero pure profit assumptions, in the production of commodities by domestic industries, the total revenue must equal the total cost in Equation (3.120). In the case of exporting, the revenue received from exporting one unit of commodity must equal the cost of exporting that unit of commodity. As for importing, per unit revenue obtained from selling the imported commodity must also equal the per unit cost of importing it.

The market is assumed to clear where all commodities supplied (whether domestically produced or imported) must be demanded and taken up fully by all the users, including inventories, as shown in Equations (3.106) to (3.119). Equations (3.120) and (3.121) are to ensure the markets cleared.

Set DEST # Sale Categories #
(Interm, Invest, HouseH, Export, GovGE, Stocks, Margins);

$$Variable\ (change)$$
$$(all,c,COM)(all,s,SRC)(all,d,DEST)\ delSale(c,s,d)\ \#\ Sales\ aggregates\ \#$$

$$E\_delSaleA\ (all,c,COM)(all,s,SRC)$$
$$delSale(c,s,"Interm") = 0.01*sum\{i,IND,V1BAS(c,s,i)*x1(c,s,i)\} \quad (3.106)$$

$$E\_delSaleB\ (all,c,COM)(all,s,SRC) \quad (3.107)$$
$$delSale(c,s,"Invest") = 0.01*sum\{i,IND,V2BAS(c,s,i)*x2(c,s,i)\}$$

$$E\_delSaleC\ (all,c,COM)(all,s,SRC) \quad (3.108)$$
$$delSale(c,s,"HouseH") = 0.01*V3BAS(c,s)*x3(c,s)$$

$$E\_delSaleD\ (all,c,COM)$$
$$delSale(c,"dom","Export") = 0.01*V4BAS(c)*x4(c) \quad (3.109)$$

$$E\_delSaleE\ (all,c,COM)\ delSale(c,"imp","Export") = 0 \quad (3.110)$$

$$E\_delSaleF\ (all,c,COM)(all,s,SRC) \quad (3.111)$$
$$delSale(c,s,"GovGE") = 0.01*V5BAS(c,s)*x5(c,s)$$

$$E\_delSaleG\ (all,c,COM)(all,s,SRC)$$
$$delSale(c,s,"Stocks") = LEVP0(c,s)*delx6(c,s) \quad (3.112)$$

$$E\_delSaleH\ (all,m,MAR) \quad (3.113)$$
$$delSale(m,"dom","Margins") = 0.01*sum\{c,COM,\ V4MAR(c,m)*x4mar(c,m)$$
$$+sum\{s,SRC,\ V3MAR(c,s,m)*x3mar(c,s,m)+V5MAR(c,s,m)*x5mar(c,s,m)$$
$$+sum\{i,IND,\ V1MAR(c,s,i,m)*x1mar(c,s,i,m)+V2MAR(c,s,i,m)*x2mar(c,s,i,m)\}\}\}$$

$$E\_delSaleI \ (all,n,NONMAR) \ delSale(n,"dom","Margins") = 0 \quad (3.114)$$

$$E\_delSaleJ \ (all,c,COM) \quad delSale(c,"imp","Margins") = 0 \quad (3.115)$$

Set LOCUSER # Non-export users #(Interm, Invest, HouseH, GovGE, Stocks,Margins);
Subset LOCUSER is subset of DEST;

$$(all,c,COM) \ DOMSALES(c) = SALES(c) - V4BAS(c) \quad (3.116)$$

E_p0A # Supply = Demand for domestic commodities #

$$(all,c,COM) \ 0.01*[TINY + DOMSALES(c)]*x0dom(c) = sum\{u,LOCUSER,delSale(c,"dom",u)\} \quad (3.117)$$

E_x0imp # Import volumes #

$$(all,c,COM) \ 0.01*[TINY + V0IMP(c)]*x0imp(c) = sum\{u,LOCUSER,delSale(c,"imp",u)\} \quad (3.118)$$

$$(all,c,COM) \ SALES(c) = sum\{d,DEST, \ SALE(c,"dom",d)\} \quad (3.119)$$

Identities for COSTS and SALES to ensure markets cleared:

$(all,i,IND) \ DIFFIND(i)$ # $COSTS - MAKE\_C$: should be zero #;

$(all,c,COM) \ DIFFCOM(c)$ # $SALES - MAKE\_I$: should be zero #

$$(all,i,IND) \ DIFFIND(i) = V1TOT(i) - MAKE\_C(i); \quad (3.120)$$

$$(all,c,COM) \ DIFFCOM(c) = SALES(c) - MAKE\_I(c); \quad (3.121)$$

3.3.10 Trade balance, terms of trade and real exchange rate

The trade balance is computed as an ordinary change (*delB*) and not as a percentage change in Equation (3.122), because zero is a plausible base-period value if the value of exports equals the value of imports. The terms of trade variable is defined in terms of the indices of export and import prices at CIF prices in Equation (3.123). The real devaluation (Equation 3.124) or the real exchange rate is the ratio of the import price index at CIF prices to the GDP deflator, which measures the changes in domestic prices in relation to world prices, using CIF import prices as a proxy for world prices. A positive value indicates that the domestically produced goods are relatively cheaper in the world market, or a real devaluation of currency is observed.

E_delB # Nominal balance of trade/nominal GDP # (3.122)
$100 * V0GDPEXP * delB = V4TOT * w4tot - V0CIF\_C * w0cif\_c$
$-[V4TOT - V0CIF\_C] * w0gdp\exp$

E_p0toft # Terms of trade # $p0toft = p4tot - p0cif\_c$ (3.123)

$E\_p0realdev$ # Real devaluation # $p0realdev = p0cif\_c - p0gdp\exp$ (3.124)

Export demand for individual commodities was explained in Section 3.3.4 and imports are explained in the various Armington substitution equations. Equations (3.125) to (3.127) give aggregate import volume, price and value of imports. Equations (3.128) to (3.130) give the aggregate export volume, price and value of exports.

E_x0imp_c # Import volume index, duty-paid weight # (3.125)
$x0imp\_c = sum\{c, COM, [V0IMP(c) / V0IMP\_C] * x0imp(c)\}$

E_p0imp_c # Duty-paid imports price index, local currency # (3.126)
$p0imp\_c = sum\{c, COM, [V0IMP(c) / V0IMP\_C] * p0(c, "imp")\}$

E_w0imp_c # Value of imports plus duty # (3.127)
$w0imp\_c = x0imp\_c + p0imp\_c$

E_x4tot # Export volume index # (3.128)
$V4TOT * x4tot = sum\{c, COM, V4PUR(c) * x4(c)\}$

E_p4tot # Exports price index, local currency # (3.129)
$V4TOT * p4tot = sum\{c, COM, V4PUR(c) * p4(c)\}$

E_w4tot # Local currency border value of exports # (3.130)
$w4tot = x4tot + p4tot$

3.3.11 GDP from the income and expenditure sides and GNE

GDP from the income side consists of total factor payments to labour, capital and land, value of other costs, total commodity taxes and production taxes expressed in nominal aggregates. The percentage change in nominal GDP from the income side is a share-weighted average of the percentage changes in nominal aggregate factor payments and indirect taxes in Equation (3.131).

$E\_w0gdpinc$ # Nominal GDP from income side # (3.131)

$$w0gdpinc = \frac{1}{V0GDPINC}\begin{bmatrix} V1LAB\_IO * w1lab\_io + V1CAP\_I * w1cap\_i \\ +V1LND\_I * w1lnd\_i + 100 * delV0tax\_csi \end{bmatrix}$$

E_x0gdpinc # Real GDP from the income side # (3.132)

x0gdpinc = [1/V0GDPINC][*
! primary factor contributions !
*V1LAB_IO*employ_i + V1CAP_I*x1cap_i + V1LND_I*x1lnd_i*
! indirect tax contributions !
*+ sum{i,IND, V1OCT(i)*x1oct(i)}*
*+ sum{i,IND, V1PTX(i)*x1tot(i)}*
*+ sum{c,COM, V0TAR(c)*x0imp(c)}*
*+ sum{c,COM,sum{s,SRC, sum{i,IND, V1TAX(c,s,i)*x1(c,s,i)}}}*
*+ sum{c,COM,sum{s,SRC, sum{i,IND, V2TAX(c,s,i)*x2(c,s,i)}}}*
*+ sum{c,COM,sum{s,SRC, V3TAX(c,s)*x3(c,s)}}*
*+ sum{c,COM, V4TAX(c)*x4(c)}*
*+ sum{c,COM,sum{s,SRC, V5TAX(c,s)*x5(c,s)}}*
! technical change contributions !
- sum{c,COM,sum{s,SRC, sum{i,IND, V1BAS(c,s,i)[a1(c,s,i)+a1_s(c,i)]}}}*
- sum{c,COM,sum{s,SRC, sum{i,IND, V2BAS(c,s,i)[a2(c,s,i)+a2_s(c,i)]}}}*
*- sum{i,IND, V1LAB_O(i)*a1lab_o(i)}*
*- sum{i,IND, V1CAP(i)*a1cap(i)}*
*- sum{i,IND, V1LND(i)*a1lnd(i)}*
*- sum{i,IND, V1OCT(i)*a1oct(i)}*
*- sum{i,IND, V1PRIM(i)*a1prim(i)}*
- sum{c,COM,sum{s,SRC,sum{i,IND,sum{m,MAR,
*V1MAR(c,s,i,m)*a1mar(c,s,i,m)}}}}*
- sum{c,COM,sum{s,SRC,sum{i,IND,sum{m,MAR,
*V2MAR(c,s,i,m)*a2mar(c,s,i,m)}}}}*
*- sum{c,COM,sum{s,SRC,sum{m,MAR, V3MAR(c,s,m)*a3mar(c,s,m)}}}*
*- sum{c,COM,sum{m,MAR, V4MAR(c,m)*a4mar(c,m)}}*
*- sum{c,COM,sum{s,SRC,sum{m,MAR, V5MAR(c,s,m)*a5mar(c,s,m)}}}*
*- sum{i,IND, V2TOT(i)*a2tot(i)}*
*- sum{i,IND, V1CST(i)*a1tot(i)}];*

Unlike the income side, the expenditure-side of nominal GDP is expressed in terms of price and quantity for each component in Equations (3.133) to (3.135).

$E\_w0gdpexp$ # Nominal GDP from expenditure side # (3.133)

$$w0gdpexp = x0gdpexp + p0gdpexp$$

$E\_x0gdpexp$ # Real GDP from expenditure side # (3.134)

$$x0gdpexp = \frac{1}{V0GDPEXP}\begin{bmatrix} V3TOT * x3tot + V2TOT\_I * x2tot\_i + \\ V5TOT * x5tot + V6TOT * x6tot + \\ V4TOT * x4tot - V0CIF\_C * x0cif\_c \end{bmatrix}$$

$E\_p0gdpexp$ # GDP price index, expenditure side # (3.135)

$$p0gdpexp = \frac{1}{V0GDPEXP}\begin{bmatrix} V3TOT * p3tot + V2TOT\_I * p2tot\_i + \\ V5TOT * p5tot + V6TOT * p6tot + \\ V4TOT * p4tot - V0CIF\_C * p0cif\_c \end{bmatrix}$$

Similar to the above, the percentage change in the nominal domestic absorption or gross national expenditure (GNE) is the sum of its price and quantity indices in Equation (3.136). The quantity index is a share-weighted average of the percentage changes in real household consumption, investment, government and changes in inventories, as shown in Equation (3.137). The GNE price index is a share-weighted average of the percentage changes in the price of each GNE component in Equation (3.138).

E_w0gne # Nominal GNE from expenditure side # (3.136)

$$w0gne = x0gne + p0gne$$

$E\_x0gdpexp$ # Real GNE from expenditure side # (3.137)

$$x0gne = \frac{1}{V0GNE}\begin{bmatrix} V3TOT * x3tot + V2TOT\_I * x2tot\_i + \\ V5TOT * x5tot + V6TOT * x6tot \end{bmatrix}$$

E_p0gne # GNE price index, expenditure side # (3.138)

$$p0gne = \frac{1}{V0GNE}\begin{bmatrix} V3TOT * p3tot + V2TOT\_I * p2tot\_i + \\ V5TOT * p5tot + V6TOT * p6tot \end{bmatrix}$$

3.3.12 Other prices and miscellaneous definitional equations

The equations described in Sections 3.3.1 to 3.3.12 are by no means the complete list of equations in BRUGEM. There are many more. Here are some examples of definitional equations, such as terms of trade (Equation 3.123), real devaluation (Equation 3.124) and the nominal consumption function expressed in terms of the ratio of consumption to nominal GDP or the propensity to consume (Equation 3.139).

$$E\_f3tot \ \# \ Consumption\ function \ \# w3tot = w0gdpexp + f3tot \quad (3.139)$$

The objective of the sections 3.3.1 to 3.3.11 was to focus on the main equations. Other equations include relationships between indirect tax rates, power of sales taxes, and tax collections.

A number of equations in BRUGEM enable decompositions. These are useful for analysing the contributions of various exogenous variables or components to the movement in the endogenous variable of interest. One such example is the GDP decomposition by expenditure components (Equations 3.140 - 3.145), where *INITGDP* is the initial GDP in value (*V0GDPEXP*) from the database. This is only updated by the percentage change in the price of GDP and not by the quantity. The derivation of the change variable is illustrated in Box 3-2.

Variable (change) (all,e,EXPMAC)
contGDPexp(e) # Contributions to real expenditure-side GDP #;
Formula (initial) $INITGDP = V0GDPEXP$;
Update $INITGDP = p0gdp\exp$;
E_contGDPexpA $INITGDP * contGDP\exp("Consumption") = V3TOT * x3tot$ (3.140)

E_contGDPexpB $INITGDP * contGDP\exp("Investment") = V2TOT\_I * x2tot\_i$ (3.141)

E_contGDPexpC $INITGDP * contGDP\exp("Government") = V5TOT * x5tot$ (3.142)

E_contGDPexpD $INITGDP * contGDP\exp("Stocks") = V6TOT * x6tot$ (3.143)

E_contGDPexpE $INITGDP * contGDP\exp("Exports") = V4TOT * x4tot$ (3.144)

E_contGDPexpF $INITGDP * contGDP\exp("\text{Imports}") = -V0CIF\_C * x0cif\_c$ (3.145)

Box 3-2: Derivation of a change variable for decomposition

$$A = B + C$$

$$100\frac{dA}{A_0} = 100\frac{dB}{A_0} + 100\frac{dC}{A_0}$$ where we can define $contB = 100\frac{dB}{A_0}$, $contC = 100\frac{dC}{A_0}$

$$contB = 100\frac{dB}{A_0} = (100 * \frac{dB}{B}) * \frac{B}{A_0} = \left(\frac{P}{P}\right) * \frac{B}{A_0} * b$$ where PA_0 is like *INITGDP*

The same principle in Box 3-2 is used to generate the contributions for the decomposition results of Table 6-2, as shown and discussed later in Chapter 6.

3.4 Dynamic equations

As explained in Section 3.2, an annual recursive dynamic model is a series of comparative static simulations linked together via several dynamic equations.

There are three important dynamic mechanisms within BRUGEM. They are: (1) a stock-flow relation between investment and capital stock with the assumption of a one-year gestation lag; (2) a positive relationship between investment and the rate of return; and (3) a relationship between wage growth and employment (Horridge 2002). These are described in the following Sections 3.4.1 to 3.4.4.

3.4.1 Capital accumulation

In BRUGEM, the current period year *t*'s capital stock available for production is equal to the capital stock existing at the start of the year or the end of the previous period, year *t*-1. Depreciation rates by industry are required to work out the capital accumulation function based on the perpetual inventory method, where $K_{i,t}$ capital for industry i in year t is the depreciated value of last year's capital $K_{i,t-1}$ using depreciation rate D_i plus last year's investment $I_{i,t-1}$ in Equation (3.146). The change in capital stock is shown in Equation (3.147).

$$K_{i,t} = I_{i,t-1} + K_{i,t-1}.(1-D_i) \quad (3.146)$$

$$\Delta K_{i,t} = I_{i,t-1} - D_i K_{i,t-1} \quad (3.147)$$

To relate to the values that appear in the database, we can multiply both sides by Π_0 , the price of new capital at the start-of-the-period where $I_{i,t-1}\Pi_0$ is provided by the total capital created for industry i or the coefficient $V2TOT(i)$ and $K_{i,t-1}\Pi_0$ is provided by the total capital stock in the current period for industry i or coefficient $CAPSTOK(i)$ calculated in the method described in Section 4.3.2.10 of Chapter 4. The subscript '0' denotes the initial (start-of-period) value. Due to the assumption that investment has a "gestation period" of one year, a change of investment in this period will only affect the growth rate of capital in the next period and not the current period in Equation (3.148).

$$\Delta K_{i,t}\Pi_0 = I_{i,t-1}\Pi_0 - D_i K_{i,t-1}\Pi_0 \quad (3.148)$$

In percentage change form, the capital growth is denoted by *k* where $delUnity$ is of value 1 in Equation (3.149):

$$0.01[K_{i,t}\Pi_0].k = [I_{i,t-1}\Pi_0 - D_i K_{i,t-1}\Pi_0].delUnity \quad (3.149)$$

The homotopy variable $delUnity$ is added to the right-hand side in Equation (3.149) because this solution technique presents an issue when we break Equation (3.146) into:

$$K_{i,t} = K_{i,t-1} - K_{i,t-1}D_i + I_{i,t-1} \quad (3.150)$$

In year-to-year simulations, we want the initial solution for year *t* to reflect values for year *t*-1, since the changes we are simulating are from year *t*-1 to year *t*. If this is the case, then the initial value of $K_{i,t}$ is $K_{i,t-1}$. The Euler solution method requires that the initial (database) values for variables form a solution to the underlying levels form of the model. Unless net investment in year *t*-1 is zero in industry *i*, then the initial data for a year *t* computation will not be a solution. This is because the second term $(-K_{i,t-1}D_i + I_{i,t-1})$ is not necessarily equal to zero, so the relationship in Equation (3.148) does not hold. To overcome this problem of initial value, we add an artificial or homotopy variable $delUnity$ as a technical device for augmenting Equation (3.150), such that $K_{i,t} = K_{i,t-1} + (-K_{i,t-1}D_i + I_{i,t-1}) * delUnity.$ Then $K_{i,t} = K_{i,t-1}$ is a valid solution when $delUnity$ is set to zero in the initial solution.

For a dynamic solution, this homotopy variable is shocked by value of 1 (that is, $delUnity = 1$) to cause the correct deviation in the opening capital stock for year *t* from its value in the initial solution or its value in year *t*-1. The variable $K_{i,t}$ is updated correctly. Capital accumulation, Equation (3.149), in percentage change form is activated by exogenising the shift variable $faccum(i)$, with the homotopy variable exogenous and shocked by the value of 1 in Equation (3.151). The new capital investment added is represented by $CAPADD(i)$ or $\Delta K_{i,t}$ in Equation (3.147).

$$\begin{aligned}&E\_faccum \text{ \# Capital accumulation equation \#}\\&(all,i,IND)\ 0.01*[CAPSTOK\_OLDP(i)]*x1cap(i) = CAPADD(i)*delUnity\\&+faccum(i)\end{aligned} \quad (3.151)$$

The notations and description relating to capital and investment variables and coefficients are shown in Table 3-1.

Table 3-1: List of variables, coefficients and descriptions for investment and capital

Description	Algebraic symbol	TABLO coefficient	TABLO variable
Elasticity of investment to the expected gross rate of return	α	ALPHA	
Addition to CAPTSTOK from last year's investment	$I_{i,t-1}\Pi_0 - D_i K_{i,t-1}\Pi_0$	CAPADD	
Current capital stock measured in current prices	$K_{i,t}\Pi_t$	CAPSTOK	x1cap+p2tot
Current capital stock measured in last year's prices	$K_{i,t}\Pi_0$	CAPSTOK_OLDP	x1cap
Depreciation rates	D	DPRC	
Expected gross rate of return	E	GRETEXP	delgretexp, gretexp
Initial expected gross rate of return	E_0	GRETEXP0	
Investment/capital ratio	G	GROSSGRO	gro
(Maximum/trend) investment/capital ratio	Q	QRATIO	
Capital rental/capital stock ratio	R	GROSSRET	delgret
Initial capital rental/capital stock ratio	R_0	GROSSRET0	
Trend investment/capital ratio	G_{trend}	GROTREND	gtrend
Maximum investment/capital ratio	$G_{\max} = Q * G_{trend}$	GROMAX	
Normal gross rate of return	R_{normal}	RNORMAL	rnorm
Expected gross rate of return/normal gross rate of return ratio	$M = E / R_{normal}$		mratio

3.4.2 Investment allocation mechanism

Capital accumulation is industry-specific and is linked to the industry-specific net investment, which in turn is linked to the industry-specific rate of return. In general, investors are willing to undertake more investment in an industry in response to an increase in its expected rate of return. However, they are cautious in supplying such funds and will not do so indefinitely. In any year, the capital supply functions will limit the growth in that industry's capital stock, such that any disturbances in its rate of return will dissipate slowly.

In BRUGEM, the two components that determine the investment allocation mechanism are based on Horridge (2002) and are discussed below. Firstly, the investment/capital ratios (GROSSGRO) are positively related to the expected rates of return (GRETEXP). Secondly, the expected rates of return will converge to the actual rates of return via a partial adjustment mechanism. The coefficients and associated variables are listed in Table 3-1. Keeping the notation simple, without the time and industry subscripts and depreciation rate, the theory states that G, the investment to capital ratio or the gross rate of capital growth in the next period, is a function of E, the expected gross rate of return for the next period. The percentage change in G (*gro*) is driven by the percentage change in the planned investment to capital ratio for each industry in Equation (3.152).

$$\begin{aligned}&E\_finv4 \text{ \# Planned investment/capital ratio \#}\\&(all,i,IND)\ gro(i) = x2tot(i) - x1cap(i) + finv4(i)\end{aligned} \tag{3.152}$$

The ordinary change in an industry's gross rate of return is defined as the ratio of the changes in the rental price of capital $p1cap(i)$ and the price of newly created capital $p2tot(i)$ as shown in Equation (3.153).

$$\begin{aligned}&\text{E\_delgret \# Gross rate of return \#}\\&(all,i,IND)\ delgret(i) = 0.01 * GROSSRET(i) * [p1cap(i) - p2tot(i)]\end{aligned} \tag{3.153}$$

It is hypothesised that each industry has a long run or normal rate of return, R_{normal} and that when E, the expected gross rate of return, is equal to the long run rate of return R_{normal} then G, the gross capital growth rate, will be G_{trend} the normal gross growth rate in Equation (3.154).

$$G_{trend} = F(R_{normal}) \tag{3.154}$$

A logistic curve of functional form in Equation (3.155) is depicted in Figure 3-13, which implies that with the prudency of investors, the gross capital growth rate will not increase indefinitely with the increase in the ratio of the expected to normal gross rate of returns (*m-ratio*) determined by Equation (3.156).

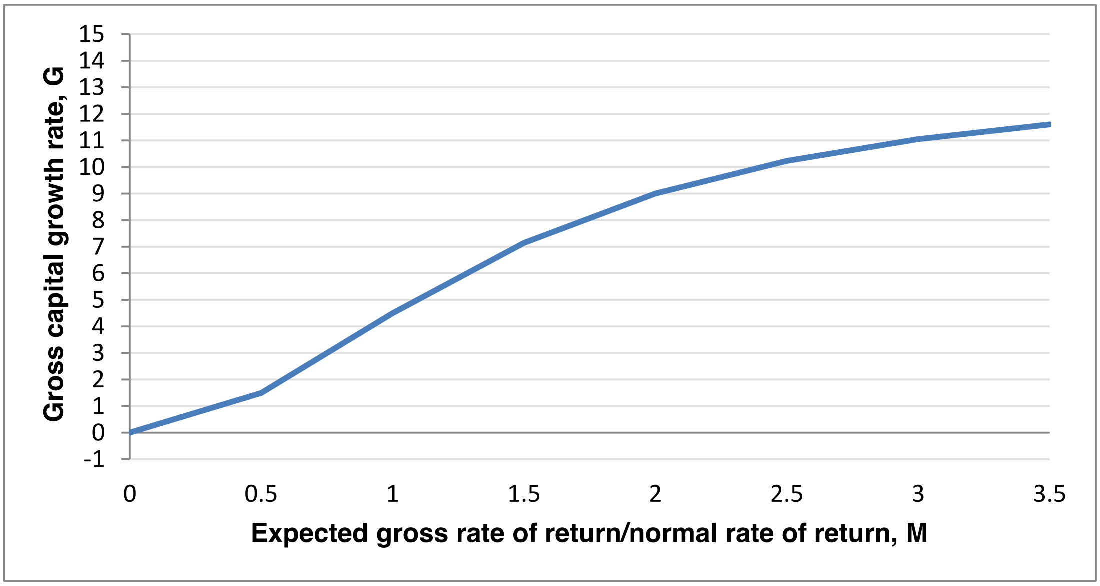
$$G = \frac{Q.G_{trend}.M^{\alpha}}{(Q-1+M^{\alpha})} \tag{3.155}$$

where $M = E / R_{normal}$ or in percentage form:

$$\begin{aligned}&E\_mratio \ \# \ \text{Ratio,(expected/normal) rate of return} \ \# \\ &(all,i,IND) \ mratio(i) = gretxp(i) - rnorm(i)\end{aligned} \tag{3.156}$$

and when M is large where the expected gross rate of return is much greater than the normal rate of return, then Q equals the maximum over trend investment to capital ratio. For BRUGEM, it is assumed that the investment elasticity α is 2, Q is 3 or maximum growth rate of capital is three times the normal growth rate of capital stocks as specified in the ORANIG-RD model and the long run investment to capital ratio G_{trend} is 4.5 per cent (see Section 4.3.2.10 and Table 4-18) for all industries in the database. If M is 1, then G equals the normal gross growth rate of 4.5 per cent and if M is zero then G is zero.

Figure 3-13: Graph representation of the capital supply function



It is postulated that the end-of-period expected rate of return for each industry, *GRETEXP(i)*, is an average of the initial or start-of-period expected rate, *GRETEXP0(i)*, and the end of the period actual rate of return, *GROSSRET(i),* or the ratio of unit rental price of capital to unit asset price of capital. In the notations of Table 3-1, this implies:

$$E_1 = (1-a)E_0 + aR_1 \text{ where } 0 < a < 1 \quad (3.157)$$

or $$E_0 + \Delta E = (1-a)E_0 + a(R_0 + \Delta R) \quad (3.158)$$

where subscript '0' indicates start-of-period and subscript '1' denotes the end-of-period.

Equation (3.153) can be simplified further to Equation (3.159), which is the same as Equation (3.156) in TABLO code.

$$\Delta E = a(R_0 - E_0 + \Delta R) \quad (3.159)$$

In this formulation, it is assumed that investors are both conservative and myopic where only the past and current rates of return affect their expected rates of return for the next period. A parameter value of 0.2 is chosen for the value of a in Equation (3.157), indicating that a slower rate of adjustment where the expected rate of return is closer to the start-of-period expected rate, *GRETEXP0(i),* rather than end-of-period actual rate of return, *GROSSRET(i).* This helps to control some industries (such as civil engineering and construction) that exhibit an unusually high value of *mratio* or expected rate of return due to the inherent features of the published IOT, which the core CGE database is based on. This parameter value allows for more control over the movement up the capital supply curve, as the expected rate of return exceeds the normal rate of return.

The percentage change in the expected rate of return is given by the Equations (3.160) and (3.161). This implies that a higher rental price of capital, $p1cap(i)$, will increase the expected rate of return, $delgretexp(i)$, if the price of new capital, $p2tot(i)$, is held fixed. Conversely, a higher price of new capital, $p2tot(i)$, will lower the expected rate of return if the rental price of capital is held fixed.

$$E\_gretxp \text{ \# Percent change in expected rate of return \#} \quad (3.160)$$
$$(all,i,IND)\ \mathrm{delgretexp}(i) = 0.01*[GRETEXP(i)]*gretxp(i)$$

$$E\_\mathrm{delgretexp} \text{ \# Partial adjustment of expected rate of return \#} \quad (3.161)$$
$$(all,i,IND)\ \mathrm{delgretexp}(i)$$
$$= \ 0.2*[\{GROSSRET0(i) - GRETEXP0(i)\}*delUnity \ + \mathrm{delgret}(i)]$$

In percentage change form, the logit function of the capital supply curve in Equation (3.155) can be expressed as Equation (3.162):

$$E\_gro \text{ \# Planned investment/capital ratio \#}$$
$$(all,i,IND)\ gro(i) = gtrend(i) \ + \ invslack \quad (3.162)$$
$$+ \ ALPHA(i)*[1.0 - (GROSSGRO(i)/[GROMAX(i)])]*mratio(i)$$

Equation (3.162) shows that the planned year-on-year investment to capital ratio, $gro(i)$, in percentage form will depend on three variables, namely the trend I/K ratio by industry, $gtrend(i)$, investment shift variable, $invslack$, and the difference between the percentage changes of expected and normal rates of return, $mratio$. This relationship is 'activated' by exogenising $invslack$. If investment is set by some other rule or is exogenous, then $invslack$ must be endogenous. This can be interpreted as a shift in the economy-wide rate of return, which enables the investment supply curve to accommodate a set value for investment.

3.4.3 Real wage adjustment equation

In BRUGEM, the real wage is assumed to be sticky in the short run due to wage contracts and the lack of opportunity for employees to negotiate in a short period of time. Therefore any economic shock is assumed to be reflected in changes in the employment level. In the long run, the consumer real wages are flexible while the employment is sticky and is consistent with the non-accelerating inflation rate of unemployment (NAIRU) assumption in macroeconomic modelling, where employment is determined by factors outside the labour market and there is a natural rate of unemployment in the economy. Ball and Mankiw (2002) discussed the concept of NAIRU both in theory and in practice.

Through a series of year-on-year simulations, the dynamic equations allow the real wage to adjust over a period (say 5 years) and eventually return aggregate employment to its base case level (Giesecke 2004).

The real wages are allowed to adjust to the employment level in the following manner. If the end-of-period employment, $employ\_i$, exceeds some trend level, $emptrend$ (which can be the growth rate of the labour force), then the real wage will rise during the period by a certain portion of the difference. Equation (3.163) defines the $delempratio$, the ratio of actual employment to trend employment. Equation (3.164) shows that the ordinary change in the wage rate based on an upward sloping labour supply schedule. The wage rate will continue to rise as long as the actual employment exceeds the trend employment but will decline if actual employment falls below trend employment. Equation (3.164) links the ordinary change in the real wage to its percentage change in Equation (3.165)

$$E\_delempratio \text{ \# Ordinary change in (actual/trend) employment \#}$$
$$delempratio = 0.01 * EMPRAT * [employ\_i - emptrend] \quad (3.163)$$

$$E\_delfwage \text{ \# Real wage adjustment mechanism \#}$$
$$delwagerate = delfwage + ELASTWAGE * \{[EMPRAT0 - 1.0] * delUnity + delempratio\} \quad (3.164)$$

$$E\_delwagerate \text{ \# Change in real wage index \#}$$
$$delwagerate = 0.01 * WAGERATE * realwage \quad (3.165)$$

ORANIG-RD does not have explicit links between population, labour force and employment. In BRUGEM, additional dynamic equations in the labour market are added to link up the population growth rate (q), labour participation rate (ppr), labour supply rate, employment rate and change in unemployment rate $(d\_UNEMPLOY)$, as shown in Equations (3.166) to (3.169). These equations enable the choice of setting how the labour supply can be determined. For example, we can assume that the labour participation rate remains unchanged in Equation (3.169), letting the labour force growth rate grow in proportion to the population growth rate.

$$E\_d\_EMP\_LAB \ \# \text{ Change in EMPLOYED/LABOUR ratio } \# \qquad (3.166)$$
$$d\_EMP\_LAB = (EMP\_LAB)*0.01*emprate$$

$$E\_d\_UNEMPLOY \ \# \text{ Change in unemployment rate } \# \qquad (3.167)$$
$$d\_UNEMPLOY = -0.01*(EMP\_LAB)*emprate$$

$$E\_emprate \ \# \text{ employment rate or percentage change of EMPLOYED/LABOUR} \# \qquad (3.168)$$
$$emprate = employ\_i - labrate$$

$$E\_ppr \ \# \text{ percentage change in labour participation rate } \# \qquad (3.169)$$
$$ppr = labrate - q$$

3.4.4 Accumulation of net foreign assets or liabilities

Another departure from standard ORANIG-RD is the inclusion of additional equations in BRUGEM to track net foreign assets (NFA) or liabilities (NFL) and current account balance (CAB). Despite the lack of comprehensive balance of payment data (IMF 2014a) for Brunei, the current account balance and financial accounts via net foreign assets can be tracked through data that can be obtained and using simple assumptions. In the case of Brunei, there are no foreign liabilities, so a negative value of NFL is equivalent to positive NFA. As for current account balance, the equation is written in the form of a current account deficit (CAD), so a negative value of CAD is equivalent to a current account surplus.

The purpose of these equations is to link the Brunei economy to the rest of the world and to track how the current account balance and net foreign assets position react to the depletion of oil and gas. The stylised representation of this equation block is provided in Equations (3.170) to (3.173).

Interest on NFL	$\mathrm{INT\_NFL}_t\mathrm{=NFL}_t\mathrm{*ROI\_FL}_t$	(3.170)
Current account deficit	$\mathrm{CAD}_t = \mathrm{M}_t - \mathrm{X}_t + \mathrm{INT\_NFL}_t$	(3.171)
Start-of-year NFL	$\mathrm{NFL}_t = \mathrm{NFL\_B}_{t-1}$	(3.172)
End-of-year NFL	$\mathrm{NFL}_{t+1} = \mathrm{NFL}_t + \mathrm{CAD}_t$	(3.173)

The current account deficit is defined as the difference between total payments to, and total receipts from, the rest of the world via net exports plus the interest paid on NFL in Equation (3.171). The interest received (on NFA), or paid (on NFL), is a dynamic equation, as shown in Equation (3.171). A negative interest generated in Equation (3.170) indicates that an interest income from NFA will reduce the current account deficit in Equation (3.171), as well as reduce the start-of-year NFL in Equation (3.172). The more negative NFL becomes, the more NFA is accumulated. The end-of-period NFA/NFL is given by the sum of the start-of-period value NFA/NFL and the current account balance in Equation (3.173). These are expressed in Equations (3.174) to (3.176) in the percentage change form.

E_d_cad # Current account of the balance of payments # (3.174)

$$100*d\_cad = V0CIF\_C*w0cif\_c - V4TOT*w4tot + 100*d\_\mathrm{int}\_fd$$

$E\_d\_\mathrm{int}\_fd$ (3.175)

B$ value of interest on foreign liabilities (asset) repayable (receivable)

$$d\_\mathrm{int}\_fd = ROIFOREIGN*d\_fd\_t$$

$E\_d\_f\_fd\_t$ # Gives shock to start-of-year foreign liabilities (assets) in year-to-year sims # (3.176)

$$d\_fd\_t = (FDATT\_1\_B - FDATT\_B)*delUnity + d\_f\_fd\_t$$

Any excess of spending on imports over exports receipts and/or reduction in the return earned on the foreign assets for Brunei, will lead to current account deficit in Equation (3.174).

3.5 Closing the model

As pointed out by Horridge (2003), in a complex model, many closures can be used for different purposes. Some basic requirements must still hold. For example, as a feature of a neoclassical model, where only relative prices matter, price variables must always appear as price ratios. In order to determine the overall price level, at least one price variable measured in local currency units has to be made exogenous or set as the numeraire to help explain the changes in absolute price level. The modeller can choose one of the popular choices, such as exchange rate or the consumer price index.

For similar reasons, in order to determine the total size of the economy, some quantity variables must also be set as exogenous. Often these include primary factor endowments, such as land and final demand aggregates.

The choice of closure reflects two different types of consideration. Firstly, the closure may be associated with the period of time for economic variables to adjust to a new equilibrium. This time-sensitive assumption can influence the factor markets in particular. In the short run (say between one to three years), there will be some rigidities in the labour market where the real wage is sticky as employees cannot negotiate wage contracts; and in the capital market where capital stock will take some time to be installed. Secondly, the choice of closure is set by the requirements of a particular simulation (variables where shock values are to be imposed need to be exogenous) and the assumptions the modeller makes about variables not explained by the model. In the model, there is a lack of theory to explain the changes in the size and composition of absorption. Therefore, the closure can be chosen in such a way that increased GDP appears as an increase in absorption (by fixing the trade balance) or, alternatively, as an improvement in balance of trade while other expenditure components are held fixed.

In BRUGEM, there are also some variables that do not have equations explaining them and these can be set as exogenous. These are the technical change variables, tax rate variables, shift variables, land endowments, foreign prices, inventory to sales ratios and so on. These are some of the requirements in setting up the closure.

3.6 Conclusions

This chapter has covered the key underlying theoretical structure of BRUGEM. Besides the standard core equations of the ORANI-G model, BRUGEM also has equations describing the stock-flow relationships, such as those between capital and investment in capital accumulation, debt and savings in net foreign liability accumulation. It allows for lagged adjustment processes in the labour market and investment. In the labour market where wages are sticky in the short run, any pressure in that market will appear as changes in employment. In the long run, this pressure will be reflected as changes in real wages since the aggregate employment returns to base case.

The model can be used to construct a plausible base forecast for the next ten years or more in the case of the forecast simulation, which is explained in Chapter 7. Additional data, such as the capital stocks, exogenous predictions about the future directions of technological change, employment, import prices and position of export demand curves, are required to produce such forecasts (Horridge 2002). Predictions can be based either on assumptions, say uniform growth rates, or obtained from detailed forecasts made by government and private agencies or even international organisations such as the IMF. A second simulation can be constructed to examine a perturbed scenario whereby some variables are shocked to different values from the base scenario to simulate the policy impact, of say, more investment in the petrochemicals industry. The difference between these two scenarios can then be interpreted as the effect of the policy change. This policy simulation is discussed in Chapter 8.

A dynamic model helps to keep track of the state of the economy through time as Brunei faces the depletion of its oil and gas income. Changes to Brunei's fiscal position will be important as it is currently very much influenced by the commodity prices and revenues received from the oil and gas sector in the form of royalties and taxes. The government may need to raise funds by implementing taxes, which will affect domestic savings, or borrowing externally and therefore incur foreign liabilities, especially when there is insufficient income generated from the non-oil sector and/or from the SWF to finance its fiscal expenditures in the future.

The current account deficit is the difference between investment and domestic savings. Investment depends on expected rates of return relative to the cost of borrowing funds. Any structural or microeconomic reforms implemented to reduce the cost of borrowing can influence investments. Using dynamic modelling, the future implications for the current account deficit, government accounts and foreign liabilities can be worked out.

Before any simulation can be carried out, we need a functional IO core database, the second component to BRUGEM. This is discussed in Chapter 4.

Chapter 4: Construction of the core CGE database for BRUGEM

This chapter is about the construction of the IO database used in BRUGEM. Section 4.1 introduces the core database. The structure of the BRUGEM database, data requirements and conditions that need to be met are described in Section 4.2. Section 4.3 details the compilation process outlining the sources of data, features of the Brunei IOT, treatment of the data and the necessary data job steps to arrive at a database for the model. Section 4.4 draws some observations of the IOT 2005 and differences between the published IOT and the author-compiled version of IO data for 2005. Conclusions are presented in Section 4.5.

4.1 Introduction

The theoretical structure of BRUGEM was described in Chapter 3. This chapter focuses on the construction of the core database, which consists of three main parts. The first part is the IO data of the base year, which describes the structure of the Brunei economy in 2005. The second part contains behavioural parameters, such as elasticities that govern the ease with which economic agents substitute between inputs to production and final demand. The third part of the database consists of additional information on government revenue and expenditure, net foreign liabilities, industry capital stocks and depreciation rates, which will be necessary for modelling dynamic behaviour. Together, the three parts form an initial solution to the model.

The main ingredients in building the database for BRUGEM are the official IOT 2005 published in 2011 (DEPD 2011) and the supply and use tables (SUT) with imports, margins and tax tables. The formats of the IOT and SUT are shown in Tables 4-5 to 4-8 in Section 4.3.1.

Haji Duraman (1998) developed the first IOT for Brunei for the year 1991. This comprised 12 sectors. Subsequently, a larger IO system consisting of 74 sectors for the base year 2005 was created by a consulting company called DIW econ GmbH from Germany (DEPD 2011). This system comprises a SUT, and IOT for domestic output and imports along with supplementary data for extended IOT with satellite systems. The IOT, shown schematically in Table 4-5, contains rich information about the economy in general. It shows the linkages between the various sectors and economic agents within the Brunei economy. For each producer, the IOT shows the input cost structure of its production and also the income generated. For each good and service produced, the IOT also shows its sales structure or demand for consumption, investment and exports. The IOT registers the flow of goods and services both within the domestic economy and with the rest of the world. Aggregate national accounts information, such as consumption, investment, exports, imports, and GDP on both the expenditure and income side can also be obtained from the IOT. In the context of CGE modelling, the IOT provides cost shares and sales shares for inter-industry analysis. The IOT can also serve the purpose of checking the consistency of the national accounts data and to highlight any shortcomings in data reconcilation.

The use table (Table 4-6), shows the use or purchase of the commodity by domestic producers as intermediate inputs and also by the final demanders (households, government investors and foreigners) in the rows. In the columns, it shows the cost structure of the domestic producers with the composition of inputs, both intermediate and primary factors of production. The use table for imports is shown in Table 4-7.

The supply table (Table 4-8) of the SUT provides information about the commodity outputs of each domestic industry in the column and the commodities produced by the industries in the rows. Typically, the main diagonal contains the largest entries where an industry chiefly produces its primary product. However, this is not always the case empirically, as there may be secondary production by another industry. The supply table helps us to identify the primary output in which the industry specialises and also other commodities an industry may produce. At the same time, the table shows that the commodity can be produced by one or more industries.

At the time of writing, two sets of official IOTs are available. One is for the base year 2005, which was published in October 2011. The other is for the base year 2010, which was published in January 2015. By January 2015, all data work for this thesis was completed, based on the published IOT 2005. This IOT 2005 has a dimension of 74 commodities by 74 industries (Appendix 4-1), compared to the IOT 2010, which is much smaller with 46 sectors (Appendix 4-2). The reasons why IOT 2005 was preferred over IOT 2010 are explained below.

Box 4-1: Sources of data for the Brunei SUT 2005:

Census Data

- Population and Housing Census 2001
- Registrar of Companies (Business Register)
- Economic Censuses of 2002 and 2007

Annual and Quarterly Data

- Quarterly Survey of Businesses
- External Trade Statistics
- Balance of Payments
- Government Budget
- Oil Production
- Energy Balance

Other Data

- Household Expenditure Survey 2005
- Labour Force Survey 1995 and 2008
- Census of Direct Foreign Investment
- Construction Statistics
- Economic Input-Output Survey 2009

The year 2005 was chosen as the benchmark year for economic and statistical reasons (DEPD 2011). Firstly, more statistical information is available for the year 2005 than for many other years (see Box 4-1). Secondly, 2005 was a year without exceptional developments in the economy, such as the strong price increases of Brunei's main export commodities of oil and gas, or the global financial and economic crisis.

The style of the Brunei IOT 2005 compilation closely follows the conventions used in the 2008 edition of "Eurostat Manual of Supply, Use and Input-Output Tables", published by the European Commission (DEPD 2011). The more recent IOT 2010 was compiled in-house by DEPD. The main difference lies in the industrial classification. Appendix 4-1 shows the original list of industries and commodities for IOT 2005. The IOT 2010 has fewer sectors, as listed in Appendix 4-2, and it has more disaggregated agricultural and livestock sectors, with five smaller sectors (rice, vegetables, fruits, other crops and livestock). In IOT 2005, the *AgriAnmPrd* sector is very small, contributing 0.5 per cent of total domestic output. By 2010, the agriculture sector itself, without animal products, contributed only 0.4 per cent of total GDP in current prices (DOS 2012a). It was considered insignificant for the purpose of this thesis.

In the IOT 2010, large and dominant industries such as oil and gas mining sectors are aggregated into one sector. It is useful to keep oil and gas sectors separate because both have different resource life spans and different export demand elasticities. Both are also key intermediate inputs to different industries, for example crude oil for refineries and natural gas for petrochemicals production.

In IOT 2010, there is no separation of the methanol and petrochemicals industries. These were targeted by the government to be the downstream industries for economic diversification as explained earlier in Section 2.4. The new methanol industry started exporting in 2010 (see Section 2.4.2.1) and is expected to grow in importance in Brunei's economy. Therefore this new sector will be created in the database as explained in Section 4.3.2.9.

The effects of the global financial crisis of 2008/2009 were felt in Brunei with the fall in its GDP around the period 2009/2010 (see Figure 2-3 in Chapter 2). For that reason, IOT 2010 as a base year may contain some unusual economic trends. This might create some issues if used as a starting point for calibration. In addition, IOT 2010 lacks the industrial details relevant for the purpose of this thesis. Therefore, despite being older, IOT 2005 was preferred and was subsequently updated to produce a new IOT 2011. How this was achieved is explained in Chapter 5.

Since the published IOT 2005 is not in the required format for a CGE database necessary for the modelling in this thesis, one major task was to transform this data into a suitable format. This transformation is shown in Table 4-1. The steps used to construct the database are explained in detail in section 4.3.

The following section outlines what was needed in the final BRUGEM IO database in terms of structure and requirements.

4.2 Deriving the BRUGEM database

4.2.1 Structure of the BRUGEM database

The final BRUGEM database used in this thesis has a detailed sectoral disaggregation featuring 74 industries and 74 commodities. These were defined and abbreviated and are presented in Appendix 4-3. The original IOT had 74 sectors, as listed in Appendix 4-1. For the purpose of this thesis, the real estate services sector was disaggregated into two sectors, *RealEstSrv* and *Dwellings*, creating a total of 75 industries and 75 commodities. However, due to the existence of some "zero" industries with nil cost structures and nil domestic outputs in the original IOT, some aggregation was carried out, specifically the *ArtEntCltrl* and *MemberOrgSrv* sectors were merged with *SportRcrtSrv* to create a new sector called *ArtEntSport*. Subsequently, a new sector called *MethanolPChm* was created and the resulting IO data had 74 industries and commodities to be used for modelling work. Appendices 4-1 and 4-3 list the sectors before and after the changes, with the changes shaded.

The basic structure of the BRUGEM database (see Table 4-1) shares a similar format to that used in ORANI-G and MONASH-style CGE models. To achieve this structure, several adjustments were carried out. These are explained later in Section 4.3.2.

BRUGEM requires a database that has separate matrices for basic, tax and margin flows for commodities to producers and final users from domestic and imported sources. It also requires data in separate matrices for the cost of factors of production, typically labour, capital and land.

The column headings in Table 4-1 indicate the following demanders:

(i) Domestic producers divided into *i* industries (denoted as user 1);

(ii) Investors divided into *i* industries (denoted as user 2);

(iii) A single representative household (denoted as user 3);

(iv) An aggregate foreign purchaser of exports (denoted as user 4);

(v) Government demand (denoted as user 5); and

(vi) Changes in inventories (denoted as user 6).

The column entries in Table 4-1 represent the absorption matrices, showing the "cost structure" of each category of demanders. The commodities of C types can be obtained from two sources S (domestic and imports). Producers require more than just commodities as inputs to current production (V1BAS). They also need primary factors of production, labour, fixed capital and land.

Commodities are also required by investors (V2BAS) for capital creation, households (V3BAS) for consumption, the government (V5BAS) for consumption, and foreigners (V4BAS) as exports.

The first two rows of entries (V1BAS to V6BAS) in Table 4-1 represent direct flows of commodities from all sources to the users valued at basic prices. As mentioned earlier in Section 3.2.1, basic prices are defined as prices that are received by domestic producers (excluding sales tax and margins such as wholesale trade, retail trade and transport costs), and by importers at the port of entry (after customs clearance, which includes import duties or tariffs paid but excludes sales taxes and margins associated with deliveries to domestic users). It is assumed that basic prices are uniform across users and producing industries for domestic goods, as well as across importers for foreign goods.

Table 4-1: BRUGEM IO database

		Absorption matrix					
		1	2	3	4	5	6
		Producers	**Investors**	**Household**	**Export**	**Government**	**Stocks**
	Size	← I →	← I →	← 1 →	← 1 →	← 1 →	← 1 →
Basic flows domestic	↑ CxSxM ↓	V1BAS	V2BAS	V3BAS	V4BAS	V5BAS	V6BAS
Basic flows imported	↑ CxSxM ↓	V1BAS	V2BAS	V3BAS		V5BAS	V6BAS
Margins	↑ CxSxM ↓	V1MAR	V2MAR	V3MAR	V4MAR	V5MAR	
Taxes	↑ CxS ↓	V1TAX	V2TAX	V3TAX	V4TAX	V5TAX	
Labour	↑ O ↓	V1LAB					
Capital	↑ 1 ↓	V1CAP					
Land	↑ 1 ↓	V1LND					
Other costs	↑ 1 ↓	V1OCT					
Production tax	↑ 1 ↓	V1PTX					

C = number of commodities
I = number of industries
S = sources: domestic, imported
M = number of commodities used as margins
O = number of occupation types = 1 in BRUGEM database

Notes:
export column is for domestic goods only
no margins and taxes on inventories

	MAKE matrix	
Size	← I →	**Total**
↑ C ↓	MAKE(c,i)	Rows = sales totals
Total	Columns = total absorption	

	Import duty
Size	← 1 →
↑ C ↓	V0TAR

By convention, only domestic goods are used for margin provision and exports. Therefore, as shown in Table 4-1, only domestically produced goods appear in the export column and V4BAS has no import dimension. This implies that there can be no re-exports defined as foreign goods that are imported and then exported in the same form without any transformation.

Of all the domestically produced goods, some will be used as margin services, specifically the wholesale, retail trade and transport services, in order to facilitate the flow of commodities from the sources to their demanders.

In the BRUGEM database, seven margin services are identified: three types of trade margins (*WhReTrdRepMV, WhTrdSrv, ReTrdSrv*) and four types of transport margins (*LndTrnsPpSrv, WaterTrnsSrv, AirTrnsSrv, WrhsgSrvTrns*). Data for the use of these margins are contained in the third row, V1MAR to V5MAR. Consistent with the United Nations convention (UN 1999), there are no margins on services that are consumed directly, such as financial, legal and accounting services, education and health services, among many others. There are also no margin services associated with held or unsold inventories. V4MAR has no source dimension compared to other margin flows used elsewhere, as the margin service is only associated with the facilitation of commodity flows produced domestically by exporters. Other demanders choose commodities from either domestic or imported sources to be delivered to them.

The fourth row in Table 4-1 represents the tax matrices, V1TAX to V5TAX. No sales taxes are paid on inventories, hence there is no V6TAX matrix. Tax rates may differ between users and sources, where rates may be lower to one user relative to the other users for the same commodity.

The fifth to ninth rows in Table 4-1 contain matrices that provide a breakdown of the costs of primary factors used by producers in current production. V1LAB shows the cost of labour (or wage bill) by industry (i) as input into current production. V1CAP shows the rental value of each industry's fixed capital and V1LND, the rental value of land used by each industry. Producers also pay production taxes (V1PTX), such as business licences, land taxes, stamp duties, and payroll taxes (UN 1999). Other miscellaneous production costs, such as the cost of holding inventories, holding liquidity and so on (Dixon et al. 1982), are shown in the row labelled V1OCT. Since these costs are only associated with current production, there are no such corresponding entries for final users.

The two satellite matrices at the bottom of Table 4-1 show the multi-production matrix (MAKE) and tariff matrix (V0TAR). In BRUGEM, the MAKE matrix is of the multi-production type whereby an industry can produce more than one commodity and a commodity can be produced by more than one industry. Therefore, there are off-diagonal non-zero entries, although the main diagonal entries are expected to be the largest in terms of values by commodity and its corresponding industry. With a combination of output commodities, a producer can potentially shift resources around to vary its production levels of each output, subject to the relative price changes of the commodities, in order to maximise revenue.

The tariff matrix (V0TAR) consists of tariff revenues imposed on imported commodities. The tariff rates are levied at rates that vary by commodity but not by user, and the value of the tariff revenues are already accounted for in the basic prices of imports, as defined earlier. This matrix is shown separately from the absorption matrix as it enables calculation of *ad valorem* rates as the ratio between tax revenues and the relevant basic flows of commodities upon which the taxes are levied.

The sets, coefficients, parameters and elasticities in the database are listed in Appendix 4-4. Section 4.2.2 contains further elaboration on elasticities and parameters. Additional comments on the data for the dynamic equations are given in Section 4.2.3.

4.2.2 Database requirements

The following conditions must be satisfied by the database:

(i) Non-negativity

Except for the matrices related to changes in inventories (V6BAS) and taxes (V1TAX to V5TAX), matrices must not contain negative entries because the value of the flow of goods and services can be zero but not negative. On the other hand, a negative entry in V6BAS indicates a reduction in inventories while a negative tax indicates a subsidy. Some parameters, like the Frisch parameter and export demand elasticities, are negative by definition.

(ii) Zero pure profit

For each industry, the value of output (sales) must equal the value of production (costs). This means that the column sums of MAKE matrix (values of output) should equate to the corresponding column sums of the industries' demand for inputs into current production (total production costs). This is captured in Equation (3.120) in Section 3.3.9.

(iii) Market clearing

Demand must equal supply for both margin and non-margin commodities. The value of output of domestically produced commodities must equal the total value of demand for these commodities, that is, the total sales must equate to total production. This indicates that the row sums of the MAKE matrix must equal the row sums of basic and margin flows in Table 4-1 (see Equation (3.121) in Section 3.3.9).

(iv) GDP identity

GDP from the income side (value of total factor payments, total costs plus taxes) must be equal to the GDP from the expenditure side (total value of all final demands at market prices). This will be the case if the zero pure profit and market clearing conditions in (ii) and (iii) are met.

Besides the above, there are additional conditions to check:

1) Tax revenues and tax rates must reflect the existing taxation law and actual collection situation. At present, there are no consumption taxes, such as GST, nor payroll taxes. There are some import duties on certain imported goods.
2) Margin rates on commodity flows must seem plausible. The rates of margin on commodities sold to producers will typically be equal to or lower than those sold to households, given the difference between wholesale and retail trades.
3) The share of factors in total factor payments must seem plausible. Factor shares should not differ too much between industries with similar activities. For example, mining sectors are similar in terms of usage of more equipment relative to labour, so the oil and gas sectors both have high capital as factor share. Activities such as the public service and education, which are generally labour intensive, are expected to have high labour shares.

4.2.3 Elasticities and other parameters

Several parameters are required for BRUGEM, which are either borrowed from other models or are estimated due to the lack of actual data or empirical studies on Brunei.

Figure 3-6 in Chapter 3 shows that there are several CES parameters in the production structure: for the occupation nest (denoted by *SIGMA1LAB*), for the Armington nest (denoted by *SIGMA1*), and for the primary factor nest (denoted by *SIGMA1PRIM*). The parameter *SIGMA1LAB(i)* is the CES between different occupation types in industry (i). It governs how easy it is for substitution to take place when there is a wage rate differential. However, due to insufficient data on the occupation types and respective wage rates, there is only one representative occupation (OCC) called “labour” in the BRUGEM database. Thus, the *SIGMA1LAB* parameter, with the current occupational structure in BRUGEM, is irrelevant.

SIGMA1PRIM(i) represents the CES between primary factors – labour, capital and land for industry (i*)*. *SIGMA1OUT(i)* is the CET between the commodity produced or output in industry (i*)*. It has been assumed in this model that *SIGMA1PRIM* and *SIGMA1OUT* take the value of 0.5 for all industries. A value of 0.5 is assumed, as suggested by Bowles cited in Dixon and Rimmer (2002). The value ranges from zero to one. The value of 0.5 was chosen for *SIGMA1PRIM,* as explained in Dixon et al. (1982), based on a detailed survey and a review of empirical literature.

The CET *SIGMA1OUT* at the top nest of production is assumed to have the same value of 0.5 across all industries. This elasticity indicates the magnitude of the response to a change in relative prices.

BRUGEM assumes imperfect substitutability between domestic and imported varieties of the same commodity. This degree of substitutability is controlled by the values of the Armington elasticities. These elasticities show the degree of substitutability between domestic and imported sources of supply of commodity (c*)* to be used in current production, capital formation and household consumption as denoted by *SIGMA1(c), SIGMA2(c)* and *SIGMA3(c)* respectively. The higher the values, the more sensitive the users are to the price difference between domestic and imported varieties. These elasticities are useful in determining the trade flow patterns. There are no such estimates for Brunei for the year 2005, so the average value of 2 was adopted for all commodities in this database and the same for all users, such as industries, investors and households. Subsequently, Brunei's data was included in the GTAP[17] database 9.0 as one of the new

[17] GTAP database is developed by Global Trade Analysis Project, a network of researchers and policymakers. It is a fully documented global database which contains complete bilateral trade information, transport and protection linkages. GTAP database is a key input into CGE models to study global economic issues.

regions (Narayanan 2015), making available estimates for these elasticities for the year 2011. On average, the elasticity was around the value of 2 (Narayanan et al. 2015).

The Frisch parameter in the LES for household behaviour measures the sensitivity of the marginal utility of income to total expenditures, as explained in Section 3.3.3 of Chapter 3. A value for the Frisch parameter for Brunei can be worked out using the subsistence spending levels in Brunei dollars for all households by commodities ($P_c X_c^{sub}$), obtained from an internal report by Lars (2013). Using data for the purchases value of commodities consumed from the IOT created, and using the formulae from the household demand theory explained earlier in Section 3.3.3, we can work out the subsistence and luxury (or supernumerary) shares as well as values for household expenditure elasticities (EPS).

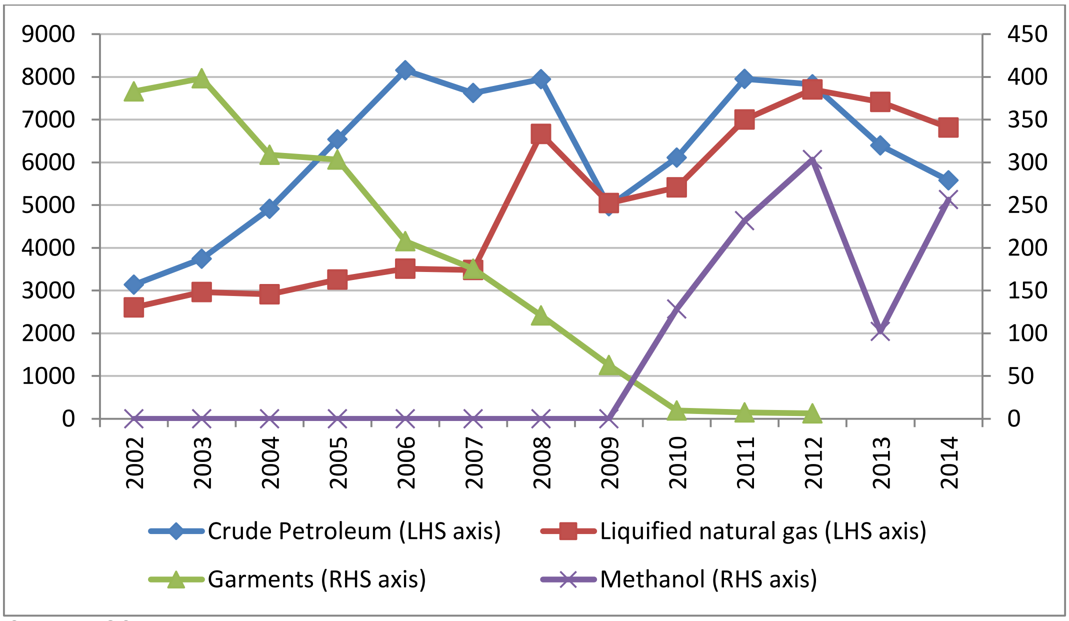
Evaluated in this way, the Frisch parameter for Brunei is -1.47 in 2005. This compares to a value of -1.82 used for the Australian models (ORANI-G and MONASH). Estimation of the Frisch parameter for Australia is described in Tulpule and Powell, as cited in Dixon et al. (1982). A smaller absolute value implies that the average middle-income household in Brunei is slightly better off than a similar household in Australia. This is perhaps not surprising: in addition to a zero personal income tax rate, a typical Brunei household also enjoys a range of subsidised goods and services, leaving more disposable income for luxury spending.

Export demand elasticities are important in determining the effects of exports on a country's terms of trade. They measure percentage changes in the quantity of exports brought about by a one per cent change in export price, with all else unchanged. The export demand schedule is downward sloping and typically is not perfectly elastic, indicating that the commodity is heterogeneous due to its characteristics and/or accessibility and therefore is an imperfect substitute for similar exports from other countries.

There are no published export demand elasticity data for Brunei. The values adopted in the BRUGEM database are estimated using several sources of data based on Brunei's major trade partners for the two key exports of oil and gas. Trade weighted data can be obtained from the GTAP 8.0 database, for behavioural parameters such as foreign substitution elasticities, and for own price-elasticities of world demand (Hertel et al. 2008).

The elasticity of export demand for individual commodities and the collective export demand elasticity are denoted by *EXP_ELAST* and *EXP_ELAST_NT* respectively. *EXP_ELAST_NT* has the value of -4.21. In the database, the individual export commodities are "traditional" main exports such as *CrudePetrol*, *NaturalGas*, *TextileAppL* and *MethanolPchm*. *TextileAppL* was one of the key non-oil and gas exports for Brunei (Tisdell 1998) until the expiration of the Multi-Fibre Agreement in 2005 (Ernst et al. 2005, Tan 2005, YNFX 2004). Figure 4-1 shows the decline of the garments exports. Many garment factories shut down and exports dwindled (Goh 2010, Rosli 2007). Methanol, which was first exported in 2010, has slowly grown in importance alongside oil and gas exports (Figure 4-1).

Figure 4-1: Values of selected key exports of Brunei (B$ million)



Source: DOS various statistical yearbooks

Specific individual export demand elasticity for crude oil, natural gas and methanol are computed as shown in Tables 4-2, 4-3 and 4-4 based on several sources of data and information:

(i) Hertel et al. (2008) on the GTAP substitution elasticities for the sourcing of imports to provide the values for $\phi(\text{c})$, the foreign elasticity of substitution between Brunei and alternative sources of supply of goods (c);

(ii) Hertel et al. (2008) on own-price elasticities of demand for the values of $\eta(\text{c})$ being the price elasticity of foreign demand for Brunei goods (c);

(iii) GTAP 8.0 database (Narayanan et al. 2012) for bilateral trade flows and trade-weights between Brunei and her trading partners; and

(iv) *Brunei Darussalam Statistical Yearbook* on the main export destinations for trade commodities, which are classified into ten categories according to the UN Standard International Trade Classification, Revision 3. These categories are first mapped into the GTAP list of commodities, which are in turn mapped into the individual commodity (c) (see Appendix 4-5) for working out the export demand elasticity for the BRUGEM database.

An example of how the export demand elasticity can be calculated from the above data sources is shown in Box 4-2. This is also consistent with specified export mineral demand elasticity, as reported in the literature (Hertel, Dixon and Rimmer cited in Freebairn 2012).

Box 4-2: An example for calculating export demand elasticity

Estimation for $\theta(c)$, the foreign elasticity of demand for traditional export commodity c (crude oil in this case), based on the computation method of Dixon and Rimmer (2002):

$$\theta(c) = \{\eta(c)[1 - S_o(c)] - \phi(c) S_o(c)\} S_{fob}(c) \qquad (4.1)$$

where

$\eta(c)$ is the price elasticity of foreign demand for commodity c;

$\phi(c)$ is the foreign elasticity of substitution between Bruneian and alternative sources of supply of commodity c;

$S_o(c)$ is the share of non-Bruneian sources in foreign purchases of commodity c; and

$S_{fob}(c)$ is the share of the FOB price of Bruneian commodity c in its purchaser's price in foreign countries.

Brunei is a small player in international trade and has little influence in the oil market since it accounts for a tiny share of the world's production (0.1 per cent for oil and 0.3 per cent for natural gas (BP 2015)). Therefore the value of $S_o(c)$ is close to 1 as Brunei faces competition from substitutes produced by other countries in foreign markets. The share of Brunei's commodity ($1 - S_o(c)$) is calculated by using the Brunei commodity export data versus the total commodity import data in that market from various sources. Using the trade-weighed shares from the GTAP 8.0 database for Brunei's destinations for oil exports (Australia, China, Indonesia, Japan, Korea, New Zealand, India, Thailand and USA) and elasticities obtained from Hertel et al. (2008), the export elasticity for Brunei's crude oil is -7.11, as shown in Table 4-2.

4.2.3.1 Export demand elasticity for crude oil

According to an OBG report (2013), the light and sweet quality of Brunei's crude has enabled it to sell at a premium, with the average oil price for Brunei's crude commanding nearly USD$5 per barrel above the average Brent crude spot price, at USD$116.13 per barrel in 2011. Therefore, the export demand elasticity for crude oil turns out to be not as elastic (see Table 4-2) as what might be observed in a typical crude oil export market.

Table 4-2: Calculation of export demand elasticity for crude oil

Crude Oil	Price elasti-city of demand *η(c)*	Substitu-tion elasticity *ϕ(c)*	% market share of Brunei's oil *[1-S_o (c)]*	% market of non-Brunei commodity *S_o (c)*	Share of FOB price of Brunei commodity *S_fob (c)*	Foreign demand elasticity θ(c)	GTAP Trade-weighted*
Australia	0.64	10.4	0.033	0.967	0.7	-7.03	0.135705
China	0.21	10.4	0.003	0.997	0.7	-7.25	0.085127
Indonesia	0.19	10.4	0.023	0.977	0.7	-7.11	0.090649
Japan	0.66	10.4	0.005	0.995	0.7	-7.24	0.140477
Korea	0.45	10.4	0.011	0.989	0.7	-7.20	0.183851
New Zealand	0.56	10.4	0.081	0.919	0.7	-6.66	0.067182
India	0.16	10.4	0.004	0.996	0.7	-7.25	0.067063
Thailand	0.24	10.4	0.034	0.966	0.7	-7.03	0.156947
USA	0.71	10.4	0.001	0.999	0.7	-7.27	0.071284
Weighted average						**-7.11**	0.998285*

*Note: *Total is slightly less than one because this only accounts for major destinations. According to GTAP trade data, there are insignificant amounts of Brunei oil being exported to many other countries with each trade-weighted at less than 0.0001 per cent.*

4.2.3.2 Export demand elasticity for liquefied natural gas

It is noted that the data for gas reported in Hertel et al. (2008) is in gaseous state and not in the form of the LNG that Brunei exports. Given the logistics and proximity to Japan and Korea (Kasim 2015a), Brunei's LNG export demand elasticity can be less elastic. The LNG market is smaller and in Asia it is dominated by supplies from Australia, the Middle East and Malaysia. According to the LNG 2011 report by the International Gas Union (2012), there are 18 LNG producers and Brunei is the 10th largest in the world and 4th in Asia Pacific after Malaysia, Indonesia and Australia, thus giving it some degree of market power. The LNG market share in global gas trade was about 31.7 per cent in 2013 and since there are only a handful of LNG exporters in the world, half of calculated value of export demand elasticity of -21.74 is assumed. The Brunei export demand elasticity for LNG is set at -10.87, being quite elastic but not as elastic as the calculated weighted average shown in Table 4-3.

Table 4-3: Calculation of export demand elasticity for liquefied natural gas

Natural Gas	Price elasticity of demand *η(c)*	Substi-tution elasticity *ϕ(c)*	% market share of Brunei's gas *[1-S_o (c)]*	% market of non-Brunei commodity *S_o (c)*	Share of FOB price of Brunei commodity *S_fob (c)*	Foreign demand elasticity θ(c)	GTAP Trade-weighted*
Japan	0.69	34.4	0.098	0.902	0.7	-21.67	0.921918
Korea	0.47	34.4	0.022	0.978	0.7	-23.54	0.074755
					Weighted average	-21.74	0.996673*
					Adjusted export elasticity	-10.87	

*Note: *Total is slightly less than one because this only accounts for major destinations. According to GTAP trade data, there are insignificant amounts of Brunei LNG being exported to many other countries with each trade-weighted at less than 0.0001 per cent*

4.2.3.3 Export demand elasticity for methanol

A similar computation method was carried out for the export demand elasticity for methanol, as shown in Table 4-4.

Table 4-4: Calculation of export demand elasticity for methanol

Methanol	Price elasti-city of demand *η(c)*	Substi-tution elasticity *ϕ(c)*	% market share of Brunei's methanol *[1-S_o (c)]*	% market of non-Brunei commo-dity *S_o (c)*	Share of FOB price of Brunei commodity *S_fob (c)*	Foreign demand elasticity θ(c)	GTAP Trade-weighted
China	0.21	6.6	0.016	0.984	0.7	-4.54	0.137
India	0.18	6.6	0.010	0.990	0.7	-4.57	0.014
Indonesia	0.2	6.6	0.088	0.912	0.7	-4.20	0.027
Japan	0.7	6.6	0.026	0.974	0.7	-4.49	0.087
Korea	0.49	6.6	0.059	0.941	0.7	-4.33	0.171
Malaysia	0.38	6.6	0.092	0.908	0.7	-4.17	0.061
Philippines	0.2	6.6	0.315	0.685	0.7	-3.12	0.036
Singapore	0.55	6.6	0.073	0.927	0.7	-4.26	0.080
Taiwan	0.47	6.6	0.030	0.970	0.7	-4.47	0.184
Thailand	0.26	6.6	0.108	0.892	0.7	-4.10	0.097
USA	0.7	6.6	0.005	0.995	0.7	-4.59	0.063
Vietnam	0.14	6.6	0.284	0.716	0.7	-3.28	0.042
					Weighted average	**-4.29**	1.000

Using the similar sources of information and author's compilation, the individual foreign elasticity demand for Brunei's other export goods were calculated with the same formula (4.1) as outlined in Box 4-2. The export demand elasticities for Brunei export goods derived are reported in Appendix 4-6.

4.2.4 Investment and capital

Several additional data and parameters are required in the base year for implementing the dynamic component pertaining to investment and capital accumulation in BRUGEM. The creation of a dynamic database is discussed further in Section 4.3.2.10. We first examine the issues related to investment and capital based on the IOT 2005 provided.

The IOT 2005 provides data for a single column of inputs to investment. BRUGEM, however, requires investment by industry. Thus, we needed to find a way to split the single column in the IOT into many columns, one for each industry. One potential source of information was the supplementary investment matrix provided by DEPD, with information on investment by commodity and industry. However, for reasons explained below, the supplementary data were considered unreliable.

From the supplementary investment matrix provided, the investment to capital rental ratio for mining alone worked out to be 2.9 per cent, much less than the economy-wide average implied by the IOT. This could cause problems in modelling given the mining sector is a key industry driver for economic growth and it is highly capital intensive with large investment. Despite the unavailability of data about the oil and gas capital investment in Brunei, the deduction was that 2005 was not a typical year (see Section 4.3.2.3) for investment in the mining sector since the capital investment can be cyclical for mining. Investment in the mining sector must first be injected before extraction can be carried out and this can be continuous in the following few years. When production comes online, there may be little or no new investment other than for maintenance and replacement of depreciated stock of machinery and equipment.

In the supplementary investment matrix provided, the construction sector shows an extremely high ratio of 572 per cent, indicating very large investment compared to the capital income received. This does not seem plausible from an investor's point of view based on the existing economic structure and activities in Brunei. Other observations of the supplementary investment matrix provided include the following:

a) The main *CrudePetrol* and *NaturalGas* industries have a combined share of 14 per cent compared to the *PubAdmDfnSoc* sector's share of 27 per cent and the *RealEstSrv* industry share of 23 per cent of the total gross fixed capital formation. This is considered low, since the *CrudePetrol* and *NaturalGas* industries are capital intensive.

b) Out of the commodities and services used by the *PubAdmDfnSoc* sector to create capital, 66 per cent are building related and 18 per cent are equipment related (primarily motor vehicles). Given such a high share of fixed capital for the public sector, there could be some anomalies in the classification about the difference between ownership of a fixed asset, through purchases, and the consumption of an intermediate commodity to produce a unit of fixed capital for subsequent capital formation. In reality, the public sector should be more labour intensive instead of being capital intensive, as implied in the supplementary investment matrix. This requires some adjustment.

c) The *RealEstSrv* industry has a column total of B$418 million, which is about 23 per cent of total gross fixed capital formation. Being a service industry, this must be due to the inclusion of dwellings, which are investment-intensive. The use matrix for capital creation shows that about 87 per cent or B$362 million comes from *ArcEngTchSrv* and about 12 per cent comes from *BldgConstruc* as the two main inputs of the *RealEstSrv* industry. This has to be treated separately because, by definition, *ArcEngTchSrv* consists of architectural and engineering services, technical and analysis services, which should go towards the creation of dwellings and are not quite related to real estate activities in general. This split is necessary for two reasons. Firstly, dwellings are an important component of household expenditure and secondly, leaving dwellings within the *RealEstSrv* industry will have misleading implications for the relative sectoral growth via capital accumulation later. Details of splitting is described in Step 8 in Section 4.3.2.8.

d) Another question arises pertaining to the calculation of the gross fixed capital formation figures which, by definition, should be the total value of producers' acquisition less disposal of fixed assets plus additions to the value of non-produced assets realised by productive activities of resident producers (UN 1999). A quick side calculation seemed to indicate that the investment figures in the supplementary matrix were not calculated based on this methodology and the disposed amounts are not accounted for from the additional information provided.

Given the above observations a) to d), the supplementary investment matrix segregated by industry and commodity was set aside and a new investment matrix was created based on some simple rules for investment allocation. This is explained later in Section 4.3.2.3.

4.3 Compilation of the core database

4.3.1 Data sources

DEPD provided the overall format of IOT 2005 as shown in Table 4-5. Originally, the final consumption (user 3) in IOT 2005 was split into three components: households, non-profit institutions serving household (NPISH) and the government. For the purpose of the BRUGEM database, the first two categories were merged as a single household since NPISH was less than one per cent of the total final consumption.

Table 4-6 shows the use table in basic prices. In the use table, there is only one row for compensation for employees (V1LAB_O). The capital rental value (V1CAP) is captured in the gross operating surplus row and there is no separate rental value for land (V1LND). There are rows of figures on taxes less subsidies (V1TAXlessSUB), consumption of fixed capital, which is the depreciation of capital (DEPRC), and other net taxes on production (V1PTX). Table 4-6 shows the use table for domestic output and Table 4-7 for imports. The use table in purchasers' price is also available in the same format as the use table in basic prices. The format of the supply table is shown in Table 4-8 in basic and purchasers' prices respectively.

There are negative taxes entries in the SUT 2005 associated with other demanders besides the producers, as seen in Tables 4-5, 4-6 and 4-8. The figures reported are those of *taxes less subsidies*. This indicates two possible scenarios whereby the taxes are either outweighed by the subsidies or these entries are purely subsidies with no taxes. From the compilation guide (DEPD 2011), it is stated that the *taxes less subsidies* on products comprises import duties and no other taxes are levied on products.

One adjustment is required with regard to the *taxes less subsidies* figures. There are negative *V6TAXlessSUB* entries in Tables 4-5, 4-6 and 4-8, indicating there are subsidies on held or unsold inventories. These inventories by definition are not traded so they should not attract any taxes or subsidies. As explained earlier in Section 4.2.1, no sales taxes are paid on inventories and there is no V6TAX matrix. Therefore, the small subsidies for the inventories in the IOT 2005 were removed during the database creation process.

Supplementary tables for margins and taxes by commodities and users are made available by DEPD. There are negative entries in the original margins table for margin commodities, which exactly offset the other positive entries in non-margins by commodities (see Table 4-9). These needed to be adjusted to obtain the suitable matrices of basic flow matrices with direct sales of the goods and services and separate margin matrices in the database. This will be explained in section 4.3.2.7.

Table 4-5: The format of the IOT at basic prices

		Producers	Final consumption	Gross fixed capital formation	Changes in inventories	Exports
	Size	IND	3	1	1	1
Basic flows	74 COM	V1BAS_ORIG	V3BAS_ORIG, V5BAS_ORIG	V2BAS_ORIG	V6BAS_ORIG	V4BAS_ORIG
Taxes less subisdies on products	1	V1TAXlessSUB	V3TAXlessSUB, V5TAXlessSUB	V2TAXlessSUB	V6TAXlessSUB	V4TAXlessSUB
Compensation of employees	1	V1LAB_O				
Other net taxes on production	1	V1PTX				
Consumption of fixed capital	1	DEPRC				
Operating surplus, net	1	NETOPSPL				
Value added at basic prices	1	VABP				
Output at basic prices	1	USEBP				
Imports	1	IMPORTS				
Supply at basic prices	1	SUPPLYBP	SUPPLYBP	SUPPLYBP	SUPPLYBP	SUPPLYBP

Table 4-6: The format of the use table of domestic output at basic prices

		Producers	Final consumption	Gross fixed capital formation	Changes in inventories	Exports
	Size	74 IND	3	1	1	1
Basic flows	74 COM	V1BAS_ORIG "dom"	V3BAS_ORIG "dom", V5BAS_ORIG "dom"	V2BAS_ORIG "dom"	V6BAS_ORIG "dom"	V4BAS_ORIG "dom"
Use of imported products, cif	1	IMPORTS	IMPORTS	IMPORTS	IMPORTS	IMPORTS
Taxes less subisdies on products	1	V1TAXlessSUB	V3TAXlessSUB, V5TAXlessSUB	V2TAXlessSUB	V6TAXlessSUB	V4TAXlessSUB
CIF/FOB adjustments on exports	1	0	0	0	0	ADJEXPORTS
Direct purchases abroad by residents	1	0	HHIMPORTS	0	0	0
Purchases on the domestic territory by non-residents	1	0	-NREXPORTS	0	0	NREXPORTS
Compensation of employees	1	V1LAB_O				
Other net taxes on production	1	V1PTX				
Consumption of fixed capital	1	DEPRC				
Operating surplus, net	1	NETOPSPL				
Operating surplus, gross	1	V1CAP				
Value-added at basic prices	1	VABP				
Output at basic prices	1	USEBP				

Table 4-7: The format of the use table of imports at basic prices

		Producers	Final consumption	Gross fixed capital formation	Changes in inventories	Exports
	Size	74 IND	3	1	1	1
Imported Flows	74 COM	V1BAS_ORIG "imp"	V3BAS_ORIG "imp", V5BAS_ORIG "imp"	V2BAS_ORIG "imp"	V6BAS_ORIG "imp"	V4BAS_ORIG "imp"

Table 4-8: The format of the supply table at purchasers' prices

		Producers	Domestic output	Imports CIF	Total supply at basic prices	Trade and transport margins	Taxes less subsdies on products	Total supply at purchasers' prices
	Size	74 IND	1	1	1	1	1	1
Supply of domestic output	74COM	MAKE	DomOutputBP	IMPORTS	SUPPLYBP	Sum of V1MAR_ORIG, V2MAR_ORIG, V3MAR_ORIG, V4MAR_ORIG, V5MAR_ORIG, V6MAR_ORIG	Sum of V1TAXlessSUB, V2TAXlessSUB, V3TAXlessSUB, V4TAXlessSUB, V5TAXlessSUB, V6TAXlessSUB	SUPPLYPP
CIF/FOB adjustments on imports				ADJIMPORTS	ADJIMPORTS			ADJIMPORTS
Direct purchases abroad by residents				HHIMPORTS	HHIMPORTS			HHIMPORTS

Table 4-9: The format of margins table

		Producers	Final consumption	Gross fixed capital formation	Changes in inventories	Exports
	Size	74 IND	3	1	1	1
Non-margin flows	67COM	V1MAR_ORIG	V3MAR_ORIG, V5MAR_ORIG	V2MAR_ORIG	V6MAR_ORIG	V4MAR_ORIG
Margin flows	7 COM	-V1TDM, - V1TPM	-V3TDM, -V3TPM, -V5TDM, -V5TPM	- V2TDM, -V2TPM	-V6TDM, - V6TPM	-V4TDM, -V4TPM
Total		0	0	0	0	0

The first major task was to convert the above IOT format into the required format for the BRUGEM CGE database, as shown in Table 4-1. Some issues associated with the original IOT 2005 had to be addressed, with some adjustments needed. These are discussed in Section 4.3.2.

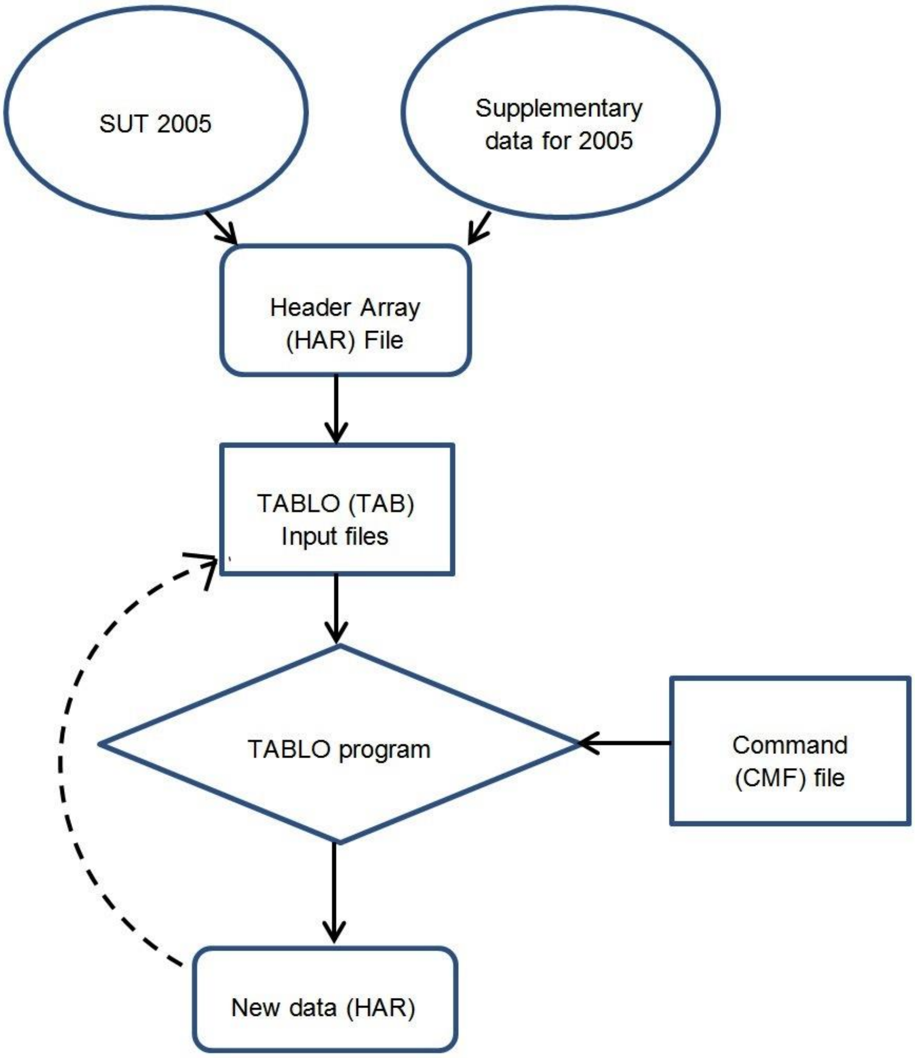
The unit of the data and statistics provided was also scaled from B$ thousand to B$ million to match the unit provided in the IOT and to ease analysis and comparison. The GEMPACK software (Harrison & Pearson 1996) can calculate figures accurately up to six digits and this kept most data in the database within that limit. The objective of this Section 4.3 is to describe how the actual BRUGEM database was constructed based on the IOT and SUT 2005.

Most data manipulations were carried out in the GEMPACK software (described in Appendix 3-2) instead of in a standard spreadsheet program. The GEMPACK program has the advantage of providing self-documentation for the user and hence making the process of trouble-shooting easier. Other than tracking the process, documentation is also useful in enabling adjustments or data manipulation to be carried out at a later date should the need arise.

For the automation of this process, the GEMPACK software requires data files to be in a certain format, called Header Array (or HAR). This is the very first step for dealing with the raw data spreadsheet files. Figure 4-2 summarises the data job process taken in constructing the BRUGEM core database.

Depending on the data job required, the TABLO input text file for each step is written to contain equations and update statements or other types of action. Combined with the necessary HAR file and command (CMF) file, the TABLO program can carry out multi-step simulation to create a solution file and updated database (Steps 11 and 12, as discussed in Section 4.3.2), or it can be used to manipulate and write data to create new data files for the subsequent data job steps (Steps 1 to 10, as discussed in Section 4.3.2).

Figure 4-2: Steps for constructing the BRUGEM IO database



4.3.2 Database creation process

4.3.2.1 Step 1: Conversion of raw data from Excel files to HAR files

The original SUT in excel spreadsheet files were first converted to HAR files using the ViewHAR program (Horridge 2003). The single HAR file is the BRUBASE.HAR, which contains all necessary figures and matrices from the original spreadsheets. Some useful aggregated data were also calculated from the primary data and these are contained in the summary file, BRUSUM.HAR. Where matrices were not available from the original tables, these were created as explained in the following data job steps.

4.3.2.2 Step 2: Multi-production matrix

In the original SUT, there are off-diagonal non-zero entries and the MAKE matrix itself is not a diagonal matrix where one commodity is only produced by a single industry. There are some main diagonal entries with smaller values than the off-diagonal entries. This indicates that the goods and services are not produced by their respective industries but by other industries. Examining the initial data reveals some discrepancies. For example, 88 per cent of *OtherMining* commodity (other mining and quarrying products) is produced by the *OtherMining* industry itself, but 12 per cent is produced by the *BldgConstruc* industry. Even though this off-diagonal number is small in value at less than B$1.3 million, it could pose an issue in the modelling if, for example, the *BldgConstruc* industry were stimulated relative to *OtherMining.* This could produce a disproportionately large amount of construction-produced *other mining and quarrying products* that would drive out *OtherMining* production. This crowding out effect can distort interpretation of results.

For this thesis, in light of future or forecast scenarios where selected industries are stimulated, some of these odd off-diagonal entries were adjusted. Specifically, for the commodities *OtherMining*, *OthNonMetal*, *FoodBvgSrv*, *OthPrfTchSrv* and *OthPrsnlSrv*, all sales were moved to their corresponding main-producing industries.

With these small adjustments, the costs of production were adjusted accordingly to retain the database balance. These adjustments were done in a way that preserved the initial labour to capital ratios in order to minimise structural changes.

There are six industries listed in Table 4-10 for which the original use table shows zero domestic production. With the exception of *MotorVehTrlr*, *ArtEntCltrl* and *MemberOrgSrv,* these industries were retained, with zero production. *MotorVehTrlr* was given a small amount of production as part of the adjustment for re-exports discussed in Section 4.3.2.5. Industries *ArtEntCltrl* and *MemberOrgSrv* were aggregated together with industry *SportRcrtSrv* to form a new aggregated industry called *ArtEntSport* (discussed in Section 4.3.2.8).

Table 4-10: Industries with zero cost structure and no domestic production

IND	Abbreviation	Description
#4	CoalMining	Mining of coal and lignite
#7	MetalOres	Mining of metal ores
#22	MachineryEqp	Manufacture of machinery and equipment n.e.c.
#23	MotorVehTrlr	Manufacture of motor vehicles, trailers and semi-trailers
#69	ArtEntCltrl	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities
#71	MemberOrgSrv	Activities of membership organisations

There are seven industries with zero investment and zero capital input (see Table 4-11), which corresponds to the six industries in Table 4-10 plus *DomSrvHH*, which consists of labour only and no capital.

Table 4-11: Industries with no investment and capital input

IND	Abbreviation	Description
#4	CoalMining	Mining of coal and lignite
#7	MetalOres	Mining of metal ores
#22	MachineryEqp	Manufacture of machinery and equipment n.e.c.
#23	MotorVehTrlr	Manufacture of motor vehicles, trailers and semi-trailers
#69	ArtEntCltrl	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities
#71	MemberOrgSrv	Activities of membership organisations
#74	DomSrvHH	Activities of households as employers of domestic personnel

4.3.2.3 Step 3: Creation of a new investment matrix

As mentioned in Section 4.2.4, the IOT 2005 only has a single column of inputs by source and without any industry dimension. A supplementary investment matrix with industry dimension was provided and, for reasons explained in Section 4.2.4, this supplementary matrix was set aside and a new investment matrix was created.

In this step, the original V2PUR_SI matrix, which has two dimensions (commodity by source), was split into a full commodity (74) by source (2) by industry (74) investment matrix, as discussed below.

As highlighted earlier in section 4.2.4, the supplementary investment matrix provided shows that the *PubAdmDfnSoc*, essentially a government industry, constitutes 27 per cent of the total investment, which was very high compared to other economies' databases (Australia 6.5 per cent and Malaysia 1.8 per cent). Similarly, the *RealEstSrv* industry has 23 per cent of the total investment which must be due to dwellings which are investment-intensive. For capital creation, 87 per cent comes from *ArcEngTchSrv* and 12 per cent from *BldgConstruc* as the two main inputs of *RealEstSrv* industry. This needed to be reallocated accordingly, otherwise this would have misleading implications for the relative sectoral growth via capital accumulation later.

The computation of the new investment matrix was based on a set of six rules. Before applying those rules we first calculated the average economy-wide ratio of investment to cost of capital , $\frac{\sum_{cs} V2PUR(c,s)}{\sum_{i} V1CAP(i)}$ and applied it across each industry's capital rentals to obtain a first guess at industry-specific investment to be used as column targets. To allocate the cost and sales structures between these 74 commodities and 74 industries, the commodities and industries were aggregated into nine commodities and ten industries, as shown in Table 4-12.

The six rules used for the distribution of investment are as follows:

(1) MININGCOM feeds 100 per cent to MININGIND;

(2) MANUFCOM is 70 per cent of the total cost structure of MANUFIND;

(3) REALESTIND has a cost structure of 75 per cent CONSTRUCCOM and 20 per cent *ArcEngTchSrv*;

(4) GOVT invests 35 per cent in MANUFCOM and 65 per cent in CONSTRUCCOM;

(5) *LndTrnsPpSrv* IND has a cost structure of 45 per cent *MotorVehTrlr* and 45 per cent CONSTRUCCOM;

(6) *OthTrsprtEqp* COM has the split of 8 per cent going to *WaterTrnsSrv* and 92 per cent into *AirTrnsSrv* IND.

Table 4-12: Aggregated commodities and industries

Aggregated commodities	Commodities
AGRICCOM	AgriAnmlPrd,ForestLog,FishAquacul
MININGCOM	Coal,CrudePetrol,NaturalGas,MetalOres,OtherMining,MiningSptSrv
MANUFCOM	FoodBvgTobac,TextilesAppL,WoodPrd,PaperPrd,PrintRecPrd,CokePetroPrd,ChemPhrmRbrP,OthNonMetal,BasicMetals,FabMetalPrd,CompElectOpt, ElectriclEqp,MachineryEqp,MotorVehTrlr,OthTrsprtEqp,Furniture,OthManuf
SERVCCOM	RprInstlSrv,ElecGasAircn,WaterTrmtSup,SwgWstSrv,WhReTrdRepMV,WhTrdSrv,ReTrdSrv,LndTrnsPpSrv,WaterTrnsSrv,AirTrnsSrv,WrhsgSrvTrns,PostlCourier,AccomSrv,FoodBvgSrv,PublishgSrv,PicSndPrdSrv,PrgmBrdctSrv, TelecomSrv,ComPrgmCnslt,InfoSrv,FinSrv,InsrnPnsFSrv, SrvFinInsrn,LegalActgSrv,MgtCnsltSrv,RnDRschSrv,OthPrfTchSrv,VetSrv, RentalLsgSrv,EmploymtSrv,TrvlAgtSrv,SecuritySrv,AdminBizSrv,PubAdmDfnSoc,Education,HealthSrv,ResCareSWSrv,ArtEntCltrl,SportRcrtSrv,MemberOrgSrv,RepairSrvHH,OthPrsnlSrv,DomSrvHH
CONSTRUCCOM	BldgConstruc,CvlEngConstr,SpecConstrc
REALESTCOM	RealEstSrv
MotorVehTrlr	MotorVehTrlr
OthTrsprtEqp	OthTrsprtEqp
ArcEngTchSrv	ArcEngTchSrv
Aggregated industries	**Industries**
AGRICIND	AgriAnmlPrd,ForestLog,FishAquacul
MININGIND	CoalMining,CrudePetrol,NaturalGas,MetalOres,OtherMining,MiningSptSrv
MANUFIND	FoodBvgTobac,TextilesAppL,WoodPrd,PaperPrd,PrintRecPrd,CokePetroPrd,ChemPhrmRbrP,OthNonMetal,BasicMetals,FabMetalPrd,CompElectOpt, ElectriclEqp,MachineryEqp,MotorVehTrlr,OthTrsprtEqp,Furniture,OthManuf
SERVCIND	RprInstlSrv,ElecGasAircn,WaterTrmtSup,SwgWstSrv,WhReTrdRepMV, WhTrdSrv, ReTrdSrv,WrhsgSrvTrns,PostlCourier,AccomSrv,FoodBvgSrv, PublishgSrv, PicSndPrdSrv,PrgmBrdctSrv,TelecomSrv,ComPrgmCnslt,InfoSrv,FinSrv,InsrnPnsFSrv,OthFinSrv,LegalActgSrv,MgtCnsltSrv,ArcEngTchSrv,RnDRschSrv,OthPrfTchSrv,VetSrv,RentalLsgSrv,EmploymtSrv,TrvlAgtSrv, SecuritySrv, AdminBizSrv, ResCareSWSrv,ArtEntCltrl,SportRcrtSrv, MemberOrgSrv,RepairSrvHH, OthPrsnlSrv,DomSrvHH
CONSTRUCIND	BldgConstruc,CvlEngConstr,SpecConstrc
REALESTIND	RealEstSrv
GOVT	PubAdmDfnSoc,Education,HealthSrv
LndTrnsPpSrv	LndTrnsPpSrv
WaterTrnsSrv	WaterTrnsSrv
AirTrnsSrv	AirTrnsSrv

These rules are shown as the shaded cells in Table 4-13. Combined with the original data of investment by commodity, irrespective of source to be used as the row target, the RAS method is used to scale the matrix accordingly to hit these targets. Bui and Nguyen (2013) provide an explanation of how the RAS process works. The final matrix produced has only nine aggregated commodities and ten aggregated industries with no source dimension, as shown in Table 4-13.

This matrix was then expanded into 74 sectors by filling up the main diagonal and off-diagonal entries using the respective shares of the disaggregated sectors over their aggregated totals. The output matrix now had both commodity and industry dimensions and the source dimension was created by using the same source shares from the original V2PUR matrix in the IOT.

Table 4-13: RASsed investment matrix by aggregated industries and commodities

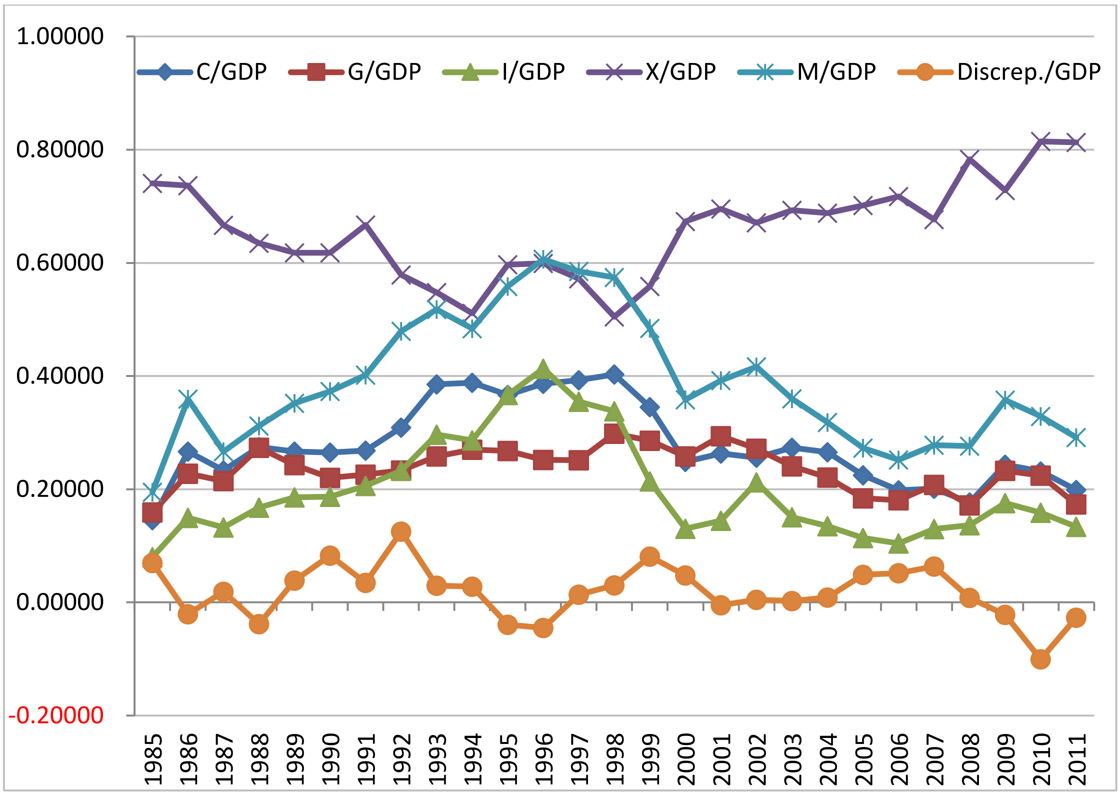
	AGRICIND	MININGIND	MANUFIND	SERVCIND	CONSTRUCIND	REALESTIND	GOVT	LndTrnsPpSrv	WaterTrnsSrv	AirTrnsSrv	Row total
AGRICCOM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MININGCOM	0.00	25.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.92
MANUFCOM	2.51	390.91	24.33	73.18	1.64	4.03	30.47	0.31	0.06	2.28	529.70
SERVCCOM	0.50	77.80	0.91	14.56	0.33	0.80	0.00	0.06	0.01	0.45	95.42
CONSTRUC COM	1.98	308.66	3.62	57.78	1.29	90.96	56.56	3.04	0.04	1.80	525.73
REALEST COM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MotorVehTrlr	0.75	117.77	1.38	22.05	0.49	1.21	0.00	3.02	0.02	0.69	147.38
OthTrsprtEqp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.64	30.41	33.06
ArcEngTchSrv	2.45	382.94	4.49	71.69	1.60	24.24	0.00	0.30	0.05	2.23	490.00
Column total	8.19	1303.99	34.72	239.25	5.35	121.25	87.03	6.74	2.83	37.86	1847.20

Following the earlier explanation provided in Section 4.2.4, the 2005 supplementary investment data indicates that the oil and gas industries attract a low level of investment (14 per cent of the total investment made), making 2005 an ‘abnormal’ year for the two dominant industries in the economy with the combined rentals of fixed capital made up of 69 per cent of the total V1CAP. Examining the GDP time series data in Figure 4-3, the year 2005 data does exhibit an exceptionally low investment to GDP ratio (11.3 per cent) since 1986. There were high investment to GDP ratios between

1993 to 1998, ranging from 28.7 per cent to 41.3 per cent. On average, the I/GDP ratio was about 20.2 per cent from 1986 to 2011. Oil and gas mining are regarded as capital-intensive industries, exhibiting lumpy investment patterns. Capital is invested and installed to be used over many years without further new investment being added, other than the amounts needed to maintain existing capital stock. Therefore oil and gas investments must have occured a few years prior to 2005.

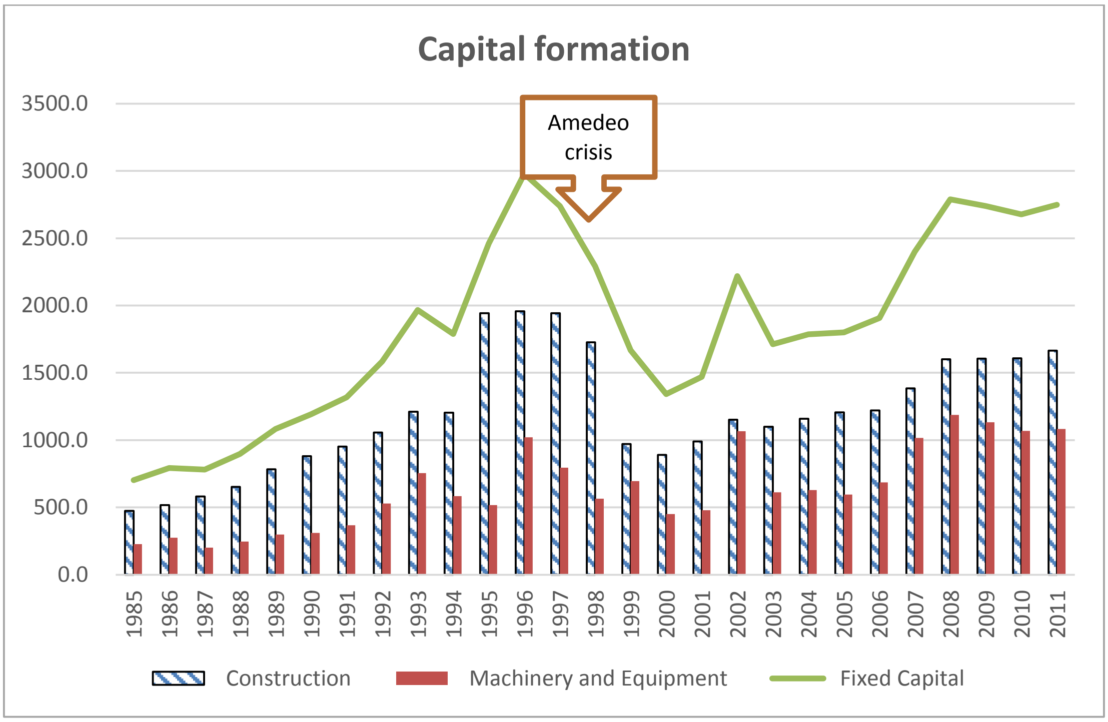
It is unclear how much of the peaks of investment in terms of machinery and equipment in 1996 and 2002, prior to the base year 2005, was attributed to oil and gas capital formation in the absence of detailed data. Coincidentally, the largest business conglomerate, Amedeo Corporation controlled by Prince Jefri (Cleary & Francis 1999), that was building several mega infrastructures in Brunei, had also collapsed in 1998. This is evident in the sudden decline in the construction component of the fixed capital formation (see Figure 4-4). This is the same period where there was a regional economic downturn and fall in oil spot prices leading to a substantial cut in the development budget in 1998 by nearly half. GDP growth had also also dipped (see Figure 2-3 in Chapter 2).

Figure 4-3: Ratio of expenditure components to GDP for the period 1985-2011



Source: DOS

Figure 4-4: Gross fixed capital formation for the period 1985-2011



Source: DOS

4.3.2.4 Step 4: Computation of factor payments and inclusion of royalties from oil and gas industries as costs

The total costs of production by industry are made up of primary factor costs (V1PRIM(i)), intermediate costs (V1MAT(i)), production taxes (V1PTX(i)) and other costs tickets (V1OCT(i)). In the use table, production taxes are zero for all industries and there is no classification for other cost tickets (V1OCT(i)), which is also assumed to have a value of zero.

The initial use table has total compensation for labour (V1LAB(i)), and capital rentals (V1CAP(i)) but does not contain any value for land rentals (V1LND(i)).This underestimates the contribution of natural resources in the production of output for industries such as agriculture-related and extractive or mining industries that 153nalyzi permanently fixed factor or natural resources like land. In order to reflect positive resource rentals for these resource-using industries, for a set of natural-resource constrained industries (*AgriAnmlProd*, *ForestLog*, *FishAquacul*, *CrudePetrol* and *NaturalGas*), a third of the gross operating surplus or V1CAP was allocated to V1LND and the same amount was removed from V1CAP.

No land rental was allocated to the other industries. To avoid a disproportionate amount of capital rentals in these industries compared to the resource-using industries, a third of their capital rentals was redistributed to other input as other costs tickets (V1OCT), which can include the costs of holding liquidity, cost of holding inventories and other miscellaneous production costs (Dixon et al. 1982).

Further inspection of the original Use Table indicates that the key export industries – *CrudePetrol* and *NaturalGas* – appeared to be net receivers of subsidies. The Use Table indicates that both the *CrudePetrol* and *NaturalGas* industries are also beneficiaries as users of the highly 153nalyzing153 commodity *CokePetroPrd* as intermediate inputs in their production.

Royalties paid by oil and gas companies to the government for their concession rights to extract the natural resources are not reflected in the IOT 2005, which should in fact be regarded as costs to the production. The dividends paid to the government are taken into consideration on the gross operating surpluses of these two industries but not royalties, which are normally related to the production level. In order to reflect the impact of royalties on oil and gas production, fiscal data (IMF 2012a) were used to estimate the figures to be added to the other costs ticket, V1OCT.

Royalties figures estimated from the IMF (2012a) were allocated to V1OCT to reflect cost of production, where a lump-sum 2005 figure of B$806 million royalties was split equally between the two industries, resulting in an entry of B$403 million each. This amount was deducted from the capital rentals and transferred into other cost tickets for both industries to maintain the balance in the MAKE matrix. The total costs of production remain unchanged; they were merely redistributed.

4.3.2.5 Step 5: Adjustment to the re-exports for certain goods and services

In the original use tables for imports, several entries in another column (export of goods and services) 154nalyzi up to a significant figure of B$871 million or 7.8 per cent of total exports in IOT 2005. This indicates that these goods and services were imported and then re-exported. However, re-exports are not produced locally and there is little connection with the Brunei economy. This is an anomaly because Brunei is not a trans-shipment centre like Singapore or Hong Kong, where re-exports occur as one of the main economic activities.

Re-exports are defined in the *Brunei Darussalam Statistical Yearbook 2011* (DOS 2012a, pp. 86) as 'goods taken out of the country in the same form as they were imported without any transformation. Re-packing, sorting or grading processes are not considered part of the transformation processes'. Past studies by Anaman and Mahmod (2003) and Anaman (2004) identified some re-exports as previously imported machinery and equipment, with no further value added, and were sent to foreign suppliers for repairs or replacement. Therefore, these types of re-export goods were not regarded as the actual exports of Brunei and needed to be adjusted accordingly since the ORANI-G theory does not accommodate re-exports. Re-exports in the IOT had to be addressed because they tended to overestimate actual exports as well as spending on imports.

Although there were some small entries related to commodities like *AgriAnmlPrd, FishAquacul, CrudePetrol, FoodBvgTobac, WoodPrd, PaperPrd,* the largest single re-exports entry was for *TextilesAppl* at B$112 million. For the *TextilesAppL* industry, raw materials are imported, reprocessed to form garments to be exported. Therefore, they are not purely re-exports as defined in the previous paragraph.

TextileAppL[18] is the third largest export for Brunei after oil and gas, before the methanol industry was established in 2010. As shown in Figure 4-1, this industry has shrunk in importance.

The other large entries related to services such as *LndTrnsPpSrv* (B$387 million), *AccomSrv* (B$200 million), *RentalLsgSrv* (B$114 million) and *OthPrfTchSrv* (B$21 million). This is explained by the IOT consultant via an email dated 12 April 2012, as follows:

> The large amount of imported land transport services is caused by contracts with foreign truck and other land transport companies (e.g. transport by pipelines). The imported accommodation services are induced by Brunei citizens travelling abroad for business and private activities. They belong to balance of payment (BOP) also to imported services. All the other large figures for imported services are in line with the recommendations of the Standard System of National Accounts (UN 1993) which are defined as components of BOP.

It appears that these entries were included to match the BOP numbers. Given that the BOP figures published by the IMF (2012a) show large values of errors and omissions due to the lack of comprehensive BOP data for Brunei, it is challenging to determine the source of these errors.

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[18] The garment industry was the third largest exporter after oil and gas but has shrunk over the years, see Goh (2010)

The existence of such re-exports in the database can lead to some problems. The following example illustrates such problems and suggests a method for adjusting the database to remove re-exports.

Say Brunei's apparel industry imports large quantities of polo shirts, sews some buttons on them and then exports them to other countries. Numerically, for illustration, the IOT may state that the output of Brunei's domestic apparel industry is B$10 million while it imports apparel of B$100 million and exports B$51 million, including B$45 million of re-exports (see Table 4-14). The problem will be that the exports ($51million) are greater than what is produced domestically (B$10 million). Table 4-14 also shows that the value of imports (B$100 million) far exceeds the total domestic absorption by both intermediate and final users (B$59 million), irrespective of the source of the apparel. Therefore, some apparel must be imported for the purpose of re-exporting.

Table 4-14: Illustration of re-exports scenario of the apparel industry

		Apparel used by demander		
Apparel producer	Units	Domestic	Foreign	Total
	Domestic	4	6	10
	Foreign	55	45	100
	Total	59	51	110

This can lead to data solving issues. Two options are available to treat this data anomaly. The first option is to remove the re-exports by subtracting equal amounts from both exports and imports since exports will be larger than domestic production if the country imports a huge quantity of the commodities and exports them again.

Therefore, in the Table 4-14 example, we remove the re-exports by subtracting B$45 million from both export and import values. This approach is used in the GTAP database (GTAP 2015). Here it is recommended that if no other information is available, the re-exports should be eliminated from both exports and imports to maintain the database balance when there is an indication that the total exports exceed domestic production or the total imports exceed domestic demand of that commodity. One consequence of this treatment is that there will be B$100 million less B$45 million or, B$55 million of imported apparel; and B$51 less B$45 million or B$6 million exported to foreigners. This may imply that industries with re-exports have exported all their domestic production (B$4 million) and only the imported source of commodity (B$55 million) is used as intermediate inputs and for final uses. This may not be accurate or reflective of the actual situation, based on the Table 4-14 example, and is therefore not a satisfactory treatment.

In the System of National Accounts 2008 (UN 2009), it is recommended that goods that have been imported and are waiting to be re-exported should be recorded as inventories. However, such treatment in this database can lead to other problems, such as an unusually large stock of inventories. Consequently, this was not adopted.

Another option is to increase producer's own inputs of the commodities or services by the amounts shown in the original export column under the use of imports table, resulting in a larger imported component. The additional imported components add cost to the local industries as it is assumed that, in practice, all imported goods or services must be purchased or routed through them. Similarly, where the goods and services are ascribed to final users, their consumption from imported sources will also increase and add to the export of domestic commodity.

Using the apparel example in Table 4-14 again, we can increase the domestic inputs by the apparel industry by B$50 million, mostly through imports, raising the total output of Brunei's apparel from B$10 to B$60 million. Then the exports of B$51 million will be less than production. It is this second approach that was adopted for the BRUGEM database.

To implement this idea, all entries in the export column in the use table for imports were moved from the "import" to "domestic" column of the original V4BAS_ORIG matrix and the MAKE matrix was adjusted accordingly to cater for the domestic production of these commodities. The initial figure of B$112 million in the Exports column of the use table under imports (see Table 4-6) for *TextileAppL* was removed and added to the use table for domestic output (V1BAS matrix). The MAKE matrix for that commodity was adjusted accordingly. The same treatment was applied to all other "imported exports", as shown in the initial use table.

4.3.2.6 Step 6: Remove the negative basic flows of household sector, CIF/FOB adjustment and territorial corrections

In the original use table, there were some tiny (less than -0.001) negative basic flows in the final consumption expenditure by household column for commodities *ComPrgmCnslt*, *SrvFinInsrn*, *RnDRschSrv*, *SecuritySrv* and *ArtEntCltrl*. These were adjusted to zero.

Additional lines of adjustments were found in the SUT provided (see Tables 4-6 and 4-8), namely:

(i) CIF/FOB[19] adjustments on exports/imports (*ADJEXPORTS & ADJIMPORTS*)

(ii) Direct purchases made abroad by residents (*HHIMPORTS*)

(iii) Purchases made on domestic territory by non-residents (*NREXPORTS*)

According to the manual (Eurostat 2008), these lines are necessarily introduced to make up the differences resulting from the different valuation methods applied in the IOT. As an example for item (i), in foreign trade statistics, imports are usually valued at CIF prices while in the SUT, the imports and exports are valued at FOB prices. This resulted in a global CIF/FOB adjustment row on imports being added to the supply table (see *ADJIMPORTS* in Table 4-8), while the same negative entry is shown for the CIF/FOB adjustment for exports in the use table (see *ADJEXPORTS* in Table 4-6).

[19] In trade terms, CIF. stands for cost, insurance and freight while FOB means free on board. There are differences in terms of the costs borne by importer and exporter. For further details about these two costs, one can refer to http://www.customs.gov.au/webdata/resources/files/Incoterms.pdf (viewed 2/2/15)

The handbook on IO compilation (UN 1999) states that the imports of goods valued at CIF include the value of imported goods FOB combined with transport and insurance services rendered by both residents and non-residents to make them equivalent to the basic values. However, since these import values already include services provided by non-residents, adjustment needed to be made to avoid over-estimation by the value of the transport and insurance costs. This is in line with Standard System of National Accounts (UN 2009), where imports are valued at FOB.

There was also a need for territorial correction. The direct purchases abroad made by residents affect both the import column and the household expenditure column. These values were added to the original commodity-specific imports and commodity-specific household expenditure. Similarly, the purchases by non-residents made domestically were added to exports and deducted from household expenditure.

4.3.2.7 Step 7: Splitting of margins by source

In IOT 2005, there is a single large entry in the "imported source" of the export column for *LndTrnsPpSrv,* which is a margin commodity. This relates to the cost of foreign-produced *LndTrnsPpSrv* associated with the transfer of commodities between the Brunei domestic producers and their foreign demanders.

One can choose to modify the ORANI-G theory and database by 159nalyzing159g imported margins and extending the margins matrix to include imports through the use of TABLO codes if one believes imported margins play a big part in the economy. Alternatively, these imported margins can be treated as domestically produced only with a higher imported component in the cost structure, similar to the treatment of the re-exports as discussed in Section 4.3.2.5.

For BRUGEM the same treatment as the re-exports was chosen instead of modifying the theory that margins can only be produced domestically. Therefore, all imported transport services must be purchased via, or routed through, the local transport industry. The imported transport is then added to the costs of the local transport services industry. Margin users will then use only locally produced transport, which now has a larger import component.

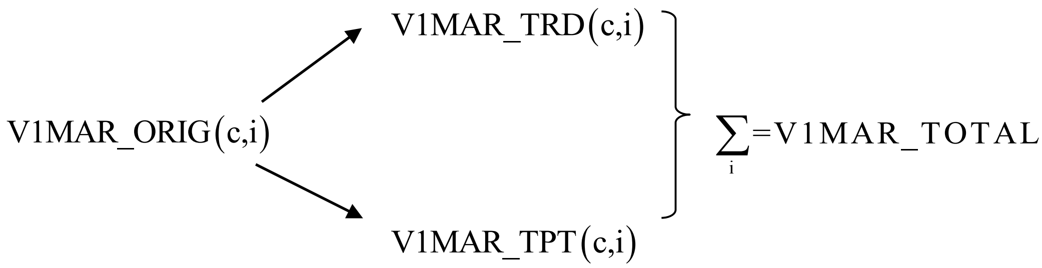
For the BRUGEM database, we need the basic values for margin commodities, which should only contain the direct usage of these margins by users. Therefore, the margin usage contained in the provided margin matrices V#MAR had to be removed from the original values in the rows of margin commodities in the IOT 2005. This comprised both direct and margin usage of these margins (DEPD 2011). This gave rise to a new V#BAS basic flows matrices that contained only direct usage and no margin usage of the commodities. For example, a van can be used as transportation (direct usage) or as a margin by transporting wood from the producers to the demanders. The margin use of this van is removed leaving only the direct usage in the basic flows. By having more detailed margins in the modelling, we can see the knock-on effects of a price increase in wood where we can expect not only a reduction in the demand for wood by consumers, but also as an intermediate input by the furniture industry. The demand for associated margins such as the retail trade and transport services sectors to facilitate the flow of this commodity to the demanders is also expected to decline.

The margins table shown in Table 4-9 in Section 4.3.1 has a commodity dimension for each intermediate and final user. There is no source dimension. Although this format shows the total margins for each type of margin commodities and by the users, it does not show the breakdown for each entry along the rows by type of margins used. Therefore, we needed to split into the various types of margins used for moving each commodity to the demanders.

The original margin matrices (V#MAR_ORIG) on all services are zero, indicating that all services are delivered directly from producers to consumers and no margin services are required.

Supplementary data on these three trade margins and four transport margins were provided and matrices by commodity were created in ViewHAR under the headings V#TDM and V#TPM respectively. These contain positive entries of the margins used to move commodities to demanders. Figure 4-5 shows that the types of margins needed to be split into the two broad categories of trade- and transport-related margins.

Figure 4-5: Splitting of margins into trade-related and transport-related margins



A new matrix for V1MAR_S (c,i,m) was created for all sources for each of the following in TABLO code:

$$(all,c,COM)(all,i,IND)(all,m,TRADEMAR)$$
$$V1MAR\_S(c,i,m)=V1MAR\_ORIG(c,i)*V1TDM(m,i)/V1MAR\_TOTAL(i) \quad (4.2)$$

$$(all,c,COM)(all,i,IND)(all,m,TRANSMAR)$$
$$V1MAR\_S(c,i,m)=V1MAR\_ORIG(c,i)*V1TPM(m,i)/V1MAR\_TOTAL(i) \quad (4.3)$$

In Equations (4.2) and (4.3), the new matrix V1MAR_S(c,i,m) is then further split into the domestic and imported sources. This created the full dimension of the margin matrix V1MAR(c,s,i,m) by the use of the domestic and imported source shares in the basic flows matrix. The use of margins for facilitating the commodity to the users is proportionate to its demand, as shown in Equation (4.4).

$$(all,c,COM)(all,s,SRC)(all,i,IND)$$
$$(all,m,MAR)V1MAR(c,s,i,m)=V1MAR\_S(c,i,m)*\left[\frac{V1BAS(c,s,i)}{sum(s,SRC,V1BAS(c,s,i))}\right] \quad (4.4)$$

Similar treatments were applied to other users (V2MAR, V3MAR, V4MAR and V5MAR) into respective dimensions by the use of the domestic shares of their basic flows. Since there are no margins on stored or unsold inventories, V6MAR is nil.

4.3.2.8 Step 8: Creation of ownership of the dwelling industry

In the original IOT, there was no commodity or industry to explicitly recognise the imputed rental value of owner-occupied dwellings. It appears to have been included in the *RealEstSrv* industry, which has nearly 90 per cent of capital component in its total primary factors. Household consumption of real estate services was nearly 21 per cent of their total budget, which indicates that most of it should go to spending on dwellings instead of paying real estate agents' commission or services. The supplementary investment matrix also indicates that there are significant inputs from commodities like *BldgConstruc* and *ArcEngTchSrv* into apparent investment in *RealEsSrv*. It is desirable from a modelling point of view that the distinctive *Dwelling ownership* component, which is capital-intensive, be separated from the real estate services industry and dealt with as a single industry. A dwelling sector was created to model its specific demand by splitting the real estate services and activities sector (*RealEstSrv)* into two sectors *RealEstSrv* and *Dwelling*.

The *Dwelling* industry is assumed to be produced domestically and there is no imported component. The *Dwelling* industry has no labour, land rentals, production tax nor other cost tickets. In terms of cost, it is almost entirely capital (the stock of dwellings). Accordingly, most of the V1CAP value from *RealEstSrv* is transferred to *Dwelling.* It is assumed that the residual *RealEstSrv* industry has a 70:30 split between the cost of labour and the cost of capital. It is assumed that 93 per cent of the investment of the original *RealEstSrv* sector goes to the *Dwelling* industry.

The cost structure of the intermediate inputs into the Brunei *Dwellings* industry is assumed to consist of: *BldgConstruc* (15 per cent), *ChemPhrmRbrP* (2 per cent), *RprInstlSrv* (2 per cent), *ElecGasAircn* (4 per cent), *WaterTrmtSup* (2 per cent), *SwgWstSrv* (2 per cent), *FinSrv* (53 per cent), *InsrnPnsFSrv* (2 per cent), *RentalLsgSrv* (12 per cent) and *AdminBizSrv* (6 per cent). These data are based on the cost structure of dwellings in the Australian data.

In terms of sales structure, *Dwelling* as a commodity is sold to households only and is assumed to make up 96 per cent of the initial household consumption of *RealEstSrv*. The associated taxes and margins of the *RealEstSrv* were moved into *Dwelling* accordingly.

The MAKE matrix was also adjusted accordingly; where the main diagonal of the *Dwelling* sector consists of the sum of the total cost structure (V1TOT) and the main diagonal of the *RealEstSrv* sector has the same amount removed, leaving the total MAKE matrix balanced as before. The resulting matrix, with the new *Dwelling* sector, had dimensions of 75 commodities and 75 industries after this disaggregation.

In addition to the split of dwellings away from *RealEstSrv,* two some small sectors needed to be aggregated to resolve some data solving problems.The sectors in question are *ArtEntCltrl* and *MemberOrgSrv.* These sectors were merged together with *SportRcrtSrv* to form an aggregated new sector, *ArtEntSport*. The resulting matrix after Step 8 had dimensions of 74 commodities by 74 industries.

4.3.2.9 Step 9: Creation of methanol and petrochemicals industry

The published IOT 2005 did not take into account an infant industry that has been growing in importance due to the Brunei government's diversification efforts. This is the methanol and petrochemicals industry. There is no industry in the published IOT 2005 that is sufficiently similar to be used to model the growth of this new industry. The technique of modelling a new project as an embryonic industry was drawn from past research (Madden 2006, Dixon et al. 1992, Madden & Dixon cited in Madden 2006). Creating a new industry that has its own unique sales and expenditure pattern would help in analysing the simulated impact of a shock upon this industry and the associated industries that are linked to it.

As discussed in Chapter 2, BMC was set up in 2006. It cost B$600 million to build with an annual capacity of 850,000 metric tonnes (OBG 2013). BMC produces methanol as a higher added value for exports. In 2010, BMC produced and exported 450,586 metric tonnes of methanol. A year later it produced 625,691 metric tonnes, with export values as reported in Table 4-15.

Table 4-15: Methanol exports in Brunei dollars for 2010-2014

Year	2010	2011	2012	2013	2014
Methanol exports (B$ million)	128.5	231.8	303.4	102.4	256.7

According to official statistics (DOS 2011, 2012a), the export of chemicals has increased since 2005 and there was a big jump in 2010. In nominal terms, chemicals made up 1.1 per cent of total exports in 2010 and 1.6 per cent in 2011 (DOS 2012a) or an increase of 45 per cent. In 2012, chemicals made up of 1.9 per cent of total exports (DOS 2014a). In the IOT 2005, chemicals were grouped together with other like-commodities and were shown to have near nil exports. Since methanol is becoming a major export for Brunei, it was desirable to have it separated from this aggregated commodity.

It could be safely assumed that most of the IOT 2005 commodity *ChemPhrmRbrP* was made up of methanol, since there was hardly any other production of pharmaceutical, rubber and plastic products in Brunei as of 2005. Using the published total export revenues and deduced cost structure of the BMC from an internal report, the 2011 input cost structure was mapped in terms of percentage share. This is summarised in Table 4-16.

Although the actual production and exportation of methanol only commenced in 2010, for modelling purposes, the structure of investment and costs needed to be recognised in the 2005 data.

Since the specific capital expenditure data was not made available for the methanol industry, one could observe from the published statistical yearbooks the trend in the FDI data. This measures the equity capital invested by foreign investors in businesses registered in Brunei where the trend appears to coincide with the timing of the set up of the B$600 million methanol plant. There was a steady rise for the FDI from Japan (BMC is a JV between local and Japanese companies) into Brunei under manufacturing activity. This can be seen in Table 4-17 from 2004 onwards until near production stage in 2010, when it slowed down. This supports the assumption of the beginning of an infant industry prior to 2010.

Table 4-16: Input cost structure of the methanol and petrochemicals industry

Intermediate inputs	% of total production costs in 2011
#6 NaturalGas	39
#16 ChemPhrmRbrP	1.5
#22 MachineryEqp	6.175
#27 RprInstlSrv	6.053
#28 ElecGasAircn	0.061
#29 WaterTrmtSup	0.63
#50 FinSrv	1.9
#51 InsrnPnsFSrv	0.3
#56 ArcEngTchSrv	0.00009
#64 AdminBizSrv	1.797
Total intermediate inputs	57.42
Compensation of employees (V1LAB)	5.0
Gross Operating Surplus (V1CAP)	37.6
Other cost tickets (V1OCT)	0.00
Production Tax (V1PTX)	0.00
TOTAL	100%

Source: Unpublished DEPD report and author's calculations

Table 4-17: Foreign direct investment from Japan into manufacturing activities from 2003-2011

B$ million	2003	2004	2005	2006	2007	2008	2009	2010	2011
FDI from Japan	0.1	23.8	32.0	53.2	114.0	171.3	92.4	64.9	159.1

Source: DEPD (2007, 2012a)

The cost and sale structure for this infant industry needed to be worked out based on the arbitrary production or output of B$1 million in 2005, which is small and did not affect the economic structure or IOT significantly. Since we work in terms of percentage rates for the shocks in the model, in order to target the actual numbers in the year where data are available, this simple number, B$1 million, also helps us to calibrate the various cost components accordingly, including capital and labour. Therefore, based on known cost proportions for 2011, B$0.376 million of capital, B$0.05 million of labour and total intermediate costs of B$0.574 million were allocated across the different commodities for methanol and petrochemicals (*MethanolPChm*) industry.

The sourcing of the input commodities was assumed to have the same share structure as that found in V1BAS sale structure. For example, *NaturalGas* is 100 per cent sourced domestically and 97 per cent of *ChemPhrmRbrP* are imported. This resulted in some small numbers in the V1BAS structure for *MethanolPChm* in the rows. To maintain a balanced row dimension of the table, what was used as input for this new industry had to be taken away, at the same amount, from other demanders. Other than the *NaturalGas* commodity, which was taken away from V4BAS (assuming a tiny amount meant for exports is used as intermediate input for the domestic production of methanol), other small amounts of inputs were removed from household consumption (V3BAS) to be used for methanol production. This step ensured that the row of total demand still balanced.

The following step was taken to create a MAKE matrix with *MethanolPChm* where the total output of B$1 million was placed in the main diagonal cell. All the *MethanolPChm* produced was assumed to be exported, so the V4BAS value for *MethanolPChm* also had the value of B$1 million in the BRUGEM database.

Once the row dimension was done, the next step was to create the necessary additional column, with a small amount of investment taken out of the *CokePetroPrd* industry (which was initially B$23.96 million) and placed into the new *MethanolPChm* industry; in 2005 the *ChemPhrmRbrP* had insufficient investment (only B$0.15 million) to spare. Overall investment totals remained unchanged, with just a small change in allocation between *CokePetroPrd* and *MethanolPChm* of B$0.155 million. The initial investment created for *MethanolPChm* was based on the aggregate investment to capital rental ratio of about 0.4, doubling the economy-wide ratio of 0.2 (see Section 4.3.2.10) for other industries, given that it was a new industry with high initial investment and was expected to continue to grow. Another balancing check was carried out to ensure that there were no lost goods; where all commodities produced had to meet demand to be consumed and there was no pure profit where the output value equated to the cost.

The final database created to this point had 74 sectors, as listed in Appendix 4-3.

4.3.2.10 Step 10: Creation of a dynamic database

As explained in Sections 3.4.1 and 3.4.2 of Chapter 3, the rate of growth of capital is linked to investment and how much investment takes place is, in turn, guided by rates of return.

Following the definition of the coefficient *GROSSGRO* in Table 3-1 of Chapter 3, the net growth rate of capital can be defined as:

$$KGR = \frac{I}{K} - D = GROSSGRO - D \qquad (4.5)$$

where I is investment, K is capital and D is the depreciation rate.

The capital rental to capital stock price ratio is given by the coefficient *GROSSRET*. The net rate of return is therefore:

$$ROR = \frac{P_k}{P_I} - D = GROSSRET - D \qquad (4.6)$$

where P_k is the unit rental price of capital , P_I is the unit asset price of capital.

Dividing Equation (4.5) by Equation (4.6), yields:

$$\frac{GROSSGRO}{GROSSRET} = \frac{KGR + D}{ROR + D} = \frac{I}{K} * \frac{P_I}{P_k} = \frac{V2TOT\_I}{V1CAP\_I} \quad (4.7)$$

In the original IOT 2005 provided, the ratio of investment to the cost of capital (Equation (4.7)) was 14 per cent economy-wide. In general, a number closer to 50 per cent would be expected for an economy in a normal year, so the level of investment in Brunei was considerably low.

The consultants who compiled the IOT 2005 used a different formula based on three variables: population growth (g), depreciation rate (d) and interest rate (i) to calculate the investment to capital income ratio:

$$\frac{investment}{capital\ income} = \frac{d + g}{d + i}$$

They argued that with the investment to capital rental ratio of 14 per cent and a depreciation rate (d) of 2 per cent, the implied interest rates (i) from the data were implausibly high at 27 per cent (Lars 2013). They suggested that this was due to some serious accounting issues for the agriculture, mining and construction sectors.

A reasonable investment to capital ratio and the rate of return needed to be worked out. The IOT consultants highlighted that the gross operating surplus reported in the IOT 2005 included all costs of using existing capital goods and all net operating surplus, which also included the income from natural resource endowments for the oil and gas industries (Lars 2013). Therefore, they proceeded to estimate the value of these oil and gas endowments such that the resulting interest rate for the overall economy equalled 12 per cent. With this result, the resource rents account for about 78 per cent of the total operating surplus in mining activities (Lars 2013).

A different approach to the consultants was taken. Given that the overall investment was low compared to the capital rental income, we decided to reduce the value of the capital income (V1CAP) of resource-using industries by moving some to V1LND to reflect the rental of natural resources or land rentals, and to V1OCT for other non-resource using industries. This data treatment was discussed in Section 4.3.2.4. This approach produced a more reasonable investment to capital rental ratio of 20 per cent. Using Equation (4.5), we derived a range of values for KGR and ROR to meet the I/K (investment/capital) target ratio of 20 per cent as per the examples given in Table 4-18.

Table 4-18: Values of capital growth rates and rates of return

Example	KGR	D	$\frac{KGR+D}{ROR+D}=\frac{1}{5}$	ROR
1	3%	6%	(3+6) / (ROR +6)	39%
2	2%	5%	(2+5) / (ROR +5)	30%
3	1.5%	3%	(1.5+3) /(ROR +3)	19.5%

There is no published data of depreciation rates by industry for Brunei, so for estimation, example 3 in Table 4-18 was used with an assumed economy-wide depreciation rate of 3 per cent and a uniform capital growth rate of 1.5 per cent. This achieved a fairly reasonable net rate of return of 19.5 per cent compared to examples 1 and 2 which were too high. We could not target both KGR and ROR at the same time to find out the amount of capital stock. By using these assumed values of KGR and D, the capital stock K by industry could be derived from Equation (4.5) and the ROR from Equation (4.6) for each industry.

The assumed economy-wide depreciation rate was close to that obtained from the Penn World Table (Feenstra et al. 2013) for Brunei for the year 2005, at 3.4 per cent. This suggests that the assumed values of capital growth rate and rate of return were reasonable.

By rearranging Equation (4.5) we obtained (4.8):

$$K = \frac{I}{KGR + D} \tag{4.8}$$

Given the sectoral expansion, *MethanolPChm* was allocated with a different capital growth rate of 3 per cent per annum and maximum gross capital growth rate of 18 per cent, but it had the same depreciation rate of 3 per cent as other industries.

Additional data and parameters were required to run in the dynamic setting. To create the necessary database to run BRUGEM, in the absence of data, several assumptions were made about the parameters, where *DPRC* = 3 per cent, *ALPHA* = 2.0, *RNORMAL* = 20 per cent at gross rate, *QRATIO* = 3 by keeping *GROMAX* = 13.5 per cent (18 per cent for *MethanolPChm*) and *GROTREND* = 4.5 per cent (6 per cent for *MethanolPChm*). Definitions of these parameters and coefficients were presented in Table 3-1 in Section 3.4.1.

4.3.2.11 Step 11: Formal checks on the database

The final step involved the checking of sales aggregates and identities to ensure that the resulting new database was balanced and ready for use in subsequent simulations. The requirements of the IO database are described in Section 4.2.2.

4.3.2.12 Step 12: Formal checks on model validity

A number of tests could be used to check the model validity of the compiled final IO database, as listed in Horridge (2003) and as described below. For these tests, the database was used on the comparative static version of BRUGEM.

1. Nominal homogeneity test

Checks needed to be carried out to test the database with the model theory to uncover any coding or data-handling errors. An effective way was to set up a simulation where the correct answers are known *a priori* (Dixon & Rimmer 2013). One common check for a Johansen-style model is the nominal homogeneity test to check if the model is working as specified. This test is based on the neoclassical theory that economic agents respond to changes in relative prices, but not to changes in the absolute level of prices (Horridge 2003). Therefore, a uniform increase in all prices does not affect any quantity variables. We choose the exchange rate (*phi*), which is an exogenous variable measured in domestic Brunei dollars, as the numeraire. So, if the nominal exchange rate were shocked by 10 per cent, we would expect to see that all nominal variables would increase by 10 per cent, while real variables remained unchanged.

2. Real homogeneity test

Another property of the model is the constant returns to scale in all production activities. This means that if all real exogenous variables (not prices) are shocked by 10 per cent, all the endogenous real variables should also move by 10 per cent, leaving the prices (nominal variables) unchanged. The model closure file was changed accordingly to implement this test. The final IO database created passed both the above real and homogeneity tests with the expected results.

3. Change in GDP should be the same from both sides in a simulation

Further model validity can be tested by running comparative static simulations to check if the results are sensible and make economic sense. The first check was to ensure that the change in real GDP from the income side equated to real GDP from the expenditure side in a simulation result. The results for the two nominal GDP variables, *w0gdpexp* and *w0gdpinc* should also be the same for up to five significant figures, indicating consistency of data.

The final database produced the sensible results under the test simulations with matching GDP numbers from both income and expenditure sides.

4. The updated database should also be balanced

The updated data file produced by the comparative static simulation was, in turn, used as the starting point or the initial solution to run a second simulation with the same shock. The summary file produced was examined to ensure that the data remained balanced.

The updated database is also balanced.

5. Repeat the above tests using a multi-step solution method

The above tests were repeated using a different 2-4-8 Euler extrapolation solution method to detect any more subtle errors, such as a percentage change variable passing through zero or data altered by formulae after being read. Any errors in the update statements could also be detected if any. The results of the repeated tests under multi-step solution indicated no errors.

6. Explain the results

Sometimes there may be errors that cannot be detected by the above tests, such as a wrong sign for the export demand elasticities in the database. Careful examination of the simulation results can help uncover such errors. From the results of the earlier simulations, there appeared to be no such errors.

4.4 Some observations of the IOT 2005

Other issues associated with the Brunei IOT 2005 required closer examination by the IOT compiler. In the IOT 2005, only three commodities had negative taxes indicating some subsidisation enjoyed by producers and households: *AgriAnmlPrd*, *CokePetroPrd* and *ElecGasAircn*. In fact, other goods and services were also subsidised in addition to these three commodities, including education and healthcare. Yet, there were no entries to indicate the existence of subsidies in the IOT 2005 within the household column for consuming these two services. Some of these subsidies were likely to be reflected elsewhere as part of government expenditure and not entirely in the transfers to households. This was because the subsidised items were enjoyed as consumption and not via cash transfers, aside from education allowances received by some households. There was no adjustment to these figures since no further information was available.

As pointed out in a report (DEPD 2011), the first published IOT for base year 2005 showed some differences with the national accounts for 2005. Nominal GDP in the IOT, as shown in Table 4-19 column (3), is 9.7 per cent greater than that stated in the national accounts in column (1). Similarly, the shares in GDP for private and public consumptions are higher in the published IOT than in the national accounts. The investment share and net exports share in the GDP are, however, lower than in the national accounts.

The compilers of the IOT explained that the differences were due to several factors. This included the reflection of additional data obtained from the *Treasury Accounting and Finance Information System*, using information from the first assessment of government capital consumption and first survey results for non-profit organisations, together with a new estimate of owner-occupied housing. This implies that the published IOT 2005 was more accurate than the national accounts figures previously compiled.

Based on the data creation process outlined in Section 4.3.2, the adjusted IOT 2005 was produced, as shown in column (4). There are some differences to the published IOT in column (3), as there are figures to account for, such as the territorial purchases by residents and non-residents and the CIF/FOB adjustment for exports. This led to the slightly different figures in all three numbers for private consumption, exports and imports. In terms of shares to GDP, both private consumption and imports show slightly larger differences compared to the published IOT. The main contributor comes from the adjustment for the large direct purchases of imported goods and services worth

B$341 million by residents, which was added to private consumption and compared to B$64 million purchases by non-residents. The rest of the differences shown in Table 4-19 are due to CIF/FOB adjustments.

Table 4-19: Differences between national accounts and the IO database for 2005

	(1) National accounts 2005 (published)		(2) National accounts 2005 (scaled^)		(3) IOT 2005 (published)		(4) IOT 2005 (adjusted)	
	B$ million	Share (%)	B$ million	Share (%)	B$ million	Share (%)	B$ million	Share (%)
GDP expenditure	15864.0	100	15864.0	100	17395.9	100	17400.0	100
Private consumption	3563.2	22.5	3746.2	23.6	4337.7	24.9	4614.4	26.5
Government consumption	2920.4	18.4	3070.4	19.4	4153.8	23.9	4153.8	23.9
Investment	1803.2	11.4	1895.8	12.0	1847.2	10.6	1848.2	10.6
Exports	11131.6	70.2	11703.2	73.8	11131.5	64.0	11153.4	64.1
Imports	-4329.2	-27.3	-4551.5	-28.7	-4263.0	-24.5	-4589.3	-26.4
Stocks	-	-	-	-	188.7	1.1	219.6	1.3
Stats. discrepancy	774.8	4.9	0	0	-	-	-	-

^Note: scaled by shares of components to total GDP

The resulting MAKE matrix is also larger compared to the published IOT due to the adjustment of re-exports and imported transport margins in domestic industries, as explained in Sections 4.3.2.5 and 4.3.2.7.

Although largely based on the published IOT for 2005, a slightly different IO database for base year 2005 was created to be used in this thesis. This contained the necessary data adjustments and the creation of two new sectors, *Dwelling* and *MethanolPChm,* as described in Sections 4.3.2.8 and 4.3.2.9, to recognise dwelling as a separate industry to the *RealEstSrv* industry and to cater for Brunei's efforts in diversifying into the methanol and petrochemicals industries.

4.5 Conclusions

It is important to create a functional database before carrying out any CGE modelling work. Data quality is certainly important but given the unavailability of some data or uncertain data quality, reasonable assumptions are necessary during the database creation process. This chapter has covered the process of creating the core database in detail, including a step-by-step description of the necessary treatment of the original data in order to create a suitable format for BRUGEM. Significant data work was involved due to a number of issues with the original data. This needed to be addressed and adjusted accordingly to fit into the model theory and to work well in BRUGEM. Given that this work is based on the first official IOT compiled for Brunei, there is scope for further enhancement. With better quality data compiled by the authority in the near future, this database can certainly be updated and improved accordingly.

Chapter 5: Understanding recent economic performance (2005-2011) with an historical simulation

As explained earlier in Chapter 3, dynamic CGE models have the capacity to trace the path for each endogenous variable through time. Depending on the research questions, as described in Section 3.1, a dynamic CGE model like BRUGEM can handle four types of simulations: historical simulation, decomposition simulation, forecast simulation and policy simulation. In this thesis, I use all four simulation techniques to develop a plausible baseline scenario for Brunei for the period 2005 to 2040 to study the impact of a policy shock.

This chapter specifically describes an application of the historical simulation technique to the Brunei economy. The simulation serves two main purposes in this thesis: to update the IOT 2005 database to a more recent year and to estimate in detail the movement of unobservable variables such as technology and preferences through recent history. The estimates for unobservable variables can help us, in turn, to uncover more about the contribution of each of the changes in these exogenous variables to observable variables, such as real GDP and employment, in the past or in the future. In Chapter 6, we discuss these contributions using the decomposition technique.

Section 5.1 briefly describes the different ways in which an IOT can be updated. Sections 5.2 discusses the strategies used in building a baseline for Brunei. Section 5.3 explains the closure method used for an historical simulation. Beginning with a discussion of the data used, Section 5.4 illustrates the actual process of building the baseline for the period 2005-2011. Section 5.5 provides some discussion on the new IOT 2011 created. Section 5.6 contains concluding remarks.

5.1 Updating the IOT for 2005

The data creation process discussed in Chapter 4 resulted in a new IOT for 2005 used as the starting point for calibration and simulation purposes. However, to be of practical use for policy analysis it had to be updated to a more recent year.

In the literature, there are numerous methods for updating an IOT. These include: the final demand method (Khan 1993); transactions proportional to value added method (Khan 1993); the RAS method and its variants (Leontief, Stone, Bacharach cited in Temurshoev et al. 2011); the minimum cross entropy method (Shannon, cited in Ahmed & Preckel 2007); least squares, normalised least squares (Friedlander, Huang et al. cited in Temurshoev et al. 2011); improved weighted squared differences method (Pavia et al. 2009 cited in Termushoev et al. 2011); and the Bayesian method (Lugovoy et al. 2015). The common methods identified by Buetre and Ahmadi-Esfahani (2000) and Ahmed and Preckel (2007) are summarised with brief descriptions in Figure 5-1.

There are limitations to the parameter estimation techniques, such as the entropy method, where the accuracy of the updated IOT is sensitive to major structural shifts in the economy (Ahmed & Preckel 2007). Another method to update an IOT is the Bayesian method, which is similar to the entropy method where inferences are made under uncertainty. By incorporating uncertainties of data into the estimation process, Lugovoy et al. (2015) produced a probabilistic estimate of IO coefficients that are consistent with all available data constraints. These, in turn, can be used as the Bayesian inference to estimate and update the IOT. Lugovoy et al. (2015) suggest that the multidimensional distribution of the estimated parameters has the advantage of being used as the input information for sensitivity analysis. However, they acknowledge that the limitation of this method is that it does not work well with a large number of sectors where the sample matrices obtained can have poor characteristics.

In Figure 5-1, the RAS method remains the most common and popular method but it cannot handle negative matrices. Nevertheless, the generalised RAS developed by Günlük Şenesen & Bates 1988, Junius & Oosterhaven 2003 (both cited in Temurshoev et al. 2011) overcomes the updating of negative matrices. In RAS and similar iterative approaches, each scale factor or multiplier is adjusted to meet one constraint at a time and as the constraints interact, the adjustment process is repeated until all constraints are satisfied and eventually converge. A more complex data structure with more than two dimensions may not work well with these scaling methods.

Horridge (2009) proposed an alternative scaling method to handle more flexible data structures with the use of the ADJUSTER program implemented via GEMPACK software which can handle a large number of sectors. The ADJUSTER program uses a proportional scaling approach to transform each matrix in the original database simultaneously by corresponding multipliers to meet the overall targets, taking into account all balancing constraints. ADJUSTER is more efficient than the typical RAS-like procedure. Another advantage is that the cost and sale shares in the transformed IOT hardly change under the ADJUSTER method (Horridge 2009).

Figure 5-1: The most popular methods for updating IOT

Final demand method	Transactions proportional to value-added method	RAS method	Entropy method
Uses the base year's inter-industry relationship to predict gross output in the future year using the future year's final demand figures.	Inter-industry relationships are made proportional to the value add in the base year and then this proportions matrix is multiplied by the predicted year's diagonal matrix of value added to obtain the transaction matrix of that future year.	Iterative scaling method with rows and columns being multiplied in turn with positive constants until they converge to hit the targets.	Uses information theory where matrices of prior and posterior probabilities are used in the objective function for minimisation, subject to additivity and data consistency constraints, and then solved to obtain the estimated posterior IOT values.

In summary, there are many variants to the main updating methods in the literature outlined in Figure 5-1. For readers who are interested in understanding more about the strengths and weaknesses of the different methods of updating IOT, the paper by Temurshoev et al. (2011) presents some findings about their relative performance.

For this thesis, a simulation technique based on Dixon et al. (2013) from earlier work done by Dixon and McDonald 1993 (cited in Buetre & Ahmandi-Esfahani 2000) was used to update the IOT for Brunei from 2005 to 2011, with the help of BRUGEM. This technique was dubbed the “gold standard" in database updating methods by Horridge (2009) as it requires more effort and data, such as price and quantity targets, and not just values as utilised by the ADJUSTER method. The main advantage of using an existing CGE model to update the IO database is that the structure of the updated database will be preserved and remain consistent with the model theory.

Due to the high costs and hence infrequent publication of the IOT by statistical authorities, the use of a dynamic CGE model to produce more timely or up-to-date IOTs whenever the latest statistics are made available, enables the modeller to have a good approximate IOT to work with. Another benefit of this technique is the revelation of typically unobservable variables, such as changes in productivity, technological progress, taste preference, and export demand shifts. These are revealed during the updating process by the imposition of available macro statistics from national accounts and other sources for the target year.

5.2 Building the baseline

Besides obtaining a more up-to-date IOT for running simulations, the historical simulation can also be used to build a baseline scenario for the period where past data are available. For the purpose of policy analysis, we need to have a baseline or reference scenario for the business-as-usual case where no policy shock is implemented for the years 2005 to 2040. The complete baseline is built in two parts: for the historical period

(2005 to 2011) using an historical simulation; and the forecast period (2012 to 2040) using a forecast simulation as shown in Figure 3-1 in Chapter 3. The forecast simulation is explained in Chapter 7.

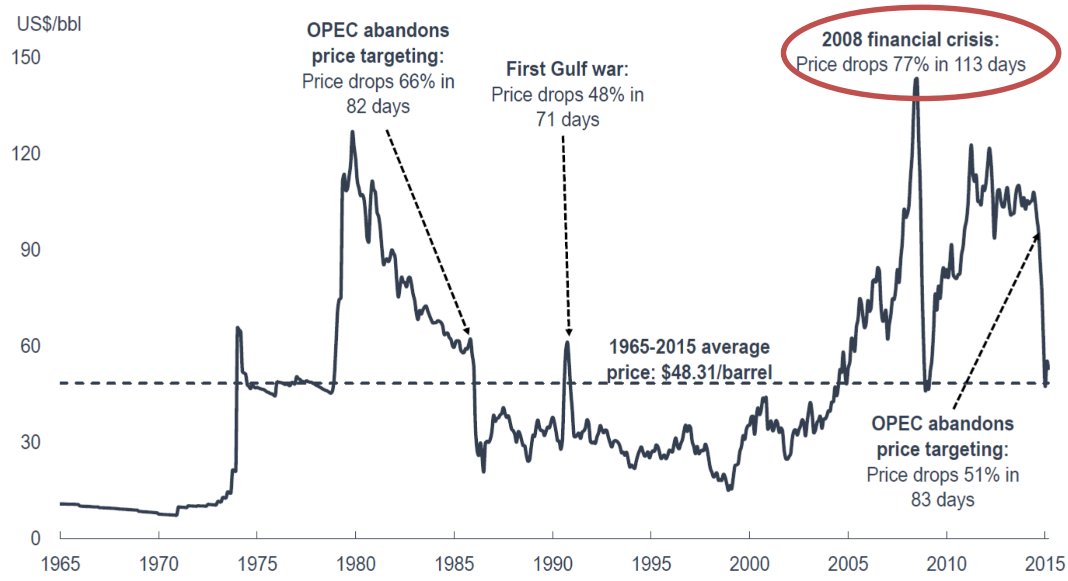
Using a step-by-step approach, the first part of the baseline is developed with the use of BRUGEM, where historical data for the years 2005-2011 are available for the macroeconomic variables of the Brunei economy. As discussed in Chapter 4, this period of study was chosen because 2005 was the year for which the BRUGEM core database was created. The end year, 2011, was chosen for two main reasons. First, some of the key publications such as the *Population and Housing Census 2011* (DOS 2012b), *Household Expenditure Survey 2010-2011* (DOS 2013b*), Economic Census 2011* (DOS 2013a) and macro statistics, were available for that year. Second, the end year occurred after the 2008/2009 global financial crisis.

The historical simulation was implemented to uncover underlying structural changes that could help guide future decisions while examining the factors that could contribute to Brunei's successful diversification. Structural changes, such as technological change, productivity, taste or preference change towards imported goods, are typically not easily measurable or observable. With the help of this CGE modelling technique, through an historical period, these unobservable variables can be identified and quantified. In addition, as already discussed, the historical simulation allowed us to update the IO database to 2011.

There are two strategies for building the historical baseline, either (i) use the yearly observed data, or (ii) use two end points of the historical data (2005 and 2011) and adopt the smooth growth assumption for that period. For this study, we adopted the latter method. The first method using yearly observed data was not suitable since the global financial crisis did affect Brunei's real GDP growth around 2008 and 2009 due to the crash in the crude oil price (see Figure 5-2). As pointed out by Dixon and Rimmer

(2011), if one were to model and reflect a country's recession due to the financial crisis, one would have to modify the standard CGE assumption of full utilisation of the capital for each industry and allow for excess capacity and sticky rental price adjustment. This is more realistic during a depressed period. Since a key focus of this study was to provide a starting point for developing a future baseline, I chose not to impose yearly shocks with the actual data for the historical part of the baseline creation (2005 to 2011); only the average annual shock values of these two end points were taken.

Figure 5-2: Crude oil prices in real 2014 US dollar terms



Source: Commodity Markets Outlook, World Bank (2015a, p. 7)

The justification for using the latter method of average smooth growth assumption was the lack of quality in the published GDP data. In this data, the statistical discrepancy ranges from -10 per cent to +10 per cent share of total GDP across the period (see Table 9-1 in Section 9.2.2.1). The DOS explained that the statistical discrepancy was caused by the different data sources and estimation methods used in the two different approaches (production and expenditure), resulting in different GDP values. The primary focus of this thesis is the future, so yearly variations or movements between 2005 and 2011 are not a key concern and the smooth growth assumption can handle the accumulation relationships adequately in this essentially comparative static setting

(Dixon & Rimmer 2002). Our aim was to establish a reasonable data set for the year 2011 as the starting point for the baseline forecast.

5.3 The historical closure in a stylised "back-of-the-envelope" (BOTE) model

As explained in Section 1.3, a BOTE model is a simplified version of the full dynamic model that can also be used to illustrate the development of an historical closure from the starting point of a "natural" long run closure. The system of equations used in the BOTE model is shown in Figure 5-3.

The BOTE model is useful to lend support to the interpretation of macro results by identifying the main mechanisms and the data items underlying certain results. This makes it an important tool that can be used to explain to policymakers who may not be familiar with the large CGE model. A CGE model integrates detailed structural and dynamic information. Through a stylised BOTE model, useful theoretical insights can be revealed and this can be supported by calculations. BOTE calculations can be used to conduct sensitivity analysis under alternative assumptions and parameter values, as well as be used to check for any errors in model coding and data handling.

The nine-equation BOTE model illustrated in Figure 5-3 has nine equations explaining nine important macro variables. The variables are real GDP and its five expenditure side components (C, I, G, X and M), capital input[20] (K), real wage (RW) and the ratio of export price index over import price index or the terms-of-trade (TOT).

Equation (1) is the GDP identity from the expenditure side, while Equation (2) is the supply side production function as a function of primary factors capital (K), labour (L) and technological change (A). In the notation, technology is expressed as a reciprocal, where a negative value indicates technological improvement and a positive value

[20] Due to the nature of Brunei's economy, where natural resources such as sub-soil oil and gas reserves are important primary factor inputs, this definition of capital encompasses all forms of capital including underlying natural resources that are used for production. Throughout the thesis where land is not explicitly specified in an equation of primary factor inputs, the capital component will be taken to include these natural resources.

technological regression. Equation (3) is the private consumption function, which is a function of average propensity to consume (APC), GDP as a proxy of income and the terms of trade (TOT). TOT determines the number of imports that each export can purchase. Therefore, a rising TOT will provide more purchasing power. Equation (4) represents a choice of fiscal policy, where public spending is fixed as a ratio of private consumption. In the absence of preference change, imports are expected to be positively related to economic activity and the price of domestic goods relative to the imported variety. Therefore, in Equation (5), import volume is a function of income, TOT as well as a taste preference variable (T) for imports. In BRUGEM, commodity exports are inversely related to their foreign currency prices via constant elasticity demand functions. This is reflected in Equation (6), where TOT is a function of exports (shown by movements along the foreign demand schedules) and a shift variable (V), indicating world market conditions or world demand for Brunei’s exports (shifts in foreign demand schedules themselves). Equation (7) shows that investment is correlated to the quantity of capital, rates of return (ROR) and an investment risk premium (Ψ). Equation (8) shows how the capital to labour ratio can be influenced by the relative price of capital and labour driven by several factors, such as the ROR, A, TOT and RW. Equation (9) is a dynamic relationship showing that the aggregate capital stock at time *t* is predetermined by the previous year’s stock and investment.

Using the left-hand panel of Figure 5-3 under the “natural” long run closure, GDP and K can be explained with Equations (2) and (9). Then Equation (7) will determine I. Ignoring the TOT for now, Equation (3) will explain C, Equation (4) explains G, and Equation (5) explains M. With the GDP identity Equation (1), X can then be explained and finally TOT in Equation (6) and RW in Equation (8). In the “natural” long run setting, these nine macro variables (GDP, C, I, G, X, M, K, TOT, RW) are endogenous while the structural variables that drive the economic activities are exogenous.

The structural drivers are technological change (A), employment (L), investor confidence (Ψ), government fiscal policy (Γ), the preference for imported goods (T) and world market conditions for Brunei's exports (V). Using the known outcomes for the nine macro variables from statistical data, the BOTE model can be used to backsolve and find out what the changes are in these structural variables in order to achieve these economic outcomes. On the right-hand side panel of Figure 5-3 are the same BOTE equations, although the split between endogenous and exogenous variables or closure is opposite to that in the left-hand side panel.

This completes the explanation of the BOTE, and the stylised illustration of the natural and historical closures required for the BRUGEM historical modelling. Throughout the remainder of this chapter, as we discuss the BRUGEM results, we will be using the BOTE structure and Figure 5-3 to assist in understanding the modelled outcomes.

Figure 5-3: Natural and historical closures of the BOTE model

"Natural" long run closure	Historical closure
(1) GDP=C+I+G+X−M	(1) **GDP**=**C**+I+**G**+**X**−**M**
(2) GDP=(1/**A**)*F(K,**L**)	(2) **GDP**=(1/A)*F(K,**L**)
(3) C=B(**APC**,GDP,TOT)	(3) **C**= B(APC,**GDP**,**TOT**)
(4) C/G=**Γ**	(4) **C**/**G**=Γ
(5) M=H(GDP,TOT,**T**)	(5) **M**=H(**GDP**,**TOT**,T)
(6) TOT = J(X,**V**)	(6) **TOT** = J(**X**,V)
(7) I=Z(K, **ROR**, **Ψ**)	(7) I = Z(K, **ROR**,Ψ)
(8) K/**L**=N(**ROR**,**A**,TOT,RW)	(8) K/**L**=N(**ROR**,A,**TOT**,RW)
(9) K_t=f($\mathbf{K}_{t-1}$, $\mathbf{I}_{t-1}$)	(9) K_t=f($\mathbf{K}_{t-1}$, $\mathbf{I}_{t-1}$)

***Bold** = exogenous variables, the rest are endogenous*

Key:					
GDP	gross domestic product	K	capital stock	V	demand-shift variable
C	private consumption	TOT	terms of trade	Γ	ratio of private to public spending
I	investment	L	labour	Ψ	investment risk premium
G	government expenditure	ROR	rate of return	T	import preference variable
X	exports	A	primary-factor augmenting technology	t, t-1	current, past time period
M	imports	APC	average propensity to consume	RW	consumer real wage

5.4 Historical simulation

In the historical simulation, the observed variables are exogenous and shocked with the calculated shock values to ensure that after updating, the main macroeconomic data in the updated database are consistent with the statistical data in 2011.

Starting with the natural closure of the model, a stylised account of which is given in Figure 5-3, the historical closure is developed in nine steps. Each step consists of the previous step plus a small number of swaps between endogenous and exogenous variables, maintaining a valid closure throughout. By Step 9, the full historical closure is implemented. Results are then compared over subsequent successive historical simulations showing the effects of the additional data introduced at each step. The steps undertaken are described in Section 5.4.2, followed by results for the period 2005 to 2011 as shown in Table 5-5.

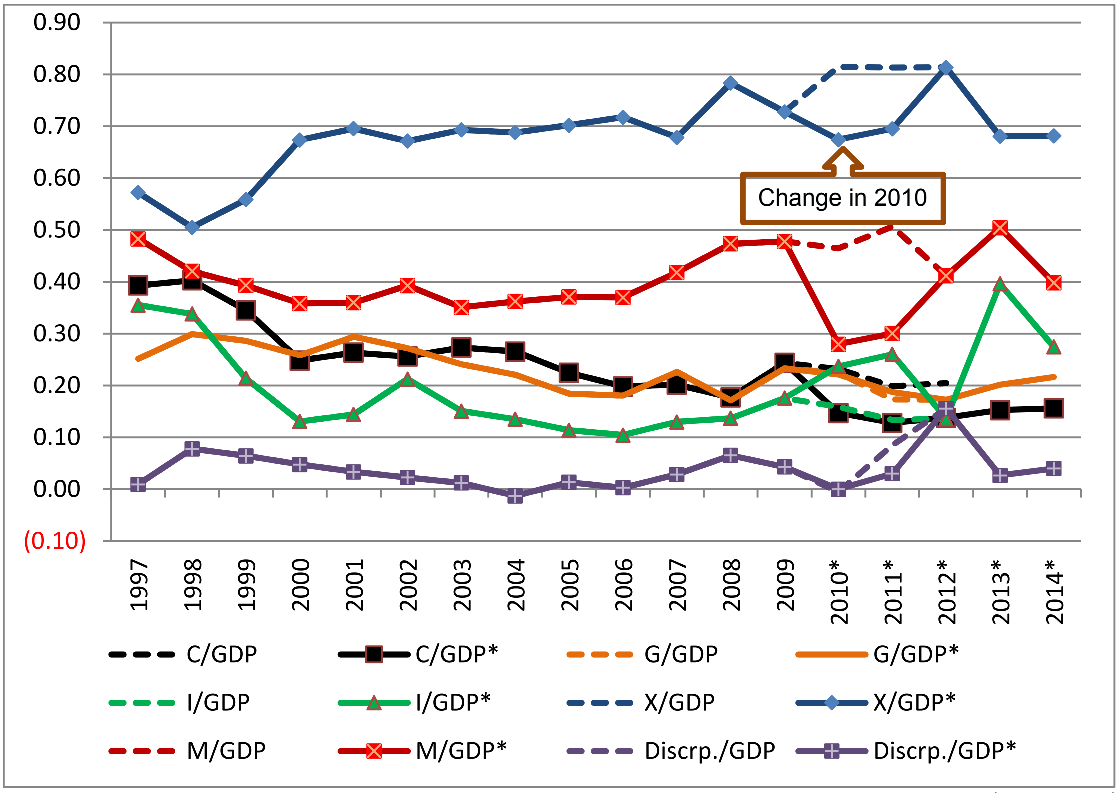
5.4.1 Data for historical simulation

The available macroeconomic data for the period 2005-2011 for the demand side of the economy are for private and public consumption, capital formation, exports and imports based on the GDP figures published in the *Brunei Darussalam Statistical Yearbook* (DOS 2007, 2011, 2012a). Also available are demographic statistics for population growth, labour force estimates and the number of households from statistical yearbooks and the *Preliminary Report on Population and Housing Census* (DOS 2012b). Some other data obtained are the export volumes and export prices for the oil and gas sectors; CIF value of exports for methanol; and export and import price indices for computation of TOT changes.

In March 2015, the DOS released a new set of national accounts retrospectively for the years 2010 to 2013, using 2010 as a new base year. This set of data takes into consideration the estimates of GDP through the IOT 2010 and, for the first time, produces GDP estimates based on all three approaches, namely the production approach, the income approach and the expenditure approach (DOS 2014c). By the time of this new data release, major data work for this thesis had already been completed and efforts to harmonise with the new data failed because of the large changes in the shares of the expenditure components to total GDP, as well as the large statistical discrepancy (see column (11) in Table 5-7).

The latest GDP data for 2011, using the new base year, shows a statistical discrepancy of 3 per cent of GDP, which is much larger in absolute terms than the -0.7 per cent of GDP (Table 5-1) indicated in the older report with a base year of 2000. The ratios of expenditure components to GDP also show significant changes (indicated by the solid lines in Figure 5-4) due to changes in the methodology used for estimating investment figures and the new data incorporations according to the DOS (2014c). For consistency in the base year used for producing the original published IOT 2005, we decided to use the earlier GDP numbers to calculate target data for 2011.

Figure 5-4: Changes in the ratios of expenditure components to GDP with new base year 2010



*Note: The dotted lines are previous base year 2000 series and solid lines indicates new base year 2010 (marked by *)*

The real macroeconomic aggregates shown in Table 5-1 are based on year 2000 prices in Brunei dollars. The investment percentage change is not imposed in the historical simulation and is left as an endogenous variable to be determined by the model. There are yearly statistical discrepancies in the published GDP figures (DOS 2007, 2012a, 2014a) for both nominal and real GDP, and these are attributed to the difference between the measurement by expenditure approach and production approach. This issue on statistical discrepancy is discussed further in Section 9.2.2.1. In Table 9-1, the statistical discrepancy for real GDP (+10 per cent of total GDP) is much larger in share than the nominal GDP (-1 per cent) for the year 2011. This discrepancy is, however, smaller for real GDP in terms of share (+1 per cent) compared to nominal GDP (+5 per cent) for the year 2005. Due to the large and volatile statistical discrepancy across the years (swinging from positive to negative), this posed some challenges in computing the appropriate real shocks when the source of discrepancy is unclear.

For the purpose of this thesis, the statistical discrepancy in the two years 2005 and 2011 were addressed by scaling the expenditure aggregates accordingly based on their shares of the total real GDP. The average annual shock was then computed to run the simulation to achieve a new IO database for the year 2011. The annual growth rate was calculated based on Formula (5.1), where *g* is the average annual growth rate, *t* is the time period, V_t is the value at the end of period and V_{t-1} is the value at the beginning of time period.

$$g = \left(\frac{V_t}{V_{t-1}} \right)^{\frac{1}{t}} - 1 \qquad (5.1)$$

Table 5-1: Macroeconomic data for historical simulation

	Real yearly growth rate* (per cent)	Share in nominal GDP 2005 (per cent)	Share in nominal GDP 2011 (per cent)
GDP expenditure	1.12	100	100
Private consumption	4.72	22.5	19.5
Government expenditure	7.04	18.4	17.0
Investment^	7.88	11.4	13.1
Exports	-0.18	70.2	79.7
Imports	8.08	-27.3	-28.6
Stats. discrepancy		4.9	-0.7
Labour force	2.08		
Population growth	1.56		

**adjusted for statistical discrepancy in national accounts*
^ this shock value is not imposed in the historical simulation

For the sectoral shocks, data were available on the export values of the key commodities, such as oil and gas, as well as methanol and garments. Given the importance of oil and gas in the economy, the shocks affecting these two key exports needed to be included. The data for the physical quantities and export values for oil and gas were available, which enabled the average annual shock values to be calculated for the period 2005-2011.

The creation of the new *MethanolPChm* sector was explained in Section 4.3.2.9 and its growth was simulated via positive shocks implemented annually to achieve its existing state as of 2011. This was achieved by building up investment and capital stock to yield output or production for exports. Since there were no data available on the investment in the methanol sector for the period 2005-2011, it was assumed to grow at the same rate as production and exports (since methanol is only produced for export).

On the other hand, the garment (*TextilesAppL*) sector was shrinking and dwindled in exports as mentioned earlier in Section 4.2.3). This industry also faced challenges in competing with neighbouring countries that had lower labour costs than Brunei. The decline in the garment sector was simulated by implementing negative shocks to both export values and investment, as investors would no longer be keen to make further investment. Similar to the case of methanol, where investment data were not available, it was assumed that the investment in the garments sector declined at the same rate as exports declined.

5.4.1.1 Expanding the *MethanolPChm* sector

As part of the simulation, we started to “grow” this infant methanol industry in 2005 (the year the JV agreement was signed) using the cost structure presented in Table 4-16. Assuming all methanol output is destined for export, the total output was first calibrated at a small number, say B$1 million in 2005, to avoid a sudden large percentage growth from 2009 to 2010 in the aggregated “Chemicals” exports (DOS 2012a), as shown in Table 5-2. The mismatch of sudden large output in one year and the pattern of investment and associated costs over the years could cause problems in the modelling. A gradual growth starting from 2005 to achieve the same outcome in 2010-2011 for the methanol industry is needed.

Table 5-2: Chemicals exports from 2005-2012

B$ million	2005	2006	2007	2008	2009	2010	2011	2012
Chemicals (incl. methanol)	4.76	4.27	3.7	6.29	6.42	134.43	243.45	311.60

Source: DOS (2007, 2012a)

Total chemicals (includes methanol) exports increased from $4.76 million in 2005 to $243.45 million in 2011 (see Table 5-2) due to a surge in methanol exports. Given this sudden expansion of the *MethanolPChm* sector, I needed to work out the appropriate closure to simulate this large growth of nearly 148 per cent per annum to reflect the export revenue of $231.8 million in 2011 (see Table 4-15 in Chapter 4). Another version of the same BOTE model equations, as shown in Figure 5-3 but in percentage change form (Figure 5-5), was used to explain the mechanism for this sector-specific expansion.

BOTE Equation (2) of Figure 5-3 could be further broken down into Equation (1) of Figure 5-5, using the percentage form Equation (3.132) as outlined in Section 3.3.11 but specific to the *MethanolPChm* sector. Equations (2) and (3) of Figure 5-5 were derived from Equations (3.16), (3.17) and (3.19) outlined in Section 3.3.1.3. Equation (4) on export demand was derived from Equation (3.70) of Section 3.3.4.

The methanol-specific BOTE shown in Figure 5-5 was used to determine the closure for the main model. Subscripts to indicate the *MethanolPChm* industry were dropped for convenience and brevity of notation and all variables were expressed in percentage changes. The target was to have data to reflect the 2011 situation when the methanol industry was in full operation. The BOTE model in Figure 5-5 illustrates how this could be achieved.

In this stylised BOTE model, two columns indicate two different closures. The typical closure is shown on the left-hand side while historical closure is on the right-hand side. The differences between these two closures lie in the choice of exogenous variables, as indicated by bold letters.

For both closures, assuming land is negligible, Equation (1) is the output equation based on the two key primary factor inputs of capital and labour, followed by the input Equation (2), where quantity of labour used in the production will be a negative function of the primary factor substitution elasticity and relative price of labour to the price of capital, and vice-versa. If the price of labour rises relative to the price of capital, there will be a switch to more use of the capital instead. Equation (3) shows the price equation for methanol and Equation (4) is the demand for output, which is a function of the price of methanol and the export shifter (remember that all of the methanol production is exported).

Figure 5-5: Industry-specific BOTE model for the *MethanolPChm* sector

"Natural" long run closure	Historical closure
(1) $y = S_L l + S_K \boldsymbol{k} - \boldsymbol{a}$	(1) $y = S_L l + S_K k - \boldsymbol{a}$
(2) $l - \boldsymbol{k} = -\sigma(\boldsymbol{p_L} - p_K)$	(2) $l - k = -\sigma(\boldsymbol{p_L} - p_K)$
(3) $p = S_L \boldsymbol{p_L} + S_K P_K + \boldsymbol{a}$	(3) $p = S_L \boldsymbol{p_L} + S_K P_K + \boldsymbol{a}$
(4) $y = -\varepsilon(p - \boldsymbol{\phi}) + \boldsymbol{f4}$	$y = -\varepsilon(p - \boldsymbol{\phi}) + f4$

***Bold** = exogenous variables, the rest are endogenous*

<u>Key (lowercase indicates percentage change):</u>

y	output	S_L, S_K	shares of labour and capital respectively, adding up to one
l	labour	σ	primary factor substitution elasticity, >0
k	capital	ε	export demand elasticity, >0
p_L	price of labour	ϕ	exchange rate (B$/foreign currency)
p_K	price of capital	$f4$	an export shifter
p	price of methanol output	a	technical change

In the "natural" long run closure, the above four equations have four unknowns: y, l, p_k and p. In the short run, we know the price of labour is given by the economy-wide nominal wage, initial capital is given, and the export shifter is an exogenous variable. The exchange rate and technical change variables are also exogenous.

The shock to the *MethanolPChm* sector is very large. If capital at the industry level is fixed and technological change is ignored, then the only mechanism for achieving a large increase in output is via an even larger (percentage) change in employment of labour. To achieve this, the output gain for methanol would require an unrealistically large increase in employment. A way to share the gain between labour and capital was devised and is discussed below.

Another rule was needed to help the model solve. Since all the methanol produced was exported, Equation (5.2) defines the value of exports w in terms of the output y and export price p.

$$w = y + p \qquad (5.2)$$

In order to implement what is known from historical data about the output y and the export value w, I needed to have a rule about the growth rates of labour and capital. So, if the ratio of labour to capital ratio is defined as r, then:

$$r = l - k \qquad (5.3)$$

Then a rule can be created to determine the labour to capital ratio by setting r as exogenous. This implies that the rate of labour would grow at the same rate as the capital stock or $l = k$ for methanol. This would address the issue of an unrealistically large increase in employment, as discussed earlier. Therefore, with Equation (5.2) included in the BOTE for the *MethanolPChm* sector, we could create a closure with swaps that make *w* endogenous and *r* exogenous, *f4* endogenous and *k* exogenous. We could then determine y, l, p_k and p under historical simulation, which were the four unknowns in the historical closure in the right-hand panel of Figure 5-5. This time, with r exogenous in Equation (5.3), p_K could be determined from Equation (2) and value of p could be obtained from Equation (3) and with p known, we could get the value of y from Equation (5.2), since w is known. By substituting $l = k$ into Equation (1) and combining the fact that $S_L + S_K = 1$, we get $y = l$. Since we know $y = l = k$, the remaining variables could be solved, including $f4$.

The swaps explained earlier took care of the demand side shock. An appropriate closure was also needed for the supply side, via the capital stock and investment variables. With the increase in output, there had to be an increase in both capital stock and investment for *MethanolPChm*. I needed to shock only one variable. In this case, due to earlier assumption about the exogenous labour to capital growth rates ratio, the capital accumulation equation needed to be switched off to let the capital stock grow at the same rate as the labour growth rate in Equation (5.3). Since the initial wage rate was tied to other industries, the *MethanolPChm* industry required its own wage rate and this was achieved by activating the industry-specific wage shifter. This would enable sectoral growth. At the same time, the nominal investment was targeted to grow at the same rate as the export revenue. An investment relationship needed to be deactivated, which is the planned investment to capital ratio, to allow the shock to investment affecting the capital stock. Using the same formula (5.1) in Section 5.4.1, it was calculated that the methanol sector had expanded by an average of 147.85 per cent per annum in terms of investment and exports for the period 2005 to 2011.

We had now included all the necessary nominal shocks in percentage change to the export revenue, aggregated payment to labour and investment to the *MethanolPChm* sector in order to achieve the observed sectoral growth in 2011.

5.4.1.2 Shrinking the *TextilesAppL* sector

To reflect a dwindling garment (*TextilesAppL*) industry, similar shocks to those applied to the *MethanolPChm* needed to be implemented, except that they were all negative shocks. The *TextilesAppL* sector was also given its own price of labour to allow this sector to slowly fall away. The export value had fallen from $306.3 million in 2005 to $7.6 million in 2011, which represents a decline of about 46 per cent per annum. Due to the lack of data, the nominal investment was assumed to decline by the same rate of 46 per cent per annum as investors shied away from a sector that had less optimistic prospects.

5.4.2 Step-wise simulation

Although the entire simulation could be carried out in one single step by incorporating all shocks together, a step-wise approach was utilised with calculated shocks implemented in the following sequence (as shown in Box 5-1 with the variables explained in Table 5-3). The rationale for this approach was that it allowed us to check the results and to attribute results to different drivers. It also allowed us to understand the impact of that particular implemented shock. Running the simulation step-by-step enables the modeller to identify the sources of error should the simulation fail at any particular step.

Giesecke (2004), Dixon and Rimmer (2003), and Tran and Giesecke (2008) have outlined the theories and steps undertaken to conduct historical simulation in a stepwise manner. A similar methodology was used in conducting this simulation.

Box 5-1: The calculated shock values implemented to the selected variables

Step 1: *q* =1.56, *delUnity* =1, *employ_i* =2.08
Step 2: *x0gdpexp* =1.12, *w0gdpexp* = 3.18
Step 3: *x3tot* =4.72
Step 4: x*5tot* =7.04
Step 5: *x0cif_c* = 8.08
Step 6: x*4tot* = -0.18, *x4("CrudePetrol)* = -3.58, *x4("NaturalGas")* =0.13,
x1cap("CrudePetrol") =-3.48, *x1cap("NaturalGas")* =0.24, *w4("CrudePetrol")* =3.33,
w4("NaturalGas") =13.61;
Step 7: *p0toft* =9.75
Step 8: *w4("MethanolPChm")* =147.85 , *w2tot("MethanolPChm")* =147.85,
w1lab_o("MethanolPChm") =147.85
Step 9: *w4("TextilesAppL")* =-46.0, *w2tot("TextilesAppL")* =-46.0,
w1lab_o("TextilesAppL") =-46.0

A summary of the variables to be shocked and the corresponding structural variables used in the swaps is shown in Table 5-3. Since we included nominal shocks for the period under study (2005 to 2011), the chosen numeraire was the GDP price index, *p0gdpexp* instead of the exchange rate, *phi.* The GDP price index provides a yardstick for measurements in price changes due to the shocks. The stepwise simulation is explained with the help of the BOTE model shown in Figure 5-3. The results of the historical simulation are shown in Table 5-4.

Table 5-3: Summary of exogenised variables and swaps for the historical simulation

Step	Known outcomes to implement (exogenous in historical	Corresponding structural variables (endogenous in historical closure)
1	Population, aggregate employment, homotopy variable	Overall wage shifter
2	Real GDP, nominal GDP	Overall primary-factor augmenting technological change, GDP price index
3	Real private consumption	Average propensity to consume out of GDP
4	Real public consumption	Overall government demand shifter
5	Total imports	Investment slack variable
6	Total exports and sectoral changes in oil and gas export values and volumes, capital stock in oil and gas sectors	General export shifter, quantity shifter in oil and gas export demands, all-factor augmenting tech change and capital accumulation shifter in both *CrudePetrol* and *NaturalGas* sectors
7	Terms-of-trade	Import preference variable
8	Nominal investment, export value and nominal payment to labour for *MethanolPChm* sector	Export shifter and long run investment shifter in *MethanolPChm* sector
9	Nominal investment export value and nominal payment to labour for *TextilesAppL sector*	Export shifter and long run investment shifter in *TextilesAppL* sector

Table 5-4: Results from the step-by-step simulation

Group	No.	Description	Step 1	Step2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	
		Shocks implemented	*population, employment, momentum*	*GDP*	*private consumption*	*public consumption*	*imports*	*exports incl oil & gas shocks*	*terms of trade*	*methanol sectoral shocks*	*garment sectoral shocks*	**Annual Ave. (%)**
		Variables	*Percentage changes between 2005 and 2011*									
Observed economic variables	1	Real GDP	8.7	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	**1.12**
	2	Real investment	14.6	12.8	8.1	-27.5	-13.9	46.8	74.4	75.8	76.6	9.95
	3	Real private consumption	7.8	5.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	**4.72**
	4	Real public consumption	0.0	0.0	0.0	50.4	50.4	50.4	50.4	50.4	50.4	**7.04**
	5	Real imports	6.8	5.5	17.0	46.5	59.4	59.4	59.4	59.4	59.4	**8.08**
	6	Real exports	9.8	7.8	2.4	-15.9	-21.8	-1.1	-1.1	-1.1	-1.1	**-0.18**
	7	Oil export volume	7.3	5.4	3.6	-5.1	-10.3	-19.6	-19.6	-19.6	-19.6	**-3.58**
	8	Gas export volume	7.5	5.6	3.4	-6.4	-12.1	0.8	0.8	0.8	0.8	**0.13**
	9	Oil export price (B$)	-0.6	25.9	10.8	-56.2	-64.5	51.4	51.4	51.4	51.4	7.16
	10	Gas export price (B$)	-1.0	25.6	10.7	-56.0	-64.2	113.4	113.4	113.4	113.4	13.46
	11	Value of oil exports	6.6	32.7	14.8	-58.4	-68.1	21.7	21.7	21.7	21.7	**3.33**
	12	Value of gas exports	6.4	32.5	14.4	-58.8	-68.5	115.0	115.0	115.0	115.0	**13.61**
	13	Methanol export volume	23.9	21.4	15.9	-28.5	-43.5	-74.6	-21.9	1379	1375	127.48
	14	Methanol export price	-4.9	20.9	7.4	-52.8	-59.8	-7.3	-2.9	68.3	68.7	9.11
	15	Value of methanol exports	17.9	46.8	24.5	-66.3	-77.3	-76.4	-24.1	2308	2308	**147.85**
	16	Garments export volume	64.2	56.6	-23.6	-98.8	-99.5	126.2	244.8	226.4	-95.9	-41.32
	17	Garments export price	-9.0	16.2	17.0	0.5	-5.5	-45.9	-28.0	-29.7	-38.9	-7.89
	18	Value of garment exports	49.4	81.9	-10.6	-98.8	-99.5	22.5	148.7	129.9	-97.5	**-46.00**
	19	Import prices CIF	0.0	26.5	11.2	-56.4	-64.8	-52.9	-10.7	-10.7	-10.7	-1.86
	20	Number of households	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	**1.56**
	21	Aggregate employment	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	**2.08**
		Other macroeconomic indicators										
	22	GDP price deflator	-11.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	2.04
	23	Exchange rate (B$/$world)	0.0	26.5	11.2	-56.4	-64.8	-52.9	-10.7	-10.7	-10.7	-1.86
	24	Aggregate capital stock	10.1	9.9	9.6	10.4	25.8	-6.6	-6.8	-6.3	-6.1	-1.04
	25	Real devaluation	13.5	12.1	-1.5	-61.4	-68.8	-58.2	-20.9	-20.9	-20.9	-3.83
	26	Terms of trade	-1.3	-1.1	-0.2	3.3	4.4	220.8	74.8	74.8	74.8	9.75
		Price ratios										
	27	Labour to CPI (real wage)	-29.8	-28.8	-20.7	162.5	239.8	36.7	-7.6	-8.6	-4.4	-0.74
	28	Capital to investment (rate of return)	6.4	4.2	-0.6	-34.6	-53.0	194.3	112.5	112.9	115.0	13.61
	29	Cost of capital	3.5	3.1	2.4	-33.3	-48.8	18.0	17.8	17.7	16.8	2.62
	30	Investment price to GNE	4.1	3.6	-0.9	-17.3	-16.0	4.6	7.5	6.9	5.3	0.87
	31	Consumption price to GNE	8.1	7.6	7.4	-33.2	-41.2	-3.2	5.8	5.9	4.4	0.72
	32	Govt consum. price to GNE	-12.1	-11.0	-8.8	41.5	51.6	1.1	-10.3	-10.0	-7.9	-1.36
	33	GDP to primary factors	0.2	1.8	2.8	-0.4	4.0	-13.9	-11.1	-10.8	-11.0	-1.93
Corresponding Structural variables	34	Overall wage shifter	-29.8	-28.8	-20.7	162.5	239.8	36.7	-7.6	-8.7	-4.3	-0.74
	35	All-factor augmenting tech change (non-mining)	0.0	1.6	1.8	2.2	8.0	-26.0	-26.4	-25.1	-24.7	-4.62
	36	All-factor augmenting tech change in oil	0.0	1.6	1.8	2.2	8.0	8.3	9.3	9.9	9.1	1.46
	37	All-factor augmenting tech change in gas	0.0	1.6	1.8	2.2	8.0	1.1	1.0	-0.5	-0.6	-0.10
	38	Contribution of technological to GDP	0.0	-1.4	-1.5	-2.0	-7.0	6.0	5.5	5.2	5.4	0.90
	39	Average propensity to consume out of GDP	0.0	0.0	33.8	2.1	-9.4	-47.0	-24.4	-24.3	-25.4	-4.78
	40	Overall govt demand shifter	0.0	0.0	0.0	50.4	50.4	50.4	50.4	50.4	50.4	7.04
	41	Investment slack variable	0.0	0.0	0.0	0.0	-59.6	109.8	-35.9	-34.7	-34.1	-6.71
	42	General exports shifter	0.0	0.0	0.0	0.0	0.0	361.5	12.0	-6.6	33.8	4.97
	43	Quantity shifter in oil export	0.0	0.0	0.0	0.0	0.0	1000	2124	2536	1183	61.32
	44	Quantity shifter in gas	0.0	0.0	0.0	0.0	0.0	8669	4157	4960	2437	323.02
	45	Capital stock in oil sector	10.5	10.2	8.6	3.4	7.0	-19.1	-19.1	-19.1	-19.1	-3.48
	46	Capital stock in gas sector	10.5	10.3	8.5	2.9	5.6	1.4	1.4	1.4	1.4	0.24
	47	Investment in oil	18.7	16.2	1.7	-55.0	-51.9	39.1	67.7	66.7	68.6	9.10
	48	Investment in gas	19.4	16.9	0.6	-60.6	-59.7	127.1	173.6	175.8	177.7	18.56
	49	Quantity shifter in methanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2124	1075	220.12
	50	Capital stock in methanol	20.9	20.6	17.8	8.2	9.7	1.9	9.2	1035	1038	117.14
	51	Investment in methanol	29.1	26.6	6.7	-76.5	-79.6	-99.2	-93.7	3052	3126	160.66
	52	Quantity shifter in garment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-99.7	-62.36
	53	Capital stock in garment	14.6	13.9	5.6	-2.8	-3.6	16.3	25.7	24.7	-90.5	-32.44
	54	Investment in garment	56.6	50.2	-22.2	-73.1	-63.1	74.6	219.6	185.4	-96.6	-43.13
	55	Uniform imp/dom twist	0.0	0.0	0.0	0.0	0.0	0.0	699.0	1096.	510.4	35.19

5.4.2.1 Step 1: Population, aggregate employment and homotopy variable

Since there was no specific population variable in the model, the variables for the number of households (*q*) was used as a proxy. The population variable, aggregate employment variable and the homotopy (*delUnity*) variable, which activates the capital accumulation equation in the model, were shocked in Step 1.

The shock to the number of households or population only has an impact on the composition of household expenditure. A comparative-static version of the BRUGEM was used for the historical simulation. In this version of the model, there is no explicit link between households and labour supply. For this reason, aggregate employment was also shocked in this step based on the published data as it was expected that with positive population growth, more people would participate in the labour force and subsequently be employed. Aggregate nominal household expenditure in the model was determined by aggregate nominal income and the average propensity to consume, and the number of households had no direct impact. However, the allocation of the household budget by commodity was determined by the LES for which there was a subsistence component of consumption on each commodity, as explained in Section 3.3.3. The subsistence component was fixed per household, so an increase in the number of households leads to an increase in subsistence expenditure and, for a given budget, a decrease in supernumerary expenditure.

In the absence of technological change but with a small positive growth in employment, real GDP (row 1) grew by 8.7 per cent in six years (see Table 5-5) as the economy expanded from the supply side in Equation (2) of the BOTE model (see Figure 5-3). Without any change in technology and the ROR, the capital-to-labour ratio was expected to remain unchanged according to Equation (8) of the right-hand side column of Figure 5-3. However, the capital-to-labour ratio decreased as the rate of increase in aggregate employment (row 21) exceeded growth in the capital stock (row 24). This was accompanied by a fall in the overall real wage (row 34), which induces employers to accommodate the national shift in factor proportions.

As expected, an increase in employment with no corresponding shift in export demand schedules leads the economy to produce more than it consumes domestically. The result is real devaluation of the currency (row 25) to accommodate an increase in net exports.

Given the large real devaluation, the result for net exports was rather small. Imports (row 5) were expected to increase as real GDP grew via Equation (5), which was also brought about by the increase in private consumption via Equation (3). Exports from Brunei consist almost entirely of oil and gas, both heavily capital-intensive activities with limited scope to take advantage of the increased employment. Indeed, despite the real currency devaluation by 13.5 per cent, the export prices of both oil and gas only fell by around 0.6 per cent and 1.0 per cent respectively, effectively limiting the fall in the TOT to 1.3 per cent.

Nominal aggregate household expenditure was linked to nominal income, but aggregate real household expenditure increased (row 3) by slightly less than GDP. This reflects the slight decrease in the TOT (row 26), making imports, an important component of household expenditure, more expensive. We found a greater increase in the investment expenditure (row 2) than in the GDP. This reflects not only the modest increase in household expenditure and net exports, but also the exogeneity of government expenditure (row 4) in this step.

5.4.2.2 Step 2: Gross domestic product (GDP)

The observed real GDP growth was in fact lower than the result shown in Step 1 (row 1). To implement the available real GDP growth data in Step 2, we endogenised all primary-factor augmenting technological change uniformly over all industries. Based on historical data, the nominal GDP growth was shocked by 1.12 per cent per annum and, with this growth rate being lower than the employment growth of 2.08 per cent, regressive technological change of 1.6 per cent in aggregate (row 35) was observed over the period 2005 to 2011. The link between the decline in productivity and the growth rate of the economy is represented in equation (2) of Figure 5-3.

The GDP growth rates in both real and nominal terms were included in the shocks since nominal GDP data was available.

With employment and GDP in place, the effect of the declining real wage was slightly dampened since the increase in employment in Step 1 did not produce as much economic output as expected, due to reduced productivity (row 35). Regressive technological change affects the capital-to-labour ratio and subsequently the real wage, which was expected to fall via Equation (8) leading to the decline in capital stock (row 24) as well as investment (row 2). The decrease in real GDP growth rate was also reflected in the fall in private consumption (row 3) via Equation (3). With fewer economic activities, imports would fall (row 5) via Equation (5) in Figure 5-3, as would exports (row 6) via Equation (1), leading to an improvement in TOT (row 26).

5.4.2.3 Step 3: Real private consumption

The fall in private consumption anticipated in Step 2 was not observed in the historical data. In Step 3, private consumption was given a positive shock of 4.72 per cent per annum. In order to implement this shock, we endogenised the ratio of nominal consumption to nominal GDP (*f3tot*) or the average propensity to consume out of GDP.

Since aggregate private consumption grows much faster than GDP and hence income, the average propensity to consume increased by 33.8 per cent (row 39) from 2005 to 2011. With no change in GDP at this step, compared to Step 2, the increase in private consumption crowds out other types of expenditure, leading to a reduction in investment (row 2) and net exports (rows 5 and 6) and real appreciation of the currency (row 25).

As the share of imports in household consumption was high relative to the share of imports elsewhere, we might have expected a large increase in imports as a result of the increase in consumption as a share of GDP. In this context, the increase in imports appeared quite modest, well below the increase in consumption. For a given value of net exports, further expansion of imports required further expansion of exports. The major export sectors, oil and gas, had limited capacity for expansion due to their use of natural resources (a fixed factor).

Recalling the national accounting identity, $X - M = S - I$, the expected negative effect on investment (I) of a reduction in domestic saving (S) was dampened by the fall in net exports (X-M). The large fall in the value of net exports accounted for almost all of the reduction in savings, and investment continued to increase by more than GDP, albeit at a lesser rate than Step 2.

5.4.2.4 Step 4: Real public consumption

Using the statistical data on government expenditure, the aggregate public consumption variable was shocked by 7.04 per cent per annum in Step 4. Since there was no change of GDP from the supply side and the private consumption was fixed by the previous step, the increase in public consumption must lead to the decrease in other expenditure items on the demand side to maintain the GDP identity. There was a marked decline in both the investment (row 2) and net exports (rows 5 and 6).

Public consumption was the most labour intensive component of expenditure on GDP, accounting for 24 per cent of GDP, over 50 per cent of employment and just 5 per cent of capital in the base year IOT 2005. The large increase in expenditure on public administration, education and health services drew a further 20 per cent of the labour force into these activities, leading to a reduction in labour and output in almost all other activities. This was facilitated by a very large increase in the real wage (row 27).

The increase in consumption introduced in Step 4 now had to be satisfied by a large increase in imports (row 5). The large increase in domestic expenditure, far in excess of the increase in GDP, was accompanied by a significant loss in competitiveness, shown in the large real appreciation of the currency (row 25).

An interesting feature of the result in Step 4 was that although aggregate investment declined (row 2), there was a slight increase in aggregate capital stock (row 24). This was a compositional effect. These aggregates were value-weighted sums of investment and capital stock by industry. In each industry, the increase in investment was commensurate with the increase in capital stock. However, in the three government-related industries (public administration, education and health services), the labour to capital ratio was so large and rapidly increasing that the increase in the rate of return on capital far exceeded the national average. As a result, the value-weights of capital stock for these industries increased, while the value-weights of investment (reflecting the cost of capital creation) did not change. Thus, the increase in capital stock in these government-related industries was afforded more importance in the calculation of aggregate capital stock, while the increase in investment was outweighed in the calculation of aggregate investment by the decline in investment in all other industries.

This step had the largest impact on the distribution of expenditure in the economy, taking the value share of government expenditure in GDP from 24 per cent in the base year 2005 to 51 per cent in 2011. The increase was attributed to both volume and price increases. Government is a major employer and the labour constraint (with growth of just 2.08 per cent per annum compared with government expenditure growth of 7.04 per cent per annum) had a significant impact on wages and therefore costs. With consumption already fixed in Step 3, the expansion in the government sector had a deleterious effect on the other sectors of the economy, that is, net exports and investment.

5.4.2.5 Step 5: Total imports

In Step 5, the import volume variable was exogenised and a change of 8.08 per cent per annum was introduced. At this stage, GDP and all its expenditure side components, except exports and investment, were exogenous. The variable chosen to accommodate imports was the investment slack variable (*invslack*), effectively introducing a uniform shift in the required rate of return schedule over all industries.

The increase in imports was accompanied by a decrease in import prices. This was directly reflected in further real currency appreciation (row 25), which had a negative impact on exports (row 6). The increase in imports also released some domestic capacity, dampening the decline in investment. However, the main effect of this was to shift even more workers into the government sector. The compositional effect described in Step 4 was further exacerbated by another large increase in aggregate capital stocks (row 24) accompanied by only a small increase in investment (row 2).

The decline in import prices led to further improvement in TOT (row 26), which in turn increased the capital-to-labour ratio via Equation (8) and hence the real wage (row 27). With the aggregate employment fixed in Step 1, the aggregate capital stock had to increase (row 24) as did investment (row 2) via Equation (7).

5.4.2.6 Step 6: Total exports and changes to sectoral oil and gas export volumes and prices

The large decline in total exports volume at Step 5 was not observed from the data published by the DOS. Therefore, the overall export volume variable was imposed by shocking it with the observed negative value of 0.18 per cent per annum. This was accommodated by endogenising the general shifter on export demand curves (a uniform shift for all commodities). A large shift in the export demand curve (row 42) facilitated this increase in exports due to favourable changes in foreign preference for Brunei goods.

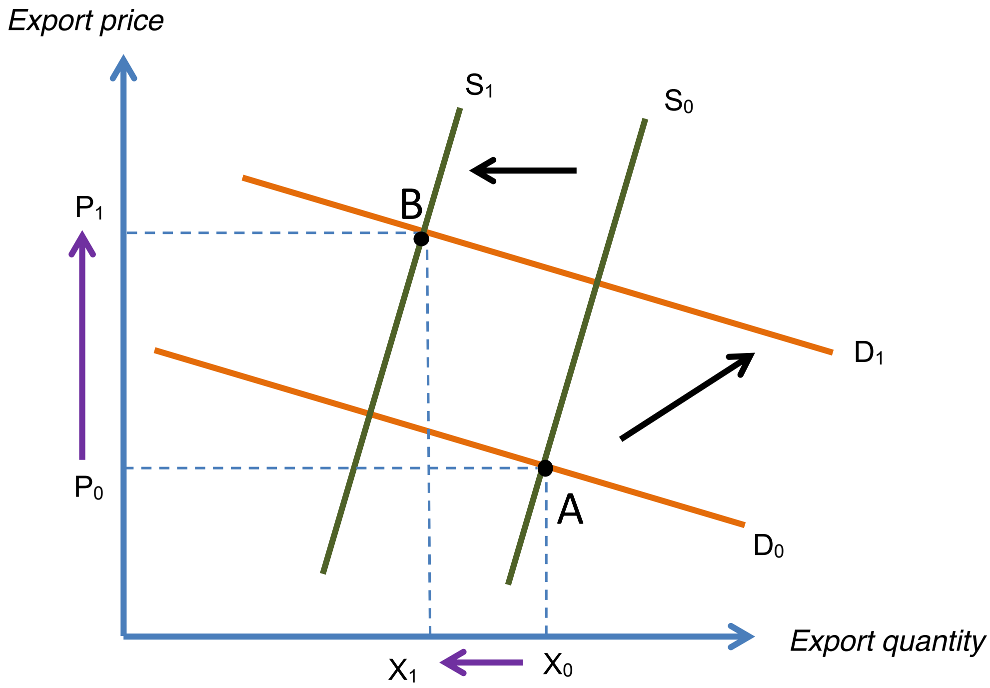
Given the dominance of oil and gas in Brunei's economy, data on the exports of these sectors were introduced, together with the aggregate export shock. For the period under study, the DOS was able to provide data on the changes in export volume in physical units and export values in local currency for oil and gas. The volumes of oil and gas exports were shocked by -3.58 per cent and 0.13 per cent per annum respectively by endogenising the positions of the export demand schedules for the two commodities (rows 43 and 44). To reflect both the demand and supply conditions of the hydrocarbons market, the positive shocks of 3.33 per cent and 13.61 per cent per annum were also included for the oil and gas export values respectively (rows 11 and 12). These, in turn, allowed the model to solve for the export prices of oil and gas in local currency. Observations of quantity and export values of oil and gas were accommodated by endogenising the positions of both the supply and demand schedules. The shift in the demand schedule was achieved simply by endogenising the position of the export demand schedule. The shift in the supply schedule was more complex.

The increase in investment in the oil and gas sectors from Step 5 (rows 47 and 48) could not be verified without data availability. However, increased investment could be implied from the information gathered from Royal Dutch Shell plc, which showed that the capital expenditure (CAPEX) in the Asia-Pacific region grew by an average of 31.2 per cent per annum between 2005 and 2012 (Table 5-3) and projects were undertaken during that period. Without adequate financial data specific to Brunei, it was assumed that there was some capital growth resulting from these investments, given that Brunei is one of Royal Dutch Shell plc's heartlands (see Box 5-2). We exogenised the capital growth paths of the oil and gas sectors and allowed the capital stocks to grow in line with the activity level of these industries over the period (rows 45 and 46). The oil sector was given a negative capital growth in line with its declining exports while the gas sector was given a small positive growth since gas exports grew during the period 2005-2011. The remaining movement required in the supply schedule was accommodated via endogenous technological change.

The export markets for oil and gas are illustrated respectively in the following Figures 5-6 and 5-7. For the oil market, although the price of crude oil had increased, the export volume declined. This is illustrated in Figure 5-6, where the supply curve has shifted to the left from S_0 to S_1. This indicates a fall in the supply of crude oil for exports, despite an upward shift of demand schedule from D_0 to D_1 shown in row 43, resulting in a higher price P_1. The decline in supply occurred due to the fall in capital stocks (row 45) and the adverse all primary-factor augmenting technological change (row 36) for the oil sector.

In this step, the nominal export value for crude oil has increased (see Box 5-1) despite the decline in the physical quantity of export due to the increase in export price moving from P_0 to P_1. With the imposed known values, the resulting movement is at point B for the demand and supply of crude oil export in Figure 5-6.

Figure 5-6: Changes to demand and supply for exports of oil



Box 5-2: BSP and capital expenditure

Brunei Shell Petroleum Sdn Bhd (BSP) is a JV between Royal Dutch Shell plc and the Brunei government. The firm does not provide data on CAPEX for Brunei. Therefore, for this study we used estimates from elsewhere. Using the annual reports and investor handbooks for the period 2006-2012 of the Royal Dutch Shell plc (being the oldest and most dominant multi-national oil and gas operator in Brunei), I managed to gather some information about the trend of CAPEX in the Asia-Pacific region, including Brunei, as presented in Table 5-4. Although the year 2005 appears to show one of the higher growth periods of CAPEX investment in Asia-Pacific, the Brunei IOT 2005 does not reflect such high investment in the oil and gas sector (less than B$270 million in total) implying that more CAPEX might have gone to other countries instead, such as Australia and Malaysia.

Brunei is regarded as one of Royal Dutch Shell plc's core countries, with the available infrastructure, expertise and growth potential for continuous investment (Royal Dutch Shell plc 2009). Although the oil fields outputs were declining, with new technology, BSP was able to reinvigorate the Champion West field (undeveloped for over 25 years) to yield new oil production in 2006 (Royal Dutch Shell plc 2008). BSP also continued to invest and develop several projects in 2007 (Royal Dutch Shell plc 2007) and had exploration discoveries in 2006, 2008 and 2010 (Royal Dutch Shell plc 2006, 2008, 2010) with some new productions in 2009 (Royal Dutch Shell plc 2009). For the period under study (2005 to 2011), the timing of production from the point of investment may have varied significantly since mining was a cyclical activity, it could be assumed that BSP continued to invest in Brunei's upstream oil and gas activities during that period, although at an undisclosed amount of CAPEX.

Table 5-5: Capital expenditure of oil and gas activities and exploration of Royal Dutch Shell plc's subsidiaries in Asia-Pacific

US$ million	2004	2005*	2006	2007	2008	2009	2010	2011	2012
Asia Pacific	536	1,070	1,264	1,326	1,720	2,010	2,794	5,683	7,037
% growth	-7.4	99.6	18.1	4.9	29.7	16.9	39.0	103.4	23.8

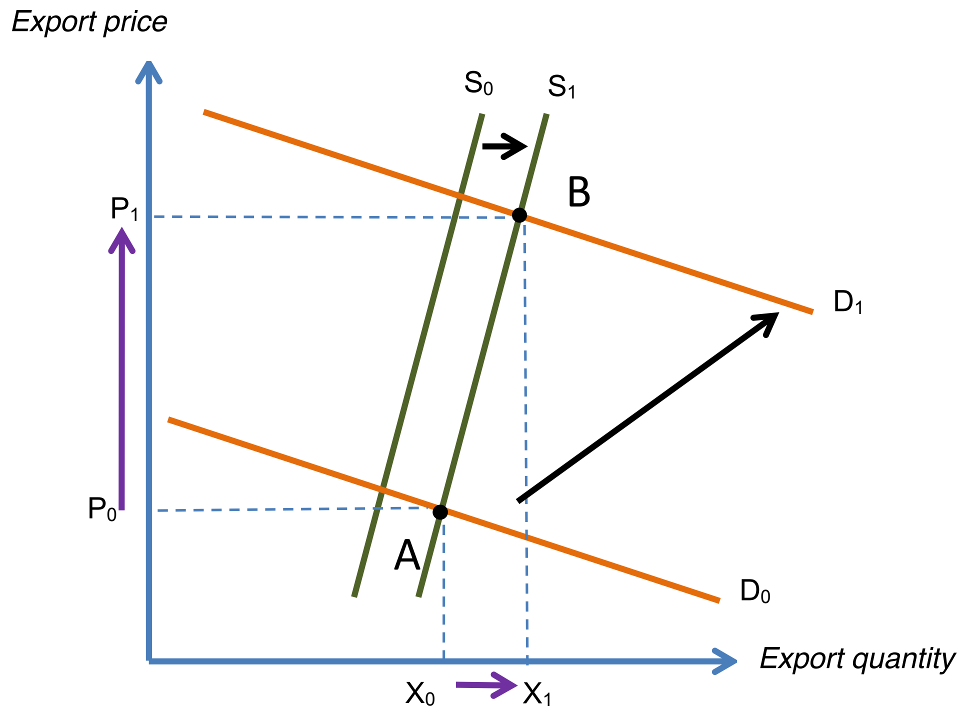
** Increased exploration activities in Australia, Malaysia and Brunei for Asia-Pacific region.*

Source: Various Royal Dutch Shell plc reports

Figure 5-7 shows the supply and demand of natural gas for exports. Both the price and volume of exports increased for natural gas, but the increase in volume was relatively small compared with the large observed increase in gas export price. Therefore, we see that the supply curve shifted right wards from S_0 to S_1, with a very large shift in the demand schedule from D_0 to D_1 shown in row 44. The large increase in nominal export value of natural gas is brought about by the increase in export price from P_0 to P_1. The demand and supply shifts resulting in the movement from point A to point B to achieve the known outcomes.

The level of capital stocks was previously high due to earlier high investment in the gas sector but it had subsequently declined (row 46).

Figure 5-7: Changes to demand and supply for exports of natural gas



An implication of this approach was that the productivity decline observed in the earlier steps was reduced and redistributed. Consequently, we found significantly large productivity gains in the non-mining sectors (row 35), a smaller decline in the oil sector (row 36) and some improvement in the gas sector (row 37) compared to previous step. However, our estimate of the average productivity decline had also reduced. This is because we had now estimated a much smaller capital stock in oil and gas (rows 45 and 46), and the oil and gas sectors accounted for around 70 per cent of Brunei's total capital stock. Less capital stock for a given set of shocks to GDP and employment implies a productivity gain, and the productivity loss observed up to Step 5 was now reversed (row 35). The contribution of technological change to GDP was now 6 per cent (row 38) for the entire period 2005-2011. The decline in the capital to labour ratio also had the impact of dampening the increase in real wages (row 27).

An interesting implication of the shocks was that the effective increase in exports (as compared to the results in the previous step) was accompanied by a large increase in aggregate investment (row 2). With GDP and its other expenditure components tied down, the increase in both of the remaining components of expenditure was counterintuitive. This was a compositional effect. The change in real GDP was the value-weighted sum of the changes in its real expenditure components. The very large increase in prices for oil and gas (rows 9 and 10) meant that the value share of exports in GDP increased from just 18.9 per cent in the final year of Step 5 to 76.7 per cent in the final year of Step 6. Furthermore, the decrease in real wages in this step reduced the price of activities related to government expenditure, which tended to be labour-intensive. These factors led to a downward adjustment in the value share of government expenditure from 57.3 per cent after Step 5 to just 17.0 per cent. This had the effect of reducing the share-weighted contribution to GDP of the very large increase in real government expenditure, as imposed in Step 5.

5.4.2.7 Step 7: Terms of trade (TOT)

In Step 7, the TOT change was targeted based on historical data. The TOT variable was exogenised by swapping with the variable determining local preferences for imported varieties. The shock to the TOT was 9.75 per cent per annum and this represented a downward adjustment from the TOT result in Step 6. To achieve this required an increase in preferences for imported varieties that devalued the currency (row 25) and reduced real wage (row 27).

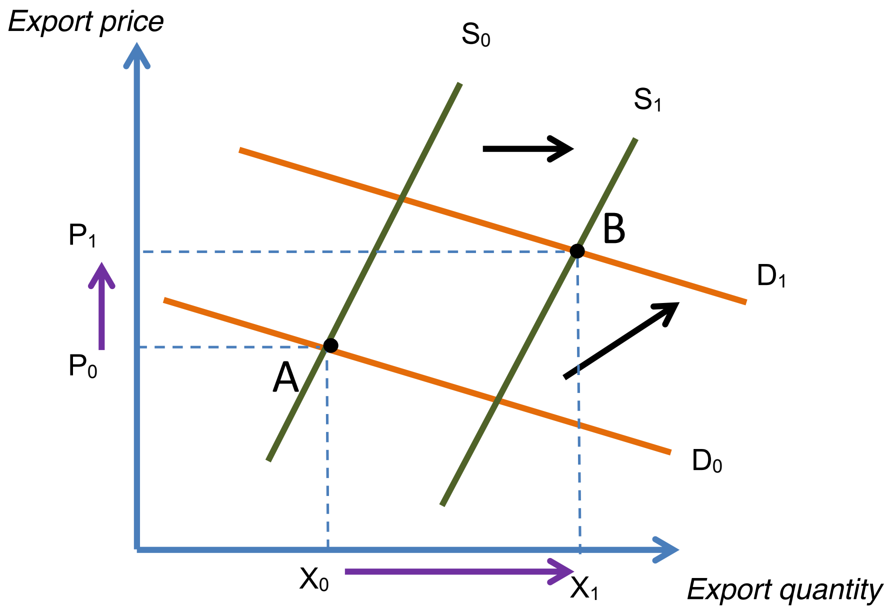
The increase in investment from Step 6 to Step 7 was again counterintuitive, when we consider that none of the real macro expenditure aggregates or GDP had changed. Again, the explanation lay in the value shares. The devaluation made imports more expensive when measured in domestic currency, increasing their negative share in GDP as compared to Step 6. The reduction in real wages decreased the value share of government expenditure. Reductions in these shares reduced the contribution of the large real increases in imports and government expenditure to GDP, thereby allocating a larger residual to investment.

5.4.2.8 Step 8: Methanol exports

In this step, the value of exports of methanol was targeted based on available data by endogenising the export quantity shifter (row 49) related to the methanol export demand curve. On the supply side, nominal investment and wage payments for the *MethanolPChm* industry were exogenised and shocked to match the growth in export value (row 15) while keeping the labour to capital ratio unchanged. The swaps were explained in Section 5.4.1.1 and results can be explained with the help of the methanol-specific BOTE model in Figure 5-5.

The positive shock to the value of methanol export was reflected in the large increase in its export volume (row 13) and export price (row 14), driven by Equation (4) in Figure 5-5. A large shift in the export demand curve was expected from the same Equation (4) that shifted the demand schedule upwards from D_0 to D_1. This was complemented by large positive percentage changes on the supply side variables shown in the rightward shift of supply curve from S_0 to S_1, driven by investment and capital stock in the *MethanolPChm* industry (rows 50 and 51). The increase in demand was matched by an increase in price from P_0 to P_1 (row 14), as seen in Figure 5-8 taking the methanol sector from point A to point B in terms of demand and supply.

Figure 5-8: Changes to demand and supply for exports of methanol

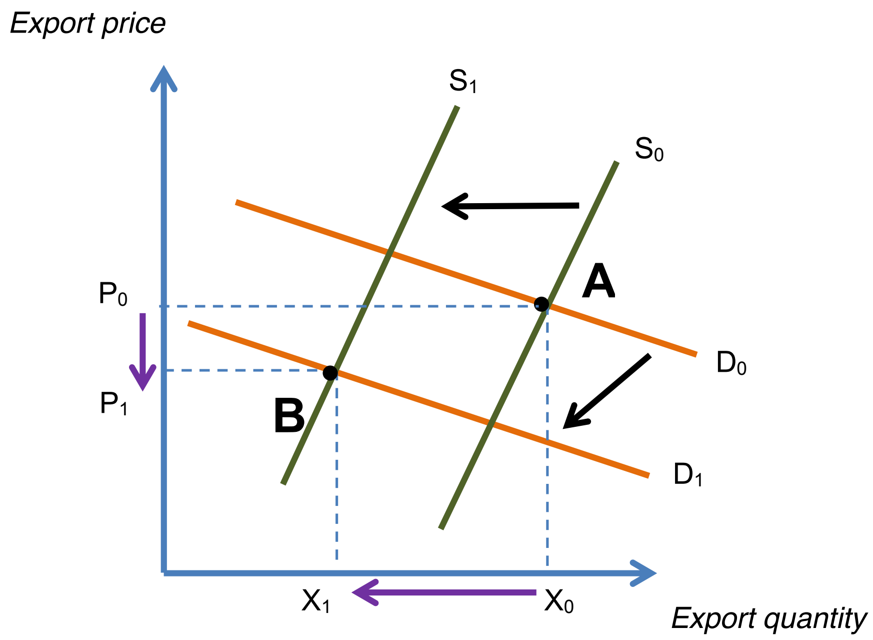


5.4.2.9 Step 9: Garment exports

To incorporate the necessary shocks to simulate a dwindling *TextilesAppL* sector, we targeted its declined value of export in 2011 (row 18) by swapping it with the export quantity shifter (row 52). Similar to the approach in Step 8, nominal investment and wage payments in the *TextilesAppL* sector were also given a negative shock, resulting in the fall in export volume and prices (rows 16 and 17). The decline in supplies was reflected in the fall of nominal investment and capital stocks in the garments sector (rows 53 and 54). The demand for Brunei garments fell and supply was cut back (moved from S_0 to S_1) with the fall in export prices (row 17), as illustrated in Figure 5-9 where supply curve and demand schedule from D_0 to D_1 moved leftwards and downwards respectively.

The aggregate capital stock however increased slightly (row 24) and with the aggregate employment fixed, the real wage increased (row 27).

Figure 5-9: Changes to demand and supply for exports in the garment sector



Step 9 was the final step to incorporate what we knew in order to achieve the known macroeconomic outcomes for the year 2011 through step-by-step historical simulation.

5.4.3 Summary findings of the historical simulation

With all observed major macro aggregates in place, we had a complete picture of economic growth in Brunei from 2005 to 2011, as shown in Table 5-5. The difference between the columns shows the effects of introducing the new shock in the subsequent step. Step 9 shows the results of the entire historical simulation when observed data were incorporated. The final column shows the average annual percentage change and the figures in bold indicate the average annual shocked values.

The price ratios (rows 30 to 32) show that the investment price index increased the most, followed by the consumer price index relative to the overall GNE price index. On average, both indices increased by 0.87 per cent and 0.72 per cent per annum respectively. On the other hand, the government price index declined by an average of 1.36 per cent annually over the period 2005-2011, indicating the price of government services had fallen. The price ratio shown in row 33 indicates that the ratio of GDP price index to the primary factors cost index had declined during the period 2005-2011. This price ratio is a function of indirect taxes and this trend indicated either falling indirect tax rates or increasing subsidy rates.

The final result for investment in 2011 (9.95 per cent per annum), which remained endogenous throughout the simulation, did not accord very closely with official statistics in the national accounts (7.88 per cent per annum). There were several factors contributing to this. The first was the statistical discrepancy. In the computation of the real percentage change shocks for GDP and its components, the statistical discrepancy was distributed across the major expenditure-side aggregates. This changed the growth rate of investment (the residual) in a way that would cause it to deviate from its published growth rate. There is no information on the likely source of the discrepancy and it is not within the scope of this thesis to track the movement of the statistical discrepancy over the period 2005-2011. However, a short discussion about statistical discrepancy is provided in Section 9.2.2.1.

There were also differences between the expenditure aggregate shares in GDP in the national accounts and the IO database for the base year 2005, as pointed out in a report by the DEPD (2011). Although the published IOT for 2005 had a lower investment to GDP ratio than the national accounts, this was accepted since better sources of information were utilised (DEPD 2011) as the starting point to build a more detailed and updated database for 2011. Investment or the capital formation growth rate was determined as a residual by putting in the growth rates of other expenditure aggregates and GDP in this historical simulation to derive IOT 2011.

We observed that over the historical period, the Brunei economy was characterised by low real economic growth, low capital growth, low investment as a share of GDP, strong growth in public consumption and imports, and declining exports. There was minimal change in the average real wage rate. There were real currency appreciation and improvement in the TOT and technological change during the period under study. The technological improvement was particularly large in the non-mining area of the economy, with a 24.7 per cent overall increase or annual average of 4.62 per cent (see the last column of row 35 in Table 5-5). The oil and gas sectors showed some degree of technological regression (row 36) and near-zero technological improvement (row 37) respectively.

Over the period 2005-2011, Brunei's real GDP growth was less than population growth, indicating a fall in real GDP per capita.

5.5 Creation of the input-output database for 2011

Through implementation of observed statistical data into the historical simulation, we obtained an updated IO database for 2011. This provided the starting point for forecast and policy simulations. Given the statistical discrepancy and the differences between national accounts and the IO database for 2005, as explained in Section 4.4 in Chapter 4, it is expected the base data created for 2011 to also differ from the national accounts, as illustrated in Table 5-6 below. When comparing the IO data and the national accounts, there were some differences ranging from +3.0 per cent for export share to -2.3 per cent in investment share in GDP for 2011 (column 10). However, these differences were relatively small compared to those for 2005 (column 9).

As mentioned in Section 5.4.1, DOS compiled another set of national accounts based on a different base year. In Table 5-6, the IOT 2011 is derived using the same base year as IOT 2005 by targeting nominal GDP figure of B$20,996 million (column (7)). This is compared with the total GDP figure of B$23,302 million (column 11) in Table 5-7 derived with a different base year 2010 (DOS 2014c). The greatest difference came from the investment and export shares of the GDP, comparing columns 8 and 12 in Table 5-7.

Table 5-6: Differences between national accounts and the input output database for 2011

	National accounts 2005 (scaled)		National accounts 2011 (scaled)		% change in share
	(1)	(2)	(3)	(4)	
	B$ million	Share (%)	B$ million	Share (%)	
GDP expenditure	15864.0	100	20996.3	100	-
Private consumption	3746.2	23.6	4061.6	19.3	-4.3
Government consumption	3070.4	19.4	3542.8	16.9	-2.5
Investment	1895.8	12.0	2732.0	13.0	+1.0
Exports	11703.2	73.8	16614.3	79.1	+5.3
Imports	-4551.5	-28.7	-5954.4	-28.4	-0.3
Stocks	-	-	-	-	-

	IOT 2005		IOT 2011 (updated via simulation)		% change in share
	(5)	(6)	(7)	(8)	
	B$ million	Share (%)	B$ million	Share (%)	
GDP expenditure	17400.0	100	20996.6	100	-
Private consumption	4614.4	26.5	4152.3	19.8	-6.7
Government consumption	4153.8	23.9	3760.4	17.9	-6.0
Investment	1848.2	10.6	2247.9	10.7	+0.1
Exports	11153.4	64.1	17227.7	82.1	+18.0
Imports	-4589.3	-26.4	-6535.7	-31.1	+4.7
Stocks	219.6	1.3	144.0	0.6	-0.7

Differences in terms of shares of GDP comparing IOT & National Accounts by year		
	(9)	(10)
	2005 ***column (6)-(2)***	**2011** ***column (8)-(4)***
Private consumption	+2.9 per cent	+0.5 per cent
Government consumption	+4.5 per cent	+1.0 per cent
Investment	-1.4 per cent	-2.3 per cent
Exports	-9.7 per cent	+3.0 per cent
Imports	-2.3 per cent	+2.7 per cent
Stocks	+1.3 per cent	0.6 per cent

Table 5-7: Comparison of computed IOT 2011 and national accounts 2011 for different base year

	IOT 2011 (computed)		National accounts 2011 (based on new base year 2010)		% differences
	(7)	(8)	(11)	(12)	(8)-(12)
	B$ million	Share (%)	B$ million	Share (%)	
GDP expenditure	20996.6	100	23302.6	100	-
Private consumption	4152.3	19.8	2976.5	12.8	+7.0
Government consumption	3760.4	17.9	4364.3	18.7	-0.8
Investment	2247.9	10.7	6064.3	26.0	-15.3
Exports	17227.7	82.1	16196.8	69.5	+12.6
Imports	-6535.7	-31.1	-6998.1	-30.0	+1.1
Stocks	144.0	0.6	-	-	+0.6
Stat. discrepancy	-	-	698.8	3.0	-3.0

The DOS report (2014c) stated that the figures in current prices for the new base year were significantly different due to the incorporation of the latest surveys and data, the use of SUT 2010 and improved compilation methods. The household consumption share had also fallen after incorporating the *Household Expenditure Survey 2010-2011* and the share of exports declined with the revised balance of payment statistics. The report explained that in the new series, the expenditures on mineral exploration and research and development were covered and capitalised as gross fixed capital formation (DOS 2014c), based on 1993/2008 SNA recommendations (UN 1993, 2009). This resulted in much higher investment shares of 24 per cent, 26 per cent, 33 per cent and 40 per cent of the total GDP corresponding to the years 2010 to 2013. This implies that there was some omission of the gross capital formation figure in the previous series, especially pertaining to machinery and equipment figures. This is shown in Table 5-9, taking the year 2011 to illustrate this point (line 3). Based on anecdotal evidence, this sudden high growth of gross capital formation did not seem to coincide with any significant investment in capital goods in Brunei during the period 2010 to 2013 in terms of any large infrastructure building or oil and gas capital expenditure.

Without sectoral investment data, the source of this increase cannot be attributed affirmatively to any particular industry. To examine the plausibility of this large investment growth and the associated growth or decline rates of other components of the GDP, we ran simulations using the growth rates presented in Table 5-8 to extract the underlying unobserved structural variables targeting the new GDP 2013 figures. The model had difficulty locating the appropriate endogenous shifts to accommodate these growth rates of exogenous variables to arrive at the targeted GDP numbers.

Table 5-8: Annual growth rate for 2005 to 2013 using new base year GDP figures

	IOT 2005	Nominal GDP 2013 (new base year and scaled to remove stat. discrp.)	Annual growth rate for 2005-2013 (%)
Private consumption	4614.4	3449.5	-3.57
Government consumption	4153.8	4557.3	1.17
Investment	1848.2	8948.4	21.79
Exports	11153.4	15378.4	4.1
Imports	-4589.3	-9694.6	9.8
Stocks	219.6	0	n/a
Total GDP	17400.0	22638.9	3.34

Therefore, for the purpose of this thesis, the IOT 2011 data computed using previous series was used for the baseline forecast instead of the new series of national accounts.

Table 5-9: Changes in the estimates of GDP 2011 by expenditure from the national accounts

At current prices Value (B$ million)	New series	Previous series	Difference
1. Household consumption	2976.5	4088.9	-27%
2. Government expenditure	4364.3	3566.6	22%
3. Gross capital formation	6064.3	2750.4	120%
- Gross fixed capital formation	6038.6	2749.7	120%
- Construction	2427.2	1666	46%
- Machinery and equipment	3611.4	1083.7	233%
- Change in inventories	25.7	0.7	3571%
4. Exports of goods and services	16196.8	16726	-3%
- Exports of goods	15566.9	15206.5	2%
- Exports of services	629.9	1519.5	-59%
5. Less imports of goods and services	6998.1	5994.5	17%
- Imports of goods	4711.6	3697.8	27%
- Imports of services	2286.6	2296.7	0%
6. Statistical discrepancy	698.8	-141.1	-595%
Total GDP for 2011	23302.6	20996.3	11%

5.6 Conclusions and policy implications

Using a step-by-step approach for an historical simulation, this study has uncovered several interesting characteristics within the Brunei economy for the period 2005 to 2011. The step-wise implementation of the shocks enabled us to attribute structural shifts in the economy to specific causes. Some examples of these attributions are: high wage growth attributed mainly to growth in the government sector; an overall high productivity with different attributions to the mining and non-mining sectors; and a strong taste preference for imported varieties. The final result for the TOT was in fact lower than it would have been based on the increases in oil and gas prices.

The real GDP growth for the period 2005-2011 was, on average, 1.12 per cent per annum. Compared with the population growth of 2.08 per cent per annum, this indicated a decline in real GDP per capita. If this trend were sustained, the standard of living would be expected to fall.

The fall in productivity in the mining sector was partly due to the high commodity prices during that period, as mining firms were encouraged to exploit more marginal deposits despite these being more difficult or costly to extract. As observed by Conolly and Gustafsson (2013), due to the time lag between investment and production, any measured productivity in the mining industry tends to be lower. The high productivity growth in the non-mining sectors in Brunei was attributed to an increase in non-mining output relative to their capital stock, especially with the large increase in methanol output. Although the trade-exposed non-mining sector faced increased input costs and significant real appreciation of currency, they might also have had more incentives to improve productivity (Ekholm et al. cited in Conolly & Gustafsson 2013) to manage their costs.

These observations are very similar to the observations of Australia's performance during the resource boom, where the surge in the TOT supported growth in activity despite the low productivity growth for the last ten years or so. Garnaut (2013) described the Australian mining boom in three phrases, starting with a surge in TOT, followed by an investment boom and finally an expansion in export volumes accompanied by declines in TOT. In Australia, the TOT grew very rapidly by about 90 per cent between 2001 and 2012 (Bullen et al. cited in Dixon et al. 2014) and, according to Garnaut (2013), fell by 18 per cent from its 2011 peak. Brunei experienced a large TOT effect of nearly 75 per cent for the period 2005 to 2011 with an increased investment during the same period of about 77 per cent.

For the period 2005-2011, the large public spending in Brunei had adverse impacts on the economy with the reduction in labour and outputs in almost all other sectors. With the limited labour force pool, a high real wage was also observed with an increase in government expenditure. This posed challenges to the private sector as it faced the effect of crowding out and increased input costs. Overall, combined with the effects of other factors such as strong TOT, currency appreciation and declining consumer price index, the growth rate of the real wage declined during 2005-2011. The strong TOT effect made the country richer in terms of purchasing power. As a result private consumption growth exceeded real GDP growth.

With the large increase in domestic absorption relative to the low growth of GDP, the Brunei economy experienced a small decrease in the real wage (an average of 0.74 per cent per annum), an increased domestic price level observed from the GDP price deflator (averaging 2.04 per cent per annum) and real appreciation of the currency (an average of 3.83 per cent per annum). The strong preference for imports contributed to the high import growth and declining exports. The real appreciation of Brunei's currency impeded its economy's competitiveness in exports as a downward export trend was observed over the period under study. With the dwindling oil and gas reserves and therefore limited future hydrocarbon exports, it is important to address the issue of competitiveness in non-oil and gas sector exports.

The government is managing the production of its oil and gas in order to extend productive life in existing fields while exploring for new ones. There remains much uncertainty as to the size of potential finds; when the production from any new discovery might materialise; as well as the timing of supply disruption due to facility maintenance, repairs or upgrades. Facilities maintenance is the main reason cited for several instances of reduced oil and gas production in 2004, 2007, 2011 and 2012 (IMF 2005, 2008b, 2012b and 2013). The government is continuing its efforts to broaden its economic base and has identified several industries for development. These include downstream petrochemicals, tourism, Islamic financial services and production of halal products, as well as information and communication technology services (ADB 2013). With the limitation of its domestic market size, the government is focusing on export-orientated industries.

The findings of this study are in line with the current situation. In aggregate, it appears that the Brunei economy had progressive technological change for the period 2005-2011. However, the technological regression in the oil and gas sectors cannot be overlooked due to their significant impact on the economy. Clarifying the situation with respect to mining capital stocks is an important area for further investigation.

With a small and weak private sector, the government remains the key driver in the economy. Without strong investment growth, government spending will continue to be the source of economic stimulus, crowding out the private sector through high wages and other costs, and the associated loss of competitiveness. The wage gap between the public and private sectors is not a new issue and the results of the simulation in this thesis illustrate that high wages can be a serious impeding factor to the growth of the private sector.

Against this backdrop, policymakers will have several issues to consider in moving forward. The overall multi-factor productivity gain requires further examination in terms of the separation of non-mining and mining sectors. Productivity measurement is important to gauge future economic growth and better data can lead to improved measurement. Forecasts of productivity in the mining sector are based on some assumptions, with capital stocks expected to grow or decline in line with the oil and gas outputs observed. With the heavy weightage of mining sector stocks in the overall capital stocks of the economy, we need to treat this capital stock number with caution as the aggregate capital stock was dragged down at a rate of 1.04 per cent per annum, despite an increase in aggregate investment of 9.95 per cent per annum. This high growth in investment may not come entirely from the oil and gas sector, although there is some empirical evidence of more investment in the Asia-Pacific region by big oil companies like Royal Dutch Shell plc, as explained in Box 5-2.

A real currency appreciation of 3.83 per cent per annum was observed for the period 2005 to 2011. This can be managed through wage restraint that affects domestic prices since the real exchange rate is a function of the nominal exchange rate and the price of goods in Brunei versus the rest of the world, measured in Brunei dollars. This issue relates to the structure of the labour market. High wages and low productivity in Brunei have led to high unit costs (Bhaskaran 2010). This structural distortion in the labour market is believed to be the result of the dominance of the two major employers: the government and the mining sector, both of which provide high wages and generous packages. The lack of economic scale in Brunei contributes to the high unit costs, which make competitive pricing of outputs challenging for Brunei. With its location within the ASEAN region, surrounded by neighbouring countries where low cost labour is readily available, moving up the value added production chain or offering differentiated products may be more effective.

These issues have been raised by several researchers. Lawrey (2010) also pointed out that relatively high wages and low productivity make Brunei's manufacturing and other private sector activities uncompetitive in the international market. This continues to reinforce the dominance of the public sector. He suggested a policy to downsize the government through measures to increase productivity, contracting out, corporatisation and privatisation. Anaman (2004) concurred, arguing that the large size of government can impede growth and that investment is important for economic growth.

To conclude, the process of updating the IOT 2011 through historical simulation has elucidated recent economic performance and structural changes. The resulting database also served another purpose, being used to develop a baseline forecast for 2012 to 2040, which is outlined in Chapter 7, and to run policy simulations, discussed in Chapter 8. Using decomposition simulation, some of the uncovered structural features of Brunei's economy were used to work out contributions in producing the output, employment and other endogenous variables of the economy. This is discussed in Chapter 6.

Chapter 6: Decomposition simulation

After the completion of the historical simulation, discussed in Chapter 5, through which we uncovered the underlying structural variables that led to the known changes in the macroeconomics outcomes, the next step was to examine the effects separately attributable to these structural variables. For example, a policymaker may want to know the effects of past technological change on current GDP, consumption, sectoral output or investment in the economy. A decomposition simulation allows us to decompose the total movements in the macro and industry variables and attribute them to the individual effects of different driving forces (Dixon et al. 2013).

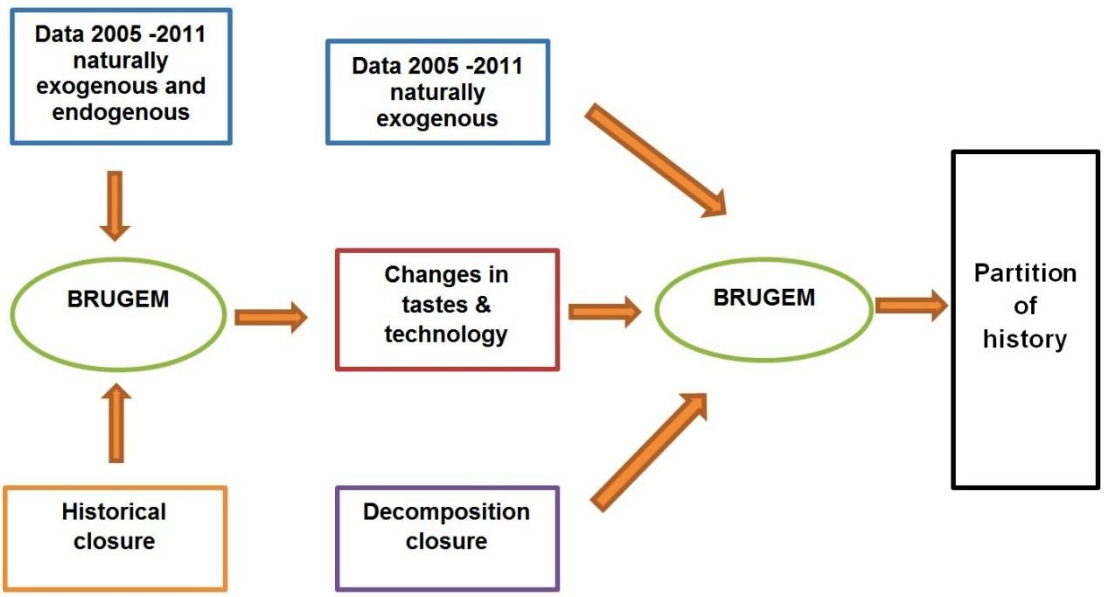
Another useful application of decomposition is to isolate the effects of individual economic policies. For example, in Australia, the tariff policy for motor vehicles was a major political issue for policymakers in the 1990s. Policymakers wanted to attribute the growth in the motor vehicle industry to their policies relating to motor vehicle supply – but how much growth was due to protectionist policies and how much was due to other factors? Dixon and Rimmer (2002) used a decomposition simulation technique to assess the significance of changes in tariffs relative to changes in other variables, such as tastes and technology, as the determinants of the performance of the motor vehicle industry. They concluded from their study that the health of the motor vehicle industry depends on many factors, apart from protection through tariffs. These factors include international trading conditions, technology, economy-wide employment growth, import/domestic preferences and required ROR on capital.

This chapter is divided into four main sections. Section 6.1 provides some background on the decomposition method and model closure. Section 6.2 outlines the stylised BOTE model used to interpret the results. Section 6.3 focuses on the decomposition simulation results. Section 6.4 compares these results to empirical studies of some other economic drivers in Brunei. The final, Section 6.5, summarises and discusses next steps.

6.1 Decomposition simulation and closures

In this chapter, we use the decomposition technique to help explain the changes of the observed economic outcomes in Brunei over the period 2005-2011. This is done in terms of the contributions made by changes in naturally exogenous variables of the model, such as industry technologies (productivity), household tastes, the propensity to consume, import/domestic preferences and changes in foreign trading conditions. The concept of historical and decompositional simulations is illustrated in Figure 6-1. The end result is a series of partitions of history each attributable to inferred changes in naturally exogenous variables.

Figure 6-1: Historical and decomposition simulations



To relate the decomposition (D) closure to the historical (H) closure, explained in Chapter 5, we can partition the variables in BRUGEM into four sets: (a) exogenous in both, denoted by $X(\overline{H}\,\overline{D})$; (b) endogenous in both, denoted by $X(H\,D)$; (c) exogenous in historical and endogenous in decomposition, denoted by $\mathrm{X}(\overline{\mathrm{H}}\,\mathrm{D})$; and (d) endogenous in historical and exogenous in decomposition, denoted by $\mathrm{X}(\mathrm{H}\,\overline{\mathrm{D}})$. $\overline{\mathrm{H}}$ and H denote exogenous and endogenous variables respectively in the historical simulation, while $\overline{\mathrm{D}}$ and D denote exogenous and endogenous variables respectively in the decomposition simulation (Dixon & Rimmer 2004, Giesecke 2004).

Once the variables are allocated into these four sets, the historical and decomposition solutions can be computed starting with the first application of the model or the historical simulation to find a solution in the form $\mathrm{X}(\mathrm{H}) = \mathrm{V}^{\mathrm{H}}(\mathrm{X}(\overline{\mathrm{H}}))$, where $\mathrm{X}(\overline{\mathrm{H}}) = \mathrm{X}(\overline{\mathrm{H}}\,\mathrm{D}) \cup \mathrm{X}(\overline{\mathrm{H}}\,\overline{\mathrm{D}})$, $\mathrm{X}(\mathrm{H}) = \mathrm{X}(\mathrm{H}\,\mathrm{D}) \cup \mathrm{X}(\mathrm{H}\,\overline{\mathrm{D}})$, and V^{H} is a *m*-vector of differentiable functions. With the variables in $\mathrm{X}(\overline{\mathrm{H}})$ being assigned the observed historical values, V^{H} can be used, in turn, to determine the values for the variables in $\mathrm{X}\,(\mathrm{H})$.

After obtaining these values from the historical simulation (see Chapter 5), we could then use the decomposition closure to find a solution in the form $\mathrm{X}(\mathrm{D}) = V^{\mathrm{D}}(X(\overline{\mathrm{D}}))$. This can be re-expressed in the percentage form as $\mathrm{x}(\mathrm{D}) = \mathrm{B}\mathrm{x}(\overline{\mathrm{D}})$, where $\mathrm{x}(\mathrm{D})$ and $\mathrm{x}(\overline{\mathrm{D}})$ are vectors of percentage changes in the variables in $\mathrm{X}(\mathrm{D})$ and $\mathrm{X}(\overline{\mathrm{D}})$respectively, while B is a *m* x *(n-m)* matrix of elasticities. In the B matrix, the *ij*-th element is the elasticity of the *i*-th component of $\mathrm{X}(\mathrm{D})$ with respect to the j-th component of $\mathrm{X}(\overline{\mathrm{D}})$, as shown in Equation (6.1).

$$B_{ij} = \frac{\partial\, \mathrm{V}_i^D\left(X\left(\bar{D}\right)\right)}{\partial X_j\left(\bar{D}\right)} \cdot \frac{X_j\left(\bar{D}\right)}{X_i\left(D\right)} \qquad (6.1)$$

With the completion of the historical simulation, all percentage changes in the variables were known, including the values of $\mathrm{x}(\overline{\mathrm{D}})$. Therefore the function $\mathrm{x}(\mathrm{D}) = \mathrm{B}\mathrm{x}(\overline{\mathrm{D}})$ could be used to decompose the movements in $\mathrm{x}(\mathrm{D})$ into the parts that could be attributed to the movements in $\mathrm{x}(\overline{\mathrm{D}})$.

$\mathrm{X}(\mathrm{H}\,\overline{\mathrm{D}})$ had the same number of variables as $\mathrm{X}(\overline{\mathrm{H}}\,\mathrm{D})$ with each variable in the $\mathrm{X}(\mathrm{H}\,\overline{\mathrm{D}})$ having a corresponding variable in $\mathrm{X}(\overline{\mathrm{H}}\,\mathrm{D})$. For example, the real private consumption by commodity (an example of $X(\overline{H}\,D)$) has a corresponding variable, such as consumer preference by commodity (an example of $X(H\,\overline{D})$). These unobservable corresponding variables, which are exogenous in decomposition closure and endogenous in historical closure, include intermediate-input saving technological change, changes in household tastes, primary-factor saving technological change and average propensity to consume. These variables are not typically explained but their values can be determined in the historical simulation. The values could then be fed into the decomposition closure used in BRUGEM to explain the observed movements of the endogenous macroeconomic and industry variables of type $X(\overline{H}\,D)$ and $X(H\,D)$.

To implement decomposition, first the originally endogenous variables in the historical simulation were swapped into type $X(\overline{H}\,D)$ with the estimated values imposed. Observations for the variables that are exogenous in both the historical and decomposition simulations $X(\overline{H}\,\overline{D})$ were also carried through in the decomposition. These two types of variables would have the same values in both historical and decomposition simulations.

Decomposition analysis was based on the results generated by base rerun[21] (X^R) in BRUGEM. Under the multi-step Euler solution method, these results do not necessarily match the baserun results from the historical simulation (X^B). This can happen in two instances of closure change, as shown in Table 6-1, due to linearisation errors. Box 6-1 shows a numerical example of linearisation error.

Linearisation errors are caused by second order terms when changing a linear equation into percentage change form, as explained in Section 3.2.2.

[21] Rerunning the base case is necessary because changing closures can often alter the numerical results even though there is no policy shock. A base rerun has the same closure as the policy shock and this prevents the contamination of reported effects of policy shocks.

Table 6-1: Results of base and base rerun under historical and decomposition closures

Results of base and base rerun	Examples of variables
$X^B(\overline{H}\overline{D}) = X^R(\overline{H}\overline{D})$	Employment, population
$X^B(H\overline{D}) = X^R(H\overline{D})$	Technological change, export shifter, average propensity to consume, taste change
$X^B(HD) \neq X^R(HD)$	Change in trade balance, real wage, capital stock, real devaluation
$X^B(\overline{H}D) \neq X^R(\overline{H}D)$	GDP, private consumption, government expenditure, exports, imports, terms of trade

Box 6-1: Numerical example to illustrate linearisation error in the base

$$X = Y * Z$$
$$\Rightarrow x \approx y + z$$
in percentage change form under multi-step solution

In base both X_0 and Y_0 are exogenous and we can solve for Z_0:

$X_0 = 30, Y_0 = 3 \Rightarrow Z_0 = 10$ and if shocks for $x = 10\%, \mathrm{y} = 2\%$ then

$$X_1 = Y_1 * Z_1$$
$$\Rightarrow X_1 = 33, Y_1 = 3.06, Z_1 = 10.78$$

Therefore $z = 7.8\%$ is a true solution. While under multi-step solution method in base, $z = 8\%$ due to linearisation errors caused by second-order terms.

6.1.1 Decomposition using GEMPACK

In GEMPACK, decomposition can be carried out by the "subtotals" command function. Harrison et al. (2000) devised a practical method that could calculate the contributions of these exogenous variables (which can be grouped together), to the changes in the endogenous variables. The methodology behind this software (Harrison et al. 2000) is explained in Appendix 6-1.

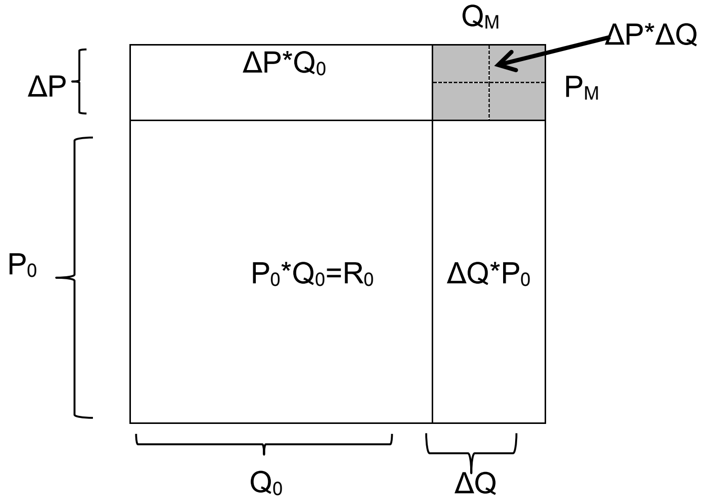
The subtotals function computes the contributions, one group at a time, while holding other groups of variables at zero values. The column headings are the groups of exogenous variables. For example, if we wanted to know the impact of group A (say column 2 in Table 6-2) variables, which consist of the employment and population growth shocks on the endogenous variables listed in the row headings, we would impose shock to the group A variables and not to the other groups of variables (columns 3 to 9)[22]. The contribution of group A variables would be calculated using Equation (6.16), as shown in Appendix 6-1. Similarly, to work out the contribution of group B shocks, we could run another simulation, where group A and other groups are held unchanged. This process was repeated until all nine groups of shocks were complete, one group at a time.

The sequence of shocks chosen was arbitrary. For example, we could shock group A first then group B then C, or group B then group A then group C. The contribution of group A variables in the first chosen sequence would be different to that in the second chosen sequence. However, the sum of contributions from all nine groups of variables would add up to the total movement in the endogenous variable Z in Equation (6.13) of Appendix 6-1. Since the decomposition results were path dependent in the GEMPACK software, the chosen path for exogenous variables was a straight line, moving from pre-shock to post-shock values. This is the preferred algorithm used by Harrison et al. (2000).

Since the model is not linear and presented as subtotals, the contributions by rows may not add up due to linearisation errors, as explained earlier. The Harrison et al. (2000) method of overcoming the linearisation error is explained in Box 6-2.

[22] Note that column 1 is the capital accumulation effect where the *delUnity* variable is given shock of 1 to activate the dynamics.

Box 6-2: Illustration of the issues associated with decomposition



The above example illustrates an equation that states a price (P_0) multiplied by a quantity (Q_0), which gives the revenue (R_0). There is an increase in price ΔP and an increase in quantity ΔQ. The actual increase in revenue is measured by the sum of the two rectangles and the small shaded area, where the increase in revenue is measured by:

$$\Delta R=(\Delta P*Q_0)+(\Delta Q*P_0)+(\Delta P*\Delta Q)$$

The attribution due to the change in price is given by the term $\Delta P*Q_0$ and the change in quantity is given by the term $\Delta Q*P_0$. The issue is that the sum of both areas do not add up to ΔR and do not fully explain the change in revenue due to the missing shaded area $\Delta P*\Delta Q$. That is why subtotals may not always add up due to this second order term represented by this shaded area.

On the other hand, we could consider the total expansion of price and quantity where:

$$P_1=(P_0+\Delta P) \text{ and } Q_1=(Q_0+\Delta Q) \text{ where } R_1 = P_1 * Q_1$$

The attribution due to the change in new price is given by the area $\Delta P*Q_1$ and the change in new quantity is given by the term $\Delta Q*P_1$, then the shaded area is counted twice in the summation of these two subtotals.

Harrison et al. (2000) proposed another method to minimise this error. They assumed that the value of R_0 moves to R_1 in a straight line, where both price and quantity expand at the same time. They suggested a mid-point method taking the values of P_M and Q_M to work out the subtotals so less of the shaded area is left out.

The new subtotals for the contributions of P and Q would be given by the following formulae respectively:

$$Subtotal\_P = \Delta P * Q_M$$
$$Subtotal\_Q = \Delta Q * P_M$$

The mid-point method is a good compromise. In this example of second order polynomial, it provides the exact solution for subtotals. With higher-order polynomial equations, as in BRUGEM, the solutions for subtotals will not be exact. Nevertheless, it does indicate the significance of the exogenous group of variables in terms of share of contribution, although the exact number may not be accurate, as explained in Section 6.1.2.

6.1.2 One-step Euler/Johansen method

The decomposition method explained above in Section 6.1.1 for a system of non-linear equations would lead to some discrepancy under a multi-step solution. In Table 6-1, the sum of the subtotals will not be equal in the cases of two groups of variables $X(HD)$ and $X(\overline{H}D)$ since their results in the base differ from the base rerun, that is $X^B \neq X^R$.

The one-step Euler/Johansen method would reproduce the same results as base, where $X^B = X^R$. However the numerical values for the results would not be accurate, as explained in Box 6-1 (where z is 8 per cent and not 7.8 per cent) due to this solution method. The sum of contributions would add up exactly across the rows. Therefore, this method provides an indication of the direction (positive or negative) and contribution of the group of exogenous to the movement of the endogenous variables.

There is no perfect method to obtain the contribution with decomposition. For the purpose of illustration, in terms of contribution and direction of influence, the one-step Euler/Johansen method was used and the “subtotals” command in GEMPACK helped us to organise into the group of exogenous variables of interest to produce the results, as shown in Table 6-2.

6.2 A stylised version of BRUGEM – the BOTE model

To interpret the results from the decomposition simulations, we could use the same stylised BOTE model as used in Section 5.3 to understand the historical simulation. For convenience, the BOTE equations were repeated, as shown in Figure 6-2 (the same as Figure 5-3). Sometimes a percentage form version of the same BOTE model (see Appendix 6-2) can illustrate the simulation results better. Whether in levels form or percentage form, a stylised BOTE model is a simplification of the underlying dynamic model. It omits most of the details of BRUGEM, including the dynamic relationships and land (or natural resources).

In the decomposition closure, GDP, C, I, G, X, M, K and TOT are the endogenous variables while L, ROR, A, APC, Γ, Ψ, V and T are exogenous. The known outcomes of the exogenous variables (i.e., structural drivers) obtained from the historical simulation were used to backsolve in the model to obtain results for the endogenous macroeconomic variables, such as real GDP, and consumption, and for endogenous microeconomic variables of interest, including output and employment by industry (see Table 6-2). The decomposition closure is the "natural" long run closure.

Figure 6-2: Decomposition and historical closures of the stylised BOTE model

Decomposition closure	Historical closure
(1) GDP=C+I+G+X−M	(1) **GDP**=**C**+I+**G**+**X**−**M**
(2) GDP=(1/**A**)*F(K,**L**)	(2) **GDP**=(1/A)*F(K,**L**)
(3) C=B(**APC**,GDP,TOT)	(3) **C**= B(APC,**GDP**,**TOT**)
(4) C/G=**Γ**	(4) **C**/**G**=Γ
(5) M=H(GDP,TOT,**T**)	(5) **M**=H(**GDP**,**TOT**,T)
(6) TOT = J(X,**V**)	(6) **TOT** = J(**X**,V)
(7) I=Z(K, **ROR**, **Ψ**)	(7) I = Z(K, **ROR**,Ψ)
(8) K/**L**=N(**ROR**,**A**,TOT,RW)	(8) K/**L**=N(**ROR**,A,**TOT**,**RW**)
(9) $K_t=f(\mathbf{K}_{t-1}, \mathbf{I}_{t-1})$	(9) $K_t=f(\mathbf{K}_{t-1}, \mathbf{I}_{t-1})$
Bold = exogenous variables, the rest are endogenous	

6.3 Simulation results

A large number of variables were shocked in the decomposition simulation. The decomposition results were divided into nine column headings containing groups of similar exogenous variables (see Table 6-2). In Table 6-2, the numbers in each column represent the effects of the group of exogenous variables on growth of the endogenous variables (listed in the row headings), in the absence of other exogenous shocks from other groups. The results across the rows show the influences from each group of shocks to the macro and sectoral variables.

In Table 6-2, the choice of "subtotals" used in the decomposition closure on the sources of structural change was based on the following reasoning. The first column represents the capital accumulation effect, which tells us about the effects of past investments on capital growth. Brunei is a developing country with a limited labour force pool. The second column of exogenous variables consists of employment and population growth. This helps to analyse their impact on Brunei's economy. Productivity or technological change is an important driving force that was analysed under a separate column (column 3). The world trade condition in column 4 is represented by the shifts in supply and export demand curves, including the oil and gas sectors shock on which Brunei depends.

Being a government-driven economy, the government demand shift variable was grouped with the propensity to consume the variable in column 5, to see their influence on the economy. Column 6 shows the effect of a change in preference for import and domestic varieties, or a change in tastes not driven by a change in relative prices. The changes in the required ROR in column 7 can have some influence on the economy as well. Column 8 shows the effects of changes in the nominal exchange rate, which acts as the numeraire. Column 9 shows the effects of "other factors", such as changes in the sector-specific wage shifter for *methanol* and *garments.* The sum of the contributions equals the total effect given in column 10. Average annual percentage changes for the endogenous variables (in the rows) are shown in column 11.

At macroeconomic level, the results of columns 1 to 3 represent the supply side shifts. These columns indicate the contributions due to the capital (column 1), labour (column 2) and technological change (column 3). The demand side shifts are indicated by the results of columns 4 to 7 representing movements in exports, imports, consumption and investment when the supply side is fixed. These demand side shifts uncover the compositional change in demand and also changes in prices shown in Table 6-2. Each of the column results will be explained in the following Sections 6.3.1 to 6.3.8.

The sectoral variables chosen in Table 6-2 were the four main export-orientated industries: *oil, gas, methanol* and *garments*. Changes in their outputs, investment, capital stock and employment are listed in rows 16-31. Only these four sectoral results will be reported.

The simulation results could be further explained with the help of the BOTE model equations shown in Figure 6-2. For brevity, only the key macroeconomic variables and selected changes in sectoral variables that support the change in the macroeconomic variables are discussed. For example, in Table 6-2, reading along row 7 we can see that the real GDP growth was mainly attributed to employment growth (column 2) and technological change (column 3). These are factors from the GDP supply side, as indicated by Equation (2) in Figure 6-2 of the BOTE model.

Table 6-2: Decomposition of changes in the macro, trade and sectoral variables for 2005-2011

	Per cent	(1) Capital accumulation	(2) Employment growth	(3) Technical change	(4) Shifts in export demand schedules	(5) Changes in propensity to consume, govt	(6) Changes in tastes for imports vs domestic	(7) Apparent changes in required rates of return	(8) Nominal exchange rate (numeraire)	(9) Other factors	(10) Total (per cent)	(11) Annual Average (per cent)
	<u>Macro and trade variables</u>											
1	Balance of trade/GDP	0.0	0.1	0.2	0.0	-0.2	0.0	-0.0	0.0	-0.0	0.1	0.0
	<u>In percentage changes</u>											
2	Aggregate employment	0.0	13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.1	2.1
3	Consumer real wage	-1.7	-57.1	-82.1	41.0	124.0	-30.8	6.0	-0.0	0.0	-0.7	-0.1
4	Producer real wage	-4.3	-41.1	-70.9	3.4	84.2	-23.5	3.4	-0.0	0.1	-48.6	-10.5
5	Aggregate capital stock	-6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-6.1	-1.0
6	Real rental cost of capital	5.5	14.1	20.8	-1.4	-27.8	6.4	-1.1	0.0	0.0	16.4	2.6
7	Real GDP	-3.1	2.9	7.2	0.2	-0.4	0.1	0.0	0.0	0.0	6.9	1.1
8	Real private consumption	0.4	-0.2	15.0	34.4	-19.5	2.0	-0.2	0.0	-0.0	31.9	4.7
9	Real public consumption	0.0	0.0	0.0	0.0	50.4	0.0	0.0	0.0	0.0	50.4	7.0
10	Real investment	-0.3	14.1	32.3	26.5	-25.0	8.5	9.8	0.0	-0.1	65.8	8.8
11	Imports, volume	7.5	1.2	12.8	21.3	-1.5	16.9	1.1	0.0	0.1	59.4	8.1
12	Exports, volume	-2.1	2.5	4.8	-5.2	-5.1	4.5	-0.4	-0.0	0.1	-1.1	-0.2
13	Non- traditional export volume	58.1	20.4	96.7	-30.8	-40.8	39.7	-7.1	-0.0	-0.2	136.0	15.4
14	Terms of trade	-0.4	-0.6	-1.8	77.4	1.3	-1.2	0.2	0.0	-0.0	74.8	9.8
15	Real devaluation	5.4	13.8	40.1	-62.0	-30.3	11.8	-1.3	-0.0	-0.1	-22.7	-4.2
	<u>Sectoral output</u>											
16	Crude Petrol	-12.9	0.9	-6.5	-0.3	-1.8	0.6	-0.1	0.0	-0.0	-20.2	-3.7
17	Natural Gas	1.1	0.8	1.9	0.3	-1.6	0.5	-0.1	-0.0	-0.0	3.0	0.5
18	Methanol	17391.2	103.1	966.8	599.1	-216.1	100.6	-34.4	-0.0	-207.9	18702.5	139.4
19	Garments	-6.7	17.4	64.5	-126.2	-36.5	-9.0	1.5	0.0	3.7	-91.2	-33.3
	<u>Sectoral investment</u>											
20	Crude Petrol	-5.5	18.5	47.9	8.3	-36.9	0.6	-0.1	0.0	-0.0	32.8	7.9
21	Natural Gas	10.7	23.9	73.1	60.5	-47.4	24.0	12.6	0.0	-0.2	157.1	17.0
22	Methanol	13806.1	477.2	1913.3	9793.4	-965.8	648.8	955.3	-0.0	-249.3	26378.9	153.4
23	Garments	64.7	13.8	60.0	-187.4	-27.2	-11.8	-1.4	0.0	-6.5	-95.8	-41.0
	<u>Sectoral capital stock</u>											
24	Crude Petrol	-19.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-19.1	-3.5
25	Natural Gas	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.2
26	Methanol	16681.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16681.2	134.9
27	Garments	-94.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-94.3	-38.0
	<u>Sectoral employment</u>											
28	Crude Petrol	-7.9	37.6	70.3	-14.4	-78.8	25.7	-4.7	0.0	-0.1	27.8	4.2
29	Natural Gas	9.6	46.5	95.4	16.4	-97.0	33.4	-6.9	0.0	-0.1	97.3	12.0
30	Methanol	11737.5	832.8	2158.8	4839.0	-1746.3	809.7	-276.1	-0.0	-1674.3	16681.2	134.9
31	Garments	36.6	24.1	71.0	-174.6	-50.0	-9.6	2.9	0.0	5.4	-94.3	-38.0

Supply side shifts (columns 1 to 3)

6.3.1 Column 1: Capital accumulation effects

The first column in Table 6-2 represents the capital accumulation effects generated by imposing the value of the homotopy variable, *delUnity*, to one. This activates the dynamic equations on capital accumulation via Equation (9), as shown in Table 6-2.

In the absence of changes in other exogenous variables, the column for capital accumulation effects (column 1) shows estimated changes due to capital growth enabled by the investment in 2005 and subsequent years.

Column 1 shows that capital accumulation has a very large impact on capital, which decreases by 6.1 per cent (row 5), and on real GDP, which decreases by 3.1 per cent (row 7). Oil and gas sectors made up a significant proportion of the overall capital stock. As explained in Section 5.4.2.6, the oil sector was given a negative capital growth while the gas sector a small positive growth.

The effect on real GDP growth can be explained by the following equation (the percentage growth form of the BOTE Equation (2), including land):

$$y = S_K k + S_L l + S_N n + a \qquad (6.2)$$

where *y, k, l* and *n* are percentage growth rates of real GDP, capital, labour and land. Variable *a* represents technical change. The shares of capital, labour and land are represented by S_K, S_L, S_N respectively. Land usage, labour and technological change are exogenous and not given any shock in the capital accumulation effect. Therefore, GDP growth attributable to capital accumulation is driven by the stimulus to capital. In the model, capital's share is around 0.55. Thus, according to Equation (6.2), with capital decreases by 6.1 per cent, real GDP will fall by around 3.4 per cent:

$$y = S_K k = -0.55(6.1) = -3.4 \qquad (6.3)$$

The BOTE calculation of real GDP growth is a little different from the real GDP decline simulated by the full model of 3.1 per cent (see the first column, Table 6-2). The difference is due, in part, to other factors, such as changes in indirect taxes that are not accounted for in Equation (6.2).

The decrease in capital decreases the economy-wide capital to labour ratio. According to BOTE Equation (8), shown in Figure 6-2, putting aside possible changes in the TOT, decreased capital to labour will lead to a decrease in producer real wage rate (row 4). In addition, according to BOTE Equation (7), the decrease in capital will lead to decreased investment (row 10) since there is less need of investment to replace the reduced capital stock.

Factors driving real domestic absorption (C+I+G) are tied down as shown in the small changes in real private consumption (row 8) and real investment (row 10) and the exogenous real public consumption (row 9) which was set to zero change. Since the economy is producing less with the decline in real GDP, this is reflected in the worsening of net volume of trade (X-M) via BOTE Equation (1) with the large increase in imports of 7.5 per cent (row 11) and a decrease in exports of 2.1 per cent (row 12).

The selected sectoral results shown in Table 6-2 highlight that the decline in capital accumulation contributes more significantly to the decline in output (row 16), investment (row 20), capital stock (row 24) and employment in the crude petrol sector (row 28) compared to the other three sectors in the first column.

6.3.2 Column 2: Employment and population growth

Column 2 shows the contributions attributable to employment and population growth. In this column and also other columns 3 to 9, the capital accumulation equation is switched off with *delUnity* variable set to zero change. Therefore, there is no change to capital stock (row 5) for columns 2 to 9. The observed growth in employment of 13.1 per cent (row 2) was imposed in historical simulation. The labour share is around 0.26 in the model and using Equation (6.2), real GDP will increase by about 3.4 per cent with this employment growth:

$$y = S_L l = 0.26(13.1) = 3.4$$

The growth of employment has a positive contribution to the growth of real GDP (row 7) as would be expected from BOTE Equation (2) shown in Figure 6-2. This BOTE calculation is slightly different to the real GDP due to indirect taxes. The increase in real GDP causes imports to rise (row 11) via BOTE Equation (5) in Figure 6-2 and exports to expand (row 12) leading to a deterioration in terms of trade (row 14) via BOTE Equation (6) in Figure 6-2. The larger expansion of exports relative to imports is facilitated by real devaluation (row 15) making imports relatively more expensive.

The growth in employment also lowers the marginal product of labour leading to the decrease in real wage (row 3). With the fall in (K/L) ratio, the marginal product of capital increases and pushes up the rental cost on capital (row 6). This is due to the profit maximising first order condition, where the value of the marginal product of capital equals to the rental price of the capital under constant returns to scale production function. This in turn led to an increase in aggregate investment (row 10) driven by the increased rate of return.

The difference between consumer real wage (row 3) and producer real wage (row 4) can be attributed to the real depreciation of currency. In this case, there is real devaluation (row 15) leading to loss of purchasing power of the consumers and real private consumption falls (row 8).

$$rw = \underbrace{p_L - p_c}_{\text{consumer real wage}} = \underbrace{(p_L - p)}_{\text{producer real wage}} + \underbrace{(p - p_c)}_{\text{real depreciation (if } p<p_c)} = -41.1 + (-13.8) = -54.9$$

The four industries of oil, gas, methanol and garment industries benefit from the increased aggregate employment growth (rows 28-31). Real depreciation also leads to their expansion since they are exposed to international trade.

6.3.3 Column 3: Effects of technological change

The historical simulation results indicate an overall improvement in all primary-factor augmenting technological change over the period of 2005-2011 of 4.6 per cent per annum (despite the technological regression in the mining sector). As is shown in column 3 of Table 6-2, the technological improvement lifts real GDP by 7.2 per cent. BOTE Equation (2) shows that the cost reductions associated with technological improvement lead directly to increase in real GDP. Row 7 also indicates that technological change is the most significant driver to the overall real GDP growth from the supply side.

However, it may appear counterintuitive that technological improvement contributes towards a fall in the real wage (see row 3 of Table 6-2). An improvement in technological change raises the marginal product of labour and therefore, eventually, the real wage. However, if we break down the effects of technological change on price of labour, this effect is not as obvious because it also depends on demand elasticity. This can be explained in the following BOTE equations in percentage change forms: Equations (2), (3) and (4) extracted from Figure 3 in Appendix 6-2. Equation (6.7) is derived by substitution of Equations (5), (7), (8) and (10) into (1) in Figure 3. The nominal exchange rate ϕ is exogenous and set to zero as numeraire.

$$y = S_L l + S_K k - a \tag{6.4}$$

$$l - k = -\sigma(p_L - p_K) \tag{6.5}$$

$$p = S_L p_L + S_K p_K + a \tag{6.6}$$

$$y = -\beta(p - \phi) + f \tag{6.7}$$

In the above equations, the lowercase letters indicate percentage changes for the GDP or output Y, labour L, capital K and technological change A. Both σ and β are positive parameters indicating substitution elasticity and demand elasticity respectively in Equations (6.5) and (6.7). The variable f is a shift variable, which is exogenous. The price of labour or nominal wage is given by p_L and the rental price of capital is given by p_K. p indicates the output price, which is a share-weighted combination of the prices of labour and capital and technological change. A negative percentage change to A indicates an improvement in technology and this will decrease the output price in Equation (6.6). The percentage change in output quantity in Equation (6.7) is inversely proportional to the percentage change in price.

In the decomposition closure of Figure 6-2, both the aggregate employment and previous period capital are exogenous. With $l = k = 0$, Equation (6.4) is reduced to

$$y = -a \qquad (6.8)$$

where the percentage change in GDP is driven by technology only. By substituting Equation (6.8) into Equation (6.7) where $f = 0$, we produce Equation (6.9):

$$p = a/\beta \qquad (6.9)$$

Substituting into Equation (6.6) and given that $p_K = p_L$ due to $l = k = 0$ in Equation (6.5) and the shares of labour and capital must sum to one, we have:

$$p = S_L p_L + S_K p_L + a = p_L + a \qquad (6.10)$$

This can be rearranged by substituting Equation (6.7) into Equation (6.10) to obtain the price of labour or nominal wage:

$$p_L = a/\beta - a = a[1/\beta - 1] \qquad (6.11)$$

In Equation (6.11), the value of a is negative. Since the demand elasticity is low (β <1) due to the fixed government demand, the second term in square brackets will be a positive number. Multiply by a negative a, this shows that there is a fall in p_L in Equation (6.11). Percentage change in the consumer real wage (rw) is given by the nominal wage percentage change adjusted by the consumer price index percentage change (which includes price of imports) in Equation (6.12).

The BOTE model suggested that the producer real wage should increase due to productivity improvement since $p_L - p = -a$ from Equation (6.10) with a being a negative number. However, simulation results showed that the producer wage has declined instead (row 4). This is a counter-intuitive result which we will come across again in Chapter 8 where it will be explained in terms of the compositional change (Section 8.2.2).

The effect of technological change on consumer real wage can also be worked out using producer real wage and Equation (6) in Figure 3 of Appendix 6-2 where the percentage change in CPI or p_c is a share-weighted sum of domestic and imported prices. Imported prices are exogenous ($p_M = 0$). Substituting Equations (6.9) and (6.11) into the definition of consumer real wage below, we can simplify into Equation (6.13):

$$rw = p_L - p_C \qquad (6.12)$$

$$rw = a\left[\frac{1}{\beta} - 1\right] - S_D \frac{a}{\beta}$$

$$rw = a\left[\frac{1}{\beta} - 1 - \frac{S_D}{\beta}\right]$$

$$rw = a\left[\frac{S_M}{\beta} - 1\right] \qquad (6.13)$$

From Equation (6.13), it is shown that the consumer real wage can either increase or decrease depending on share of imports S_M and size of β. In the case of Brunei, there is an overall high import share in the overall GDP and low demand elasticity (β <1) leading to a large fall in consumer real wage (row 3) with $S_M > \beta$ and negative value of a.

With technological improvement the economy is able to produce more efficiently, however domestic prices have to fall significantly making producers worse off since consumers prefer to buy imported varieties.

Therefore, in the results, an improvement in technological change leads to the fall in the real wage due to fixed government consumption in the economy which makes overall demand inelastic.

At sectoral level, the increase in domestic activity generated by technological change is also reflected in the favourable sectoral results for the four industries (see rows 16-31 in Table 6-2) in terms of increased output and investment, with the exception of the garments sector, which is declining.

Demand side shifts (columns 4 to 7)

6.3.4 Column 4: The effects of shifts in export demand schedules

Given the supply constraints in columns 1 to 3, column 4 to 7 will uncover the compositional change in demand and changes in price levels. The effects of the shifts in export demand schedules in the decomposition simulation are given in column 4 of Table 6-2.

In the historical simulation, the observed changes in export volumes for both aggregate export and sector-specific changes for the oil, gas, methanol and garments sectors are incorporated. The observed changes in export volumes were accommodated by endogenous changes in the positions of export demand schedules. In the decomposition simulation, the export demand shifts from the historical simulation are imposed exogenously (see BOTE Equation (6) in Figure 6-2).

As shown, the overall shifts in the export demand schedule generate an improvement in the TOT and this is the predominant contributor to the overall large TOT increase, as shown in the final column (row 14).

The large increase in consumer real wage (row 3) relative to producer real wage (row 4) is mostly due to the strong real appreciation of currency (row 15) as defined in Section 6.3.2.

Despite the decline in aggregate export volume from the historical results, sector-specific shocks had different effects on the four industries. The oil, gas and methanol sectors show a rightward shift of the export demand curves, indicating, for a given price there is increased demand by foreigners. Despite the high prices, due to the supply constraints of oil and gas, the export volume for oil had shrunk and there was only a small increase in gas exports during the period 2005-2011. This is illustrated in Figures 5-6 and 5-7. The shifts in export demand schedules contribute to most of the movements observed in the selected sectoral results (see rows 16-31).

6.3.5 Column 5: Changes in propensity to consume and government demand

Private and public consumption play significant roles in Brunei's economy. With the supply side fixed, column 5 of Table 6-2 shows the contribution to the historical changes arising from two sources: changes in the average propensity to consume (see BOTE Equation (3) in Figure 6-2), and changes in the ratio of private to public consumption (see BOTE Equation (4) in Figure 6-2).

The results in column 5 show that, together, these two sources are the key drivers of the historical changes in private consumption (see row 8) and public consumption (see row 9). The significant contribution towards real wage increase (rows 3 and 4) due to the increase in public consumption led to the crowding out effect explained in Section 5.4.2.4.

The combined movement in real public and private consumption (see rows 8 and 9 in column 11) is higher than the increase in investment. In order to maintain the GDP identity in BOTE Equation (1), there must be a shift towards deficit in the net volume of trade, with the fall in import volume (see row 11) being less than the fall in export volume (see row 12). This is facilitated by real appreciation of currency (row 15) making exports uncompetitive.

The negative impact on the real GDP (row 7) due to this group of exogenous variables is also reflected in the adverse sectoral results of the selected four industries oil, gas, methanol and garments in terms of output (rows 16-19), investment (rows 20-23) and employment (rows 28-31).

6.3.6 Column 6: Changes in import/domestic preferences

In the historical simulation, the import-twist variable was measured by imposing observed data on import and domestic prices of goods and services and the demands for imports and domestically produced goods. The movement in twists captured that part of the historically observed ratio of import/domestic varieties not explained by the relative price movements. In that sense, the changes in twists represent changes in preferences or tastes. This taste change is represented by the twist variable *ftwist_c* in BRUGEM.

Column 6 shows the effects of import/domestic twists over the period 2005 to 2011 where, in aggregate, the twists are in favour of imports that contributed positively to the increase in import volume (see row 11). This can be explained via BOTE Equation (5) in Figure 6-2.

With supply side held fixed, the twist variables contribute significantly not just to the imports but also to the growth in aggregate investment (see row 10) driven by the increased rate of return which is a function of the real rental cost of capital as shown in BOTE Equation (9) in Figure 3 of Appendix 6-2.

The effect of taste change in favour of imported variety was significant in its contribution to the aggregate import percentage change (reading across row 11). In column 6, the observed increase in exports (see row 12) required a real depreciation of currency (see row 15). Expansion of exports caused the TOT to decline (see row 14).

The taste change had a small positive contribution towards the selected industry results but this was not significant.

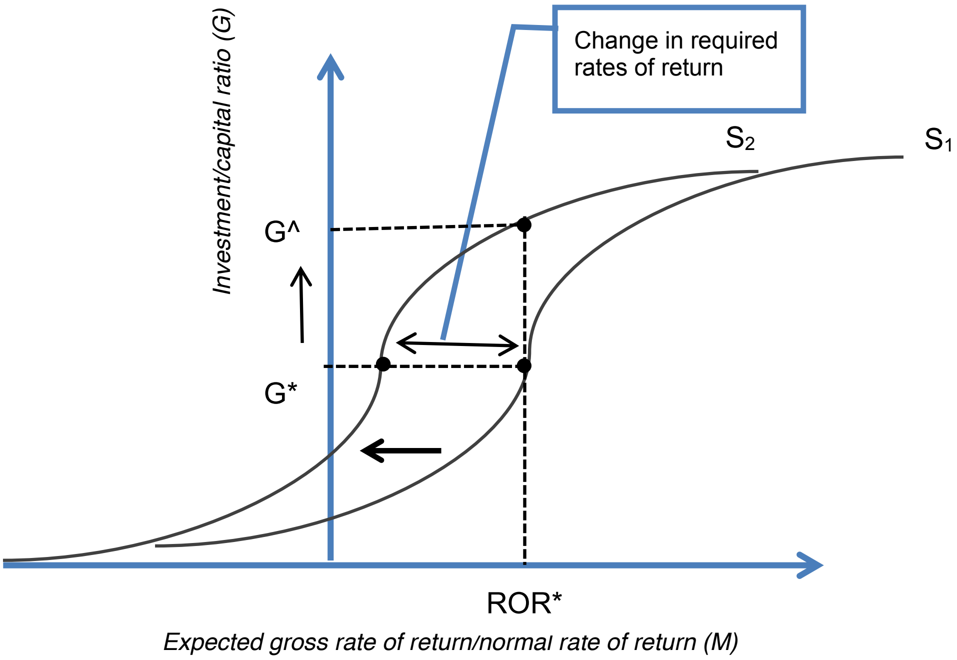
6.3.7 Column 7: The effects of apparent changes in required rates of return

Aggregate investment was endogenous in the historical simulation and determined by the model. At the industry level, two industries had investment that was exogenous: methanol and garments (see Table 5-3 in Section 5.4.2). The historical simulation results shown in Table 5-5 reveal that the aggregate investment had increased.

From the decomposition results shown in Table 6-2, column 7 shows the impact due to apparent changes in required ROR over the period 2005 to 2011. This mainly contributed to the growth observed in aggregate investment (see row 10), as well as investments for natural gas and methanol (rows 21-22). The required ROR reflects investor confidence and is indicated by the investment risk premium ψ of BOTE Equation (7) in Figure 6-2.

Figure 6-3 illustrates the increase in investor confidence indicated by the shift of the capital supply curve shifted to the left resulting in higher value of *G,* defined as the investment to capital ratio (see Table 3-1) for the same ROR. Under initial capital supply curve (S_1), the model predicts G^* at the given ROR* but observed that the outcome is a higher $G^\wedge$ for the aggregate investment. This indicates a change in investor confidence reflected in the leftward shift from S_1 to S_2 as shown in Figure 6-3 where investors are willing to invest more at the same ROR.

Figure 6-3: Required rates of returns, investment/capital growth



In column 7, there is an increase of real investment by 9.8 per cent (row 10) indicating willingness to investment. Reading across row 10, the main drivers for real investment are technical change and shifts in export demand. Required ROR is also a contributor to the increase in aggregate investment.

Other shifts

6.3.8 Column 8 and Column 9 results

As stated earlier, results from Column 8 serve the purpose of rectifying the nominal homogeneity of the model where real variables should not be affected by changes in the exogenous nominal exchange rate, which acts as the numeraire. Column 9 for "other factors" consists of the sector-specific wage shifter for the methanol and garments industries, which only affect these two industries (see rows 18-19, 22-23, 26-27 and 30-31).

Methanol industry was given a positive wage rate growth while the garments industry a wage decline. In the absence of other shocks, these changes in wage rates contribute to the decline in methanol's output, investment and employment and an increase in garments' output and employment.

6.4 Empirical findings and summary

The results derived in Section 6.3 were compared to other studies on Brunei, with a caveat is that this would not be a direct comparison due to the different time periods used. The aim of the comparison was to identify the key contributors to Brunei's GDP growth.

With the use of a Vector Autoregressive Model, Obben (1998) showed that 94 per cent of GDP could be explained by a variation in oil price, which gives an instantaneous response to GDP, while the government revenue and expenditure response involves a one to two year lag. Obben concluded that, with a one-off increase in oil price, increases in Brunei's GDP, revenue and expenditure would be expected for about three years. After this, previous levels might be restored with the exception of government revenues that might continue to decline. The correlation between GDP, oil price and Brunei's fiscal position was illustrated in Figure 2-2 using published data. Obben's analysis was limited to the choice of explanatory variables: government revenues, government expenditure and both current and lagged oil prices.

From the decomposition results shown in Table 6-2, it is argued that real GDP is also driven by a range of factors other than the price of oil. These are the growth rates in labour force and capital, as well as technological change.

Using data from 1971 to 2000, Anaman (2004) investigated the determinants of long run economic growth in Brunei, discovering that the growth of exports significantly influenced the economic growth rates, while the size of government was also important. For the period under study, 2005-2011, the contribution of government demand and propensity to consume is negative to the real GDP growth (see Table 6-2). As pointed out in Section 5.4.2.4, the expansion of government sector has crowded out other sectors, leading to the fall in net exports and investment as other expenditure components are affected. This result, however, lends some support to Anaman's proposition that a moderate government size (measured by proportion of government expenditure to GDP) will enhance economic growth, while a large government will have adverse effects due to bureaucratic delays and the slow implementation of policies (Anaman 2004). Ghazanchyan et al. (2015) also found that public consumption may exert some drag on economic growth. Their study included Brunei in a sample of 25 countries for the period 1980-2015.

There are two studies on Brunei's aggregate import demand. Narayan and Smyth (2005) improved the econometrics techniques used by Anaman and Buffong 2001 (cited in Narayan & Smyth 2005) for the period 1964-1997. They discovered that the aggregate imports in Brunei were inelastic with respect to income and world petroleum prices, but elastic in relation to population and the real exchange rate, both in the short and long run. The decomposition results in Table 6-2 uncovered the strong preference for imported varieties that were not induced by price movement, although the population or labour force growth was a small contributor to the overall imports growth.

Using data from 1961 to 2000, another study discovered that real wages, the level of oil exports as a proportion of GDP, the government export promotion policy and trend factors such as improvement of infrastructure, significantly influenced long run non-oil exports (Anaman & Mahmod 2003). Table 6-2 results show that the aggregate export volume was influenced by other factors, including world trade conditions, capital and labour force growth, technological change and taste change.

To summarise, there are some similar observations between the decomposition results and the methods carried out by other researchers; there are also differences.

Therefore, for a direct comparison, the same period under study should be used because structural changes do vary with time.

6.5 Summary and the next steps

This chapter focussed on decomposition simulation, which took the results from historical simulations and decomposed them into the respective structural drivers. It is useful to help explain the key changes of the observed economic outcomes over the period 2005-2011 in terms of the changes of typically unobservable variables. These include technological change, household taste or preference, propensity to consume, import/domestic preference and changes in foreign trading conditions.

One main finding of this decomposition was that negative capital growth adversely affected real GDP. On the other hand, technological progress and labour force growth are significant contributors to the real GDP growth. Shifts in export demand curves also affect the real GDP growth. This insight will help in formulating the appropriate policy options to drive future economic growth. This issue is discussed further in Chapters 7 and 8 in formulating the baseline forecast for the year 2012 onwards. This was necessary in order to study the effects of policy interventions.

Chapter 7: Baseline forecast (2012-2040)

One of the essential tasks in a CGE policy simulation is to build a baseline as the reference scenario. This is because we require a scenario that takes into account known policies and likely developments. This is a business-as-usual scenario, against which we can compare scenarios using alternative policy interventions. Details of the policy simulation are explained in Chapter 8.

As explained in Section 5.2, this baseline was developed in two parts: a historical baseline covering the period 2005 to 2011; and a baseline forecast covering the period 2012 to 2040.

This chapter is organised in the following manner. Section 7.1 gives an overview of the development of the baseline forecast from the theoretical foundation of BRUGEM. Section 7.2 describes the sources of forecast data and the challenges faced in dealing with inconsistencies between expert forecasts. Two distinct baseline forecasts are developed in Section 7.3. The first illustrates a scenario in which the government takes no action in the face of the depletion of hydrocarbons (Scenario 1). The second is a scenario in which some diversification efforts are undertaken (Scenario 2). Concluding remarks are provided in Section 7.4.

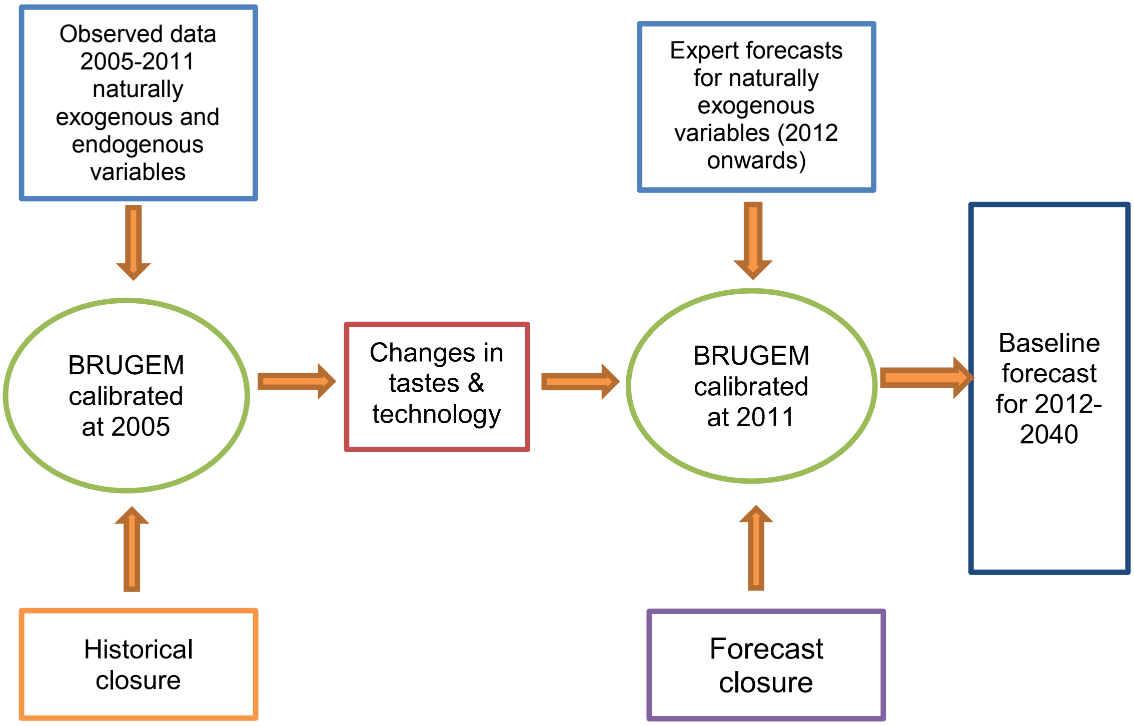
7.1 Baseline forecast and model closure

The baseline forecast was computed by applying likely growth trajectories to the structural drivers of economic activity, such as productivity and population growth. Some of these drivers, especially those relating to productivity, are difficult to observe and even more difficult to forecast. Accordingly, as explained below, we imposed values for variables that we could observe and allow the model to deduce values for some of the unobservable *drivers*. As such, the forecasting methodology used was very similar to the historical simulation technique, as explained in Chapter 5.

Expert forecasts can be obtained from various sources, covering projections of GDP growth, growth in various demographic variables, and likely future changes in prices and volumes of selected exports. The forecast closure was set up by exogenising these variables and endogenising corresponding naturally endogenous variables.

The forecast simulation started from an initial data calibration for 2011, derived earlier and as discussed in Chapter 5. The relationship between the historical (Chapter 5) and forecast simulations is illustrated in Figure 7-1.

Figure 7-1: Linkage between historical and forecast simulations



Specific swap statements were used to develop the forecast closure and then generate the baseline forecast. The year 2040 was chosen as the end year for this simulation. As discussed in Chapter 2, expert forecasts suggest that oil and gas will be depleted by then.

Since we know less about the future than the past, the forecast closure is more conventional than the historical closure described in Section 5.3. Instead of exogenising what we know about the past in the historical simulation, in the forecast closure, we exogenise what we know about the future from the forecasts available or key assumptions made.

To accommodate macro forecasts, the corresponding macro propensities or shift variables were endogenised while the relevant exogenous variables were given the shock values. For sectoral forecasts, the corresponding sectoral shift variables were endogenised instead. For example, forecasts of oil and gas prices obtained from the World Bank (2015b) were incorporated by endogenising the price shifter variable for the oil and gas export demand schedules.

7.1.1 The simulation design

As mentioned earlier, two baseline forecasts were developed, one illustrating a scenario where no action is taken and the other where some diversification efforts are considered. Both baselines were based on one common set up in which both oil and gas deplete, population grows and there is an underlying productivity growth. The common set up is discussed in Section 7.2, with specific variables made exogenous and shocks implemented. Examples of these variables are the overall primary-factor augmenting technological change (or productivity) and aggregate employment, which are focussed on based on the available forecast. These structural drivers provide the projection of the GDP growth in the forecast in the face of hydrocarbon depletion.

Technical change or productivity is difficult to observe, but since it is closely connected to real GDP growth, we can estimate it using available expert GDP forecasts, as shown in Table 7-1. This is explained in Section 7.2.1. Similarly, there is no available expert employment forecast. However, we can estimate this from population and labour force growth forecasts using the relationships stated in Equations (7.4) to (7.9), as well as some key assumptions, as explained in Section 7.2.2.1.

Further details on each of the baseline forecast closures and swaps are discussed in Sections 7.3.1.1 and 7.3.2.1.

7.2 Key assumptions and available forecast data

With the historical and decomposition simulations described in Chapters 5 and 6 providing the snapshot of the state of Brunei's economy from 2005 to 2011, we need to produce a plausible baseline scenario based on some key assumptions for the year 2012 onwards.

There are very few independent forecasts for Brunei's economy. Forecast years are also limited (see Table 7-1) and the forecasts vary from institution to institution. The ADB (2014) pointed out that the challenges of forecasting for Brunei's economy are mainly associated with the uncertainty over the timing of oil and gas production from the new fields; disruptions due to maintenance of production facilities, and the limitations of economic data in terms of availability and timeliness. The ADB provides the most conservative forecasts. However, there is some optimism in the IMF forecasts as they expect the on-going infrastructure and downstream petrochemicals projects to support medium term growth (IMF 2014a).

Table 7-1 shows the key variables for which shocks were imposed in the forecasting simulation. In the sections below, we discuss the settings for these variables, starting with total factor productivity (TFP).

Table 7-1 : Independent forecasts for Brunei

Forecast	International Monetary Fund (IMF)	Organisation for Economic Co-operation and Development (OECD)	Asian Development Bank (ADB)	International Labour Organisation (ILO)
Real GDP growth (per cent per annum)	2012 at 0.95 2013 at -1.8 2014 at -0.7 2015 at -0.5 2016 at 2.8 2017 at 3.4 2018 at 6.5 2019 at 11.2 2020 at 5.0	2012- n/a 2013- n/a 2014- n/a 2015 at -2.1 2016 at 1.9 2017 at 1.6 2018 at 1.6 2019 at 1.6 2020 at 1.6	2012 at 0.9 2013 at -2.1 2014 at -1.2 2015 at -1.5 2016 at 0.8 2010-2020 at 1.8 2020-2035 at 1.6	n/a
Population growth (per cent per annum)	Individual years from 2012-2019 ranging from 1.4 to 1.8	n/a	2010-2020 at 1.6 2020-2035 at 1.1	Individual years from 2013-2030 declining from 1.3 to 0.8
Labour force growth (per cent per annum)	n/a	n/a	n/a	Individual years from 2013-2020 declining from 1.5 to 1.1
Notes	Medium term growth supported by infrastructure construction and downstream projects	Medium term challenges to develop private sector for diversification	Sluggish growth of major trading partners	Data used is limited to population and labour force numbers only
Source	*World Economic Outlook (WEO) database, April 2015 (IMF 2015)*	*Economic Outlook for Southeast Asia, China and India – special supplement 2015 (OECD 2015)*	*Asian Development Outlook 2015 and APEC/ADB Energy Outlook (October 2013)*	*ILOSTAT database (ILO 2014b)*

7.2.1 Total factor productivity (TFP)

In the forecast closure, TFP was imposed and real GDP was implied from the forecast shown in Table 7-1 with the help of BRUGEM. We used some existing studies as a guide, as well as the model, to estimate the values of overall TFP that needed to be imposed, based on a GDP growth forecast.

TFP encompasses all factors of production and we could use the GDP income side equation (Equation 7.1), where K, L, A are capital (inclusive of natural resources), labour and a variable representing the levels all primary factor technology. Equation (7.2) is the percentage change form of Equation (7.1). The S terms are shares of labour and capital, with $S_L + S_K = 1$. By rearranging Equation (7.2), we derived the components of labour productivity $(y-l)$ namely TFP and a second term generally referred to as "capital deepening"[23].

$$GDP = \left(\frac{1}{A}\right) * f(K, L) \qquad (7.1)$$

$$y = S_L l + S_K k - a \qquad (7.2)$$

$$\underbrace{y - l}_{\textit{labour productivity}} = \overbrace{S_K(k-l)}^{\textit{capital deepening}} - \underbrace{a}_{\textit{TFP}} \qquad (7.3)$$

The OECD (2001) has come up with several measurements of TFP with the main productivity measures as shown in Table 7-2. In the context of modelling, the multi-factor productivity (MFP) is equivalent to the TFP in BRUGEM. In this forecast simulation, we focussed on the TFP.

Table 7-2: Overview of main productivity measures

Type of output measure	Type of input measure			
	Labour	**Capital**	**Capital and labour**	**Capital, labour and intermediate inputs (energy, materials, services)**
Gross output	Labour productivity (based on gross output)	Capital productivity (based on gross output)	Capital-labour MFP productivity (based on gross output)	KLEMS multifactor productivity
Value added	Labour productivity (based on value added)	Capital productivity (based on value added)	Capital-labour MFP productivity (based on value added)	-
	Single factor productivity measure		Multi-factor productivity (MFP) measure	

Source: OECD (2001, p.13)

[23] Capital deepening refers to the increase in the economy's capital stock relative to its workforce (capita per worker) which will raise output.

TFP can be measured using a parametric approach with a specific production function estimated statistically, or a non-parametric approach that is often index-based using observation of data points to compute these efficiency indices. There is very little econometric estimation of the overall TFP annual growth rate for Brunei to provide some guidance. There are some past studies on Brunei's overall productivity by Kao (2013) and on its labour productivity by the APO (2013). However, we needed the overall TFP for the forecast simulation.

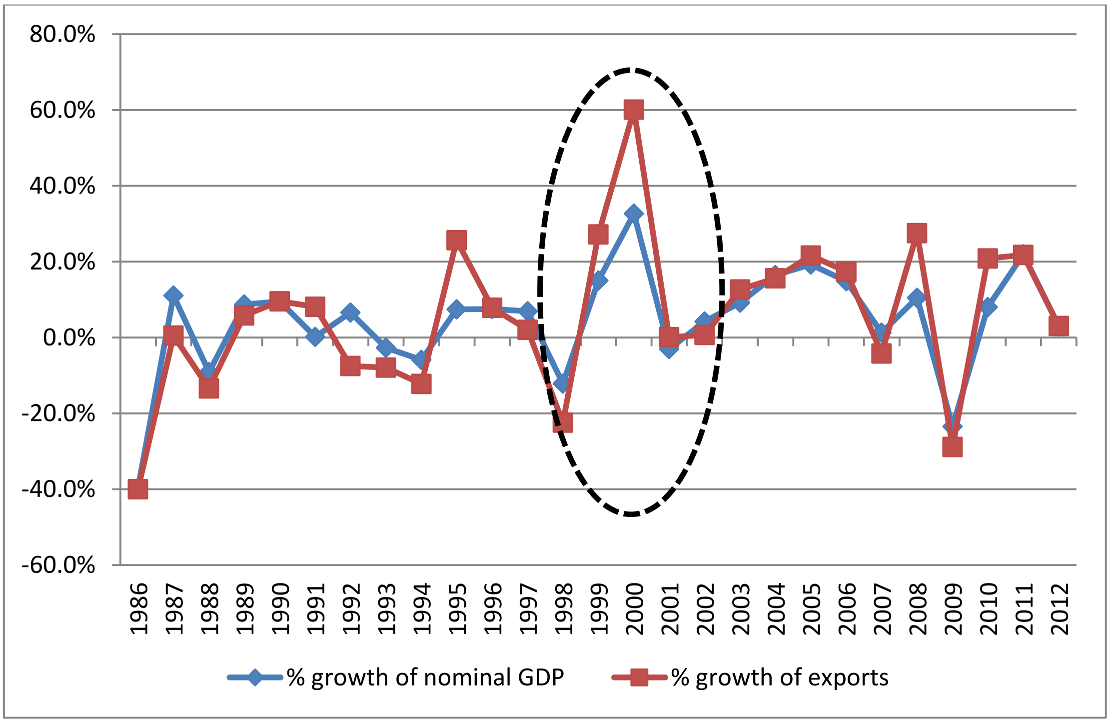
Kao (2013) used the non-parametric or index number approach and data for the period 1999 to 2001. He took an average of the three years' results to obtain a single productivity measure for ten Southeast Asian countries, including Brunei, as shown in Table 7-3 below. Kao converted the capital and labour inputs into monetary terms. The Brunei national productivity measure over the period 1999 to 2001 was US$1.265 of output for every US$1 of input and was above average in the ASEAN for that period. However, the data range used by Kao (2013) was limited to three years from 1999 to 2001 and this period registered high nominal GDP growth after recovering from the crisis of the late 1990s, as shown in Figure 7-2. GDP growth was highly variable in this period. It started with negative growth of 12.2 per cent in 1998 and became positive at 15 per cent in 1999. GDP further increased to 32.7 per cent in 2000 before falling to negative 3 per cent in 2001. The GDP growth was driven by the export growth (mainly oil and gas), which was also highly variable (see Figure 7-2). This makes the productivity estimates calculated by Kao (2013) unreliable. These static estimates are good for comparing the productivity between countries but not year-to-year growth in productivity for any single country.

Table 7-3: GDP per capita, national income per capita and productivity measures for ASEAN countries for the period 1999-2001

Country	GDP per capita (US$)	National income per capita (US$)	Labour productivity (US$)	Capital productivity (US$)	National productivity (US$)
Malaysia	3715	3390	2.0485	7.5788	1.6126
Indonesia	701	613	1.9635	6.8356	1.5253
Philippines	971	1033	2.0608	5.5311	1.5014
Singapore	22530	22180	2.1368	3.3499	1.3046
Brunei	12555	14094	2.0443	3.3213	1.2654
Myanmar	279	300	1.3215	8.5372	1.1444
Cambodia	261	293	1.3228	6.5391	1.1002
Thailand	1985	1997	1.4465	4.5450	1.0973
Laos	312	258	1.3255	4.5096	1.0244
Vietnam	401	383	1.2152	3.5660	0.9063
Average			1.6885	5.4315	1.2482

Source: Kao (2013)

Figure 7-2: Nominal GDP and export growth rates from 1986 to 2012



Note: The dotted line indicated the period covered in Kao's (2013) study

Kao's study provides some indication of the historical productivity figures for Brunei but is inconclusive for forecasting purposes. Consequently, BRUGEM is used to derive the range of economy-wide all-factor technological change required to develop the baseline forecast, applying the historical simulation technique.

As shown in Table 7-1, there have been different forecasts for Brunei's real GDP growth rates. Since we required a longer time frame for the forecast simulation, some assumptions were made for the period 2036 onwards until 2040, a point at which data are no longer available.

The Brunei statistical office published the actual real GDP growth rates for the first three years of the forecast period 2012 to 2014 (see Table 2-1 and the last column of Table 7-4) using a new base year of 2010 (DOS 2014c). The sudden drop in 2013 reflected a decline in oil and gas production by 7.2 per cent; and the non-oil and gas sector grew by 2.7 per cent in real terms (DOS 2014a). The large contraction in the energy sector was due to longer than expected maintenance of hydrocarbon facilities (IMF 2014a). In 2014, the GDP contracted further with the continuing maintenance of oil facilities affecting output. In addition to the reduced exports, falling oil prices since June 2014 (Statista Inc. 2015) also impacted export earnings for the period 2014 to 2015.

Current forecasts by the IMF are optimistic, despite the existing situation. The IMF expects Brunei's economy to pick up with the expansion of infrastructure and downstream petrochemicals projects, as explained in Chapter 2, which will support growth of between 4 to 5 percent over the medium term (IMF 2014a). The ADB produced a more modest forecast up to 2016 (ADB 2013, 2015). Another 2013 report by the Asia-Pacific Economic Cooperation (APEC) and ADB (2013) placed the medium to long term GDP forecast for Brunei at an average of 1.8 per cent per annum, falling to 1.6 per cent per annum after 2020. The OECD (2015) expects that, over the period 2017-2019, the Brunei economy will grow at an average of 1.6 per cent, as shown in Table 7-1. The ADB qualified its forecast figures for Brunei, arguing that the prospect for growth in the future hinged on the timing of several large projects. These projects were discussed in Chapter 2.

For the years 2012 to 2014, actual GDP data were used. For year 2015 onwards, since the three main sources of forecast data are quite diverse, we used a simple average of these three in the BRUGEM forecast simulation, as shown in the last column of Table 7-4. These numbers were derived by taking into consideration actual published data and reports that indicate the various large-scale projects will all be completed over the period 2017 to 2019.

Table 7-4: Real GDP forecasts from available forecasts and computed averages

Real GDP growth rate (per cent)	International Monetary Fund (IMF)	OECD	Asian Development Bank (ADB)	Assumed real GDP forecast
2012	0.95	n/a	0.9	0.9 (actual)
2013	-1.8		-2.1	-2.1 (actual)
2014	-0.7		-1.2	-2.3 (actual)
2015	-0.5	-2.1	-1.5	-1.36
2016	2.8	-1.9	0.8	0.55
2017	3.4	1.6	1.8	2.26
2018	6.5	1.6	1.8	3.3
2019	11.2	1.6	1.8	4.85
2020	5.0	1.6	1.8	3.86
2021-2035	n/a	n/a	1.6	1.6
2036-2040			n/a	1.6

The GDP forecast figures shown in Figure 7-3 were used to estimate the underlying overall productivity growth to establish a long term pattern for Brunei's economic growth based on the expert forecasts. Using a similar technique to historical simulation, the GDP was made exogenous and shocked with the forecast GDP growth rates to estimate the economy-wide productivity in BRUGEM.

Figure 7-3: GDP forecasts from different sources and the computation of average forecast values

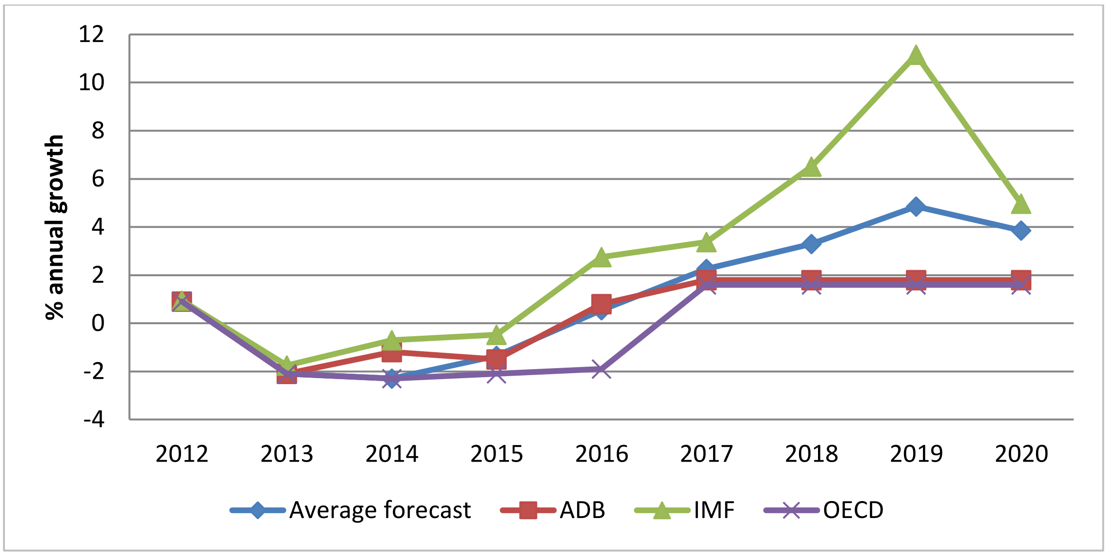


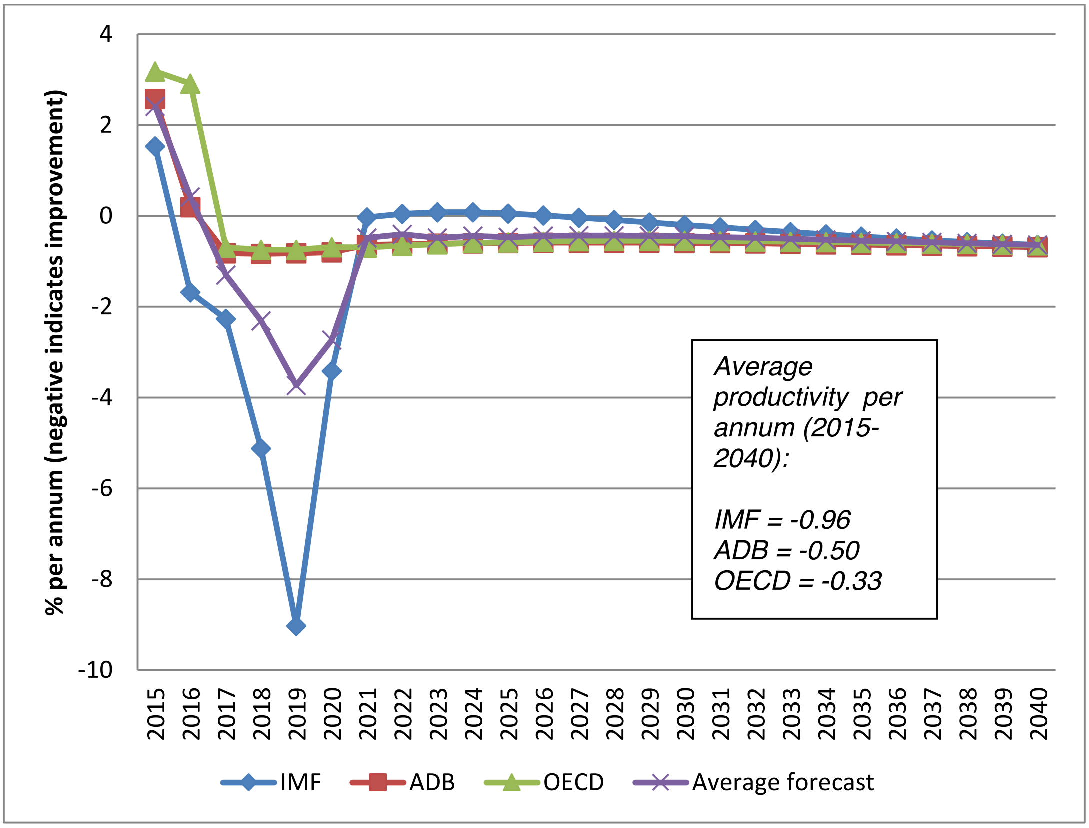
Table 7-5 shows the overall productivity estimated for 2012-2020, based on the available GDP forecast. Figure 7-4 indicates the productivity for the longer forecast period of 2015-2040, where real GDP growth of 1.6 per cent per annum was assumed for the period 2036-2040 (as forecast data was not available) based on the APEC/ADB 2013 forecast up to 2035 and the same growth rate onwards (see Table 7-4).

Table 7-5: Results of overall productivity (per cent per annum) using actual (2012-2014) and forecasted real GDP figures (2015-2020)

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	Ave.
Average forecasts	0.00	3.18	3.41	2.41	0.42	-1.30	-2.31	-3.73	-2.73	-0.07
IMF	-0.05	2.81	1.75	1.53	-1.68	-2.27	-5.12	-9.03	-3.42	-1.72
OECD	0.00	3.18	3.41	3.18	2.92	-0.69	-0.74	-0.75	-0.70	1.09
ADB	0.00	3.18	2.26	2.57	0.19	-0.82	-0.83	-0.82	-0.80	0.55

Note: Negative values indicate improvement

Figure 7-4: Economy-wide technical progress based on the different GDP forecasts for 2015-2040



Note: Negative value indicates technological improvement

The average overall productivity shown in the last column of Table 7-5 in the first row appears low. This is due to the shorter period of forecast from 2012 to 2020, which includes a period of technical regression in the years 2013 to 2015. The negative real GDP growth rates generating the low productivity were due to the unexpected long delay in the maintenance of hydrocarbon facilities. However, for the longer forecast period, the average productivity growth ranged between 0.33 and 0.95 per cent per annum (see Figure 7-4). The calculated average was dependent on the length of the forecast period and some judgement was required to determine plausible economy-wide productivity.

Based on other observations of the economy and on-going or planned projects, as described in Chapter 2, it was assumed that the overall productivity of the future economy would eventually pick up. From the range of TFP estimated (see Figure 7-4), a modest 0.5 percent per annum of underlying productivity growth was assumed as a reasonable estimate in the baseline forecast for Brunei's economy.

7.2.2 Population and labour data

Besides capital and TFP, overall GDP growth is also driven partly by productivity of the labour force, as highlighted in Equation (7.3) in Section 7.2.1. Demographic variables, such as population, are key determinants of the labour force. A population forecast was imposed in the forecast simulation. The population and labour force figures themselves are not important per se but, in the forecasting simulation, they drive the aggregate employment from the supply side of GDP that will affect economic growth. To accommodate the aggregate employment estimate, the corresponding economy-wide real wage was endogenised in the forecast closure (see Table 7-11).

I needed to have a plausible forecast for employment that could be calculated using the forecasts available on population and labour force. This is explained below in Sections 7.2.2.1 and 7.2.2.2.

7.2.2.1 Population

This section discusses the available population forecast. The ILO provides estimates and projection figures for the Brunei labour force up to the year 2020 and population forecasts up to 2030. The ILO has two labour statistics databases: LABORSTA and ILOSTAT, with the latter now replacing the former. The LABORSTA data on Brunei was incomplete, so forecast data were also obtained from ILOSTAT for labour force (from 2013 to 2020) and for population (from 2013 to 2030) (ILO 2014b).

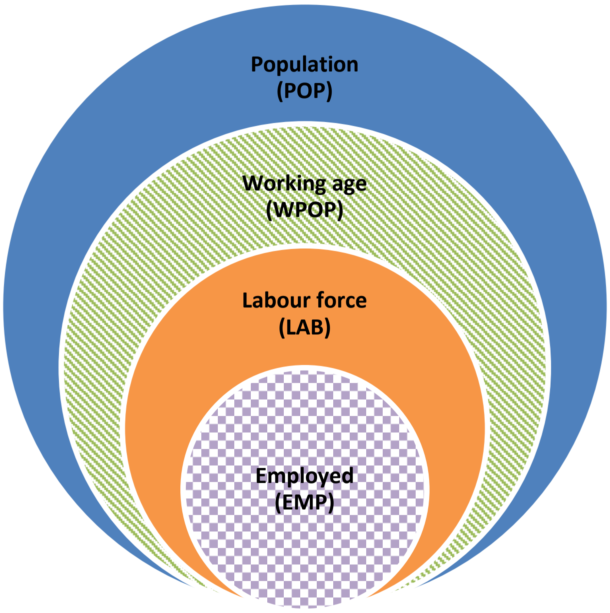
The ILO forecasts that Brunei's population will reach 499,400 by 2030 with population growth declining slowly from a current rate of 1.4 per cent in 2014 to 0.83 per cent in 2030. However, despite a similar population level in 2000, the UN has produced a long term forecast that suggests that the population will reach 685,000 in the year 2050, with an average annual growth rate of 1.44 per cent for the 50-year period from the year 2000 (UN 2004). This average annual growth rate is much higher than that provided in the ILOSTAT database.

For the period 2011-2014, actual population figures provided by DOS were imposed in the forecast simulations. From 2014 onwards, forecast data from specialist organisations were used, including information from IMF, ADB, ILO and the UN. Given the disparity of population forecast rates by these international bodies, I decided to follow the more conservative ILO predicted growth rate from 2015 onwards.

Future population growth was expected to be lower because of the following. A declining birth rate would depress the rate of growth of the incumbent population. In addition, recent policies have been directed at cutting foreign labour quotas for certain occupations (Kasim 2015b, Thien 2015). These, coupled with the implementation of Syariah Law in 2014 (Othman 2014, Bandial 2014b), might result in emerging new trends of emigration. More foreigners may leave. This will also compound the present problem of the “brain drain”, with the younger generation of Bruneians preferring to live and work abroad upon completion of their overseas studies (Han 2013) to seek better opportunities (Haji Roslan 2011, Kamit 2013, Koo 2014b). These observations support the lower population growth rate in the forecast.

The relationship between population (POP), working age population (WPOP), labour force (LAB) and employed persons (EMP) is illustrated in Figure 7-5.

Figure 7-5: The relationship between population, labour force and employed persons



The relationship between population, labour force, employment and labour participation rates can be explained using Equations (7.4) to (7.9). The labour force participation rate is the percentage of the labour force in the population. The labour force is defined as the total number of people who are willing and able to work. The unemployment rate is the percentage of people in the labour force who are not employed.

Equation (7.4) in levels and Equation (7.5) in percentage change form show that the employed person growth rate (*employ)* is expressed as the sum of the growth rate of employment (*employrate*) and labour force growth rate (*lab*).

Equation (7.6) shows the relationship between the employed and unemployed growth rate in levels and Equation (7.7) in percentage change, where *d_unemploy* is the change in unemployment rate. The ratio of employed persons to labour force (*EMP/LAB*) is one minus the unemployment rate, so if the unemployment rate is 9.3 per cent, then the employed ratio is 90.7 per cent.

Equation (7.8) expresses the labour force in various components in levels form. Equation (7.9) shows that the labour force growth rate (*lab*) is a function of the labour participation rate (*ppr*), working age population growth rate (*wpr*), and population growth rate (*pop*), in percentage change form.

$$EMP = (EMP / LAB) * LAB \quad (7.4)$$

in percentage form: $employ = employrate + lab$ (7.5)

$$EMP / LAB = (1 - UNEMPLOY) \quad (7.6)$$

in percentage form $\rightarrow employrate = -d\_unemploy * 100(LAB / EMP)$ (7.7)

$$LAB = (LAB / WPOP) * (WPOP / POP) * POP \quad (7.8)$$

in percentage form $\rightarrow lab = ppr + wpr + pop$ (7.9)

To determine the growth rate of employed persons (*employ*), I needed to forecast the unemployment rate and use what is known about the labour market. This is explained in the following section.

7.2.2.2 Labour force

To work out the plausible forecast for employment to be used in the forecast simulation, some information about labour participation rates and unemployment rates in addition to labour force growth are needed. DOS only had labour force and unemployment data for the year 2011, which was the last year of the labour force survey. For the remaining years, we used forecast data from the ILO.

The ILO's labour force projections were based on the product of forecasted population and projections of labour force participation[24]. The average labour force growth rate for Brunei for 2015-2020 was forecast as about 1.46 per cent (ILO 2014a), which is higher than the forecast average population growth of 1.68 per cent per annum.

[24] The ILO uses a two-step procedure, mechanical and judgemental approaches, to project the labour force participation rate for the period 2013-2020 using information and data released by regional and national institutions. Details of the methodology used are described in the report (ILO 2013).

The unemployment rate reported in ILOSTAT for 2011 was 1.7 per cent, which is significantly lower than the official figure of 9.3 per cent (DOS 2014a). The ILOSTAT figure did not appear to be correct given Brunei's published past unemployment rates (DOS 2014b), as shown in Table 7-6. Therefore, for the purpose of computation, the 2011 data published by DOS was used instead. The national labour force survey was conducted every 10 years in Brunei, with the year 2011 being the latest. A joint report by the DEPD and ILO revealed the reduced unemployment rate of 6.9 per cent in 2014.

Table 7-6: Unemployment rate in Brunei since 1981

Year	1981	1986	1991	1995	2001	2011	2014
Unemployment rate (per cent)	3.6	6.1	4.7	4.9	7.2	9.3	6.9

Source: DOS (2012a), DEPD & ILO (2015)

By assuming that Brunei has a natural rate of unemployment rate in the long run when the economy has reached its full capacity, the long term growth rate of the aggregate employment can be estimated. Brunei shares similar socioeconomic structures and characteristics with GCC countries, including a growing population; a large public sector predominantly employing locals; large wage differentials between private sector and public sector jobs; and a large pool of foreign workers. We could gauge Brunei's long term unemployment rate from the experience of these GCC countries. However, as pointed out in a study done by Al-Qudsi (2006), this is not a clear-cut, as the long run unemployment rate is correlated to, and subject to, cyclical shocks induced by deviations of the output gap[25] (*g*), as illustrated in Table 7-7.

[25] The output gap is the difference between the actual output and potential output of an economy. Potential output is the maximum amount of goods and services that can be produced when the economy is at its most efficient and productive full capacity.

Table 7-7: Comparison of GCC long run unemployment rates

GCC country	Long run unemployment rate (%)	Add-on with output gap(g)
Bahrain	2.67	+2.79*g
Kuwait	1.89	+1.15*g
Oman	4.69	+5.41*g
Saudi Arabia	3.29	+2.29*g
UAE	1.88	+2.26*g

Source: Al-Qudsi (2006)

In the absence of studies on Brunei's output gap, it was assumed that in the long run the economy would be operating at the maximum level of output and there would be no output gap. It was also assumed that Brunei has a NAIRU, representing the equilibrium state between the economy and the labour market, a point at which inflation is not expected to rise. The NAIRU is sometimes referred to as the natural rate of unemployment. However, the value of NAIRU is hard to measure because it changes over time, depending on the shocks that the economy experiences, which can affect inflation and unemployment (Ball & Mankiw 2002). Therefore, an assumption of the value of NAIRU was necessary. Based on the above long run unemployment rates of the GCC, as shown in Table 7-7, a conservative estimate would be 5 per cent for Brunei's NAIRU rate. This was then set as the targeted medium term (until 2020) unemployment rate from the 2011 level, as shown in Table 7-8. After this natural rate of unemployment is reached, it is assumed that there is no further change in unemployment rate.

There will always be some level of unemployment in Brunei, despite government efforts to reduce it. Most of the unemployed are locals, as foreigners are typically hired with valid working visas. The labour department keeps a tight control over the issue of labour quotas for certain professions[26] due to the increasing unemployment rate, preferring employers to hire locals over foreigners wherever possible (Kasim 2015b,

[26] The government is taking steps to cap the influx of foreign workers with 7,839 unused foreign labour quotas revoked (Kasim 2015b) and has confined the recruitment of foreign workers to five industrial sectors (commerce, retail and wholesale trade; the hotel industry, restaurants and eateries; transportation, storage and communication; social services, personal and community services; and finance, insurance and legal services (Thien 2015).

Thien 2015). The government has been seen as actively working on appropriate policies to promote the private sector employment of locals by implementing specific skills training to improve locals' employability. With these efforts, the unemployment rate is not expected to escalate and the long run value of NAIRU is assumed to reach 5 per cent in the medium term.

Some other information are needed to work out the other labour market related variables, based on the Equations (7.4) to (7.9), to generate the results in Table 7-8. The ILO has population and labour force forecasts from 2012 to 2030, after which it is assumed that both the population and labour force would stay the same, at 0.83 per cent per annum. For the years 2012, 2013 and 2014, we used the actual population growth rates (DOS 2014a, 2015).

Since there was no forecast for employment and labour force after 2030, it was assumed, for the sake of simplicity, that there would be no change in the ratios of labour force to working age population (*LAB/WPOP*) and working age population to total population *(WPOP/POP*) from 2031 onwards. This implies that *ppr* and *wpr* are zero, leaving the labour force supply rate to grow in tandem with the population growth rate, as shown in Equation (7.9). Computation of the population and labour force growth rates is shown in Table 7-8.

In Equation (7.9), the future labour participation rate (*ppr*) needed to be determined. It was assumed that this would remain unchanged, based on a few observations. Some new developments may influence the *ppr,* such as the increase in retirement age of workers. In January 2010, the official retirement age was raised from 55 to 60 years for both men and women (DP Mahmud 2009). As this new rule had not been in place for very long before the 2011 labour force survey, the impact on *ppr* due to the new retirement age was likely to be small. People aged 55 and above made up less than 3 per cent of the total employed population and less than 2.9 per cent of the total labour force. Another development was the opportunity to apply for further studies via scholarships, which may have led to some local workers temporarily withdrawing from the workforce. Various scholarship schemes (Han 2007) were offered by both private institutions and government, such as in-service training for existing officers, in the nation's continuous efforts to build human capacity. The nearly "bond-free" scholarship scheme established in 2011 by the DEPD for public sector workers, was extended to local workers in the private sector, including the self-employed (Koo 2014b). This was very attractive to existing workers who may have missed out on earlier opportunities to further their education. Nevertheless, the number of local workers pursuing higher education is unlikely to be significantly large to affect the *ppr* permanently. Therefore, it was assumed that the overall *ppr* would remain unchanged.

Besides the labour participation rate, other factors could also affect the percentage change in Brunei's working population (*wpr*), representing both local and foreign workers. A number of foreign countries, such as the Philippines (Bandial 2015a), who traditionally supply Brunei with workers such as domestic helpers, drivers and gardeners, have been imposing the minimum wage. This affects the demand for, and hiring of, their workers and may result in a preference shift towards workers from other neighbouring countries, such as from Indonesia, who command lower wages. This trend has also been observed in other GCC countries (Ruiz 2013). Overall the growth rate of foreign workers was assumed not to vary significantly.

In summary, given the dynamics in the labour market, it was assumed that the overall labour participation rate and the proportion of working age to total population would remain largely unchanged.

Table 7-8: Computation of population and employment growth rates

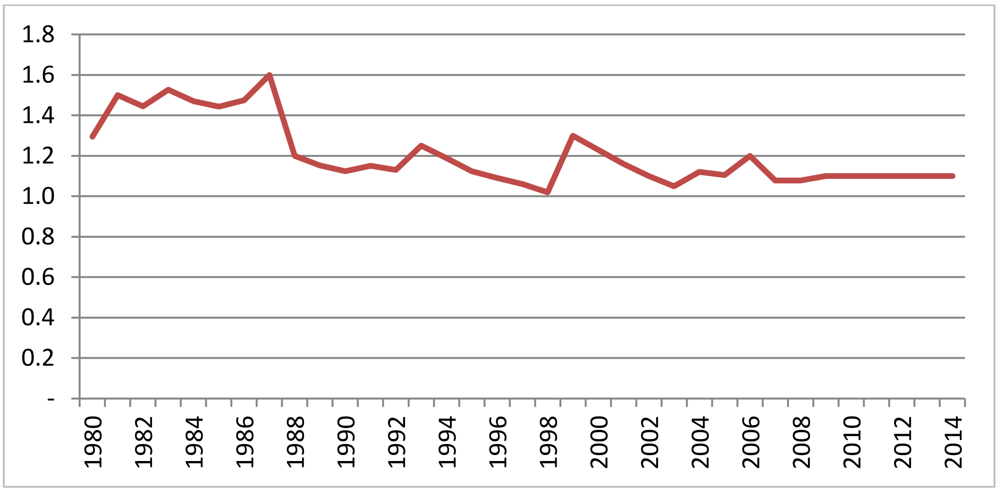
Year	Unemployment as % of labour force	d_unemploy % change	Population# ('000 persons)	pop# (%)	Revised population^ ('000 persons)	Revised pop^ (%)	Labour force^('000 persons)	lab(%)	EMP/LAB = 1-UNEMPLOY	employ% = -d_unemploy *100/(EMP/LAB) + lab
2011	9.3		406.5	1.47	393.37		201.5	0.88	0.907	
2012	8.50	-0.80	412.2	1.40	399.80	1.63	202.20	0.35	0.915	1.22
2013	7.70	-0.80	417.8	1.36	406.20	1.60	202.90	0.35	0.923	1.21
2014	6.90	-0.80	423.2	1.29	411.90	1.40	203.6	0.34	0.931	1.20
2015	6.58	-0.32	428.5	1.25	417.06	1.25	205.5	0.95	0.934	1.29
2016	6.27	-0.32	433.8	1.24	422.22	1.24	207.5	0.94	0.937	1.28
2017	5.95	-0.32	439	1.20	427.28	1.20	209.4	0.93	0.941	1.27
2018	5.63	-0.32	444.1	1.16	432.24	1.16	211.3	0.92	0.944	1.26
2019	5.32	-0.32	449.1	1.13	437.11	1.13	213.3	0.91	0.947	1.25
2020	5	-0.32	454.1	1.11	441.97	1.11	215.2	0.91	0.950	1.24
2021	5	0	459	1.08	446.74	1.08	217.1	0.90	0.950	0.90
2022	5	0	463.8	1.05	451.42	1.05	219.1	0.89	0.950	0.89
2023	5	0	468.5	1.01	455.99	1.01	221.0	0.88	0.950	0.88
2024	5	0	473.2	1.00	460.56	1.00	222.9	0.87	0.950	0.87
2025	5	0	477.8	0.97	465.04	0.97	224.8	0.87	0.950	0.87
2026	5	0	482.3	0.94	469.42	0.94	226.8	0.86	0.950	0.86
2027	5	0	486.7	0.91	473.70	0.91	228.7	0.85	0.950	0.85
2028	5	0	491.1	0.90	477.99	0.90	230.6	0.84	0.950	0.84
2029	5	0	495.3	0.86	482.07	0.86	232.6	0.84	0.950	0.84
2030	5	0	499.4	0.83	486.07	0.83	234.5	0.83	0.950	0.83
Beyond forecast data availability, assuming no change in the labour ppr, so labour force growth = population growth which is assumed to stabilise at 0.83% growth p.a.										
2031-2040	5	0		0.83		0.83		0.741	0.950	0.83

Note: The variables in column headings are taken from Equations (7.4) to (7.9) in Section 7.2.2.1
#based on ILO figures
^based on ILO and DEPD figures

7.2.3 Simulating the decline in oil and gas reserves

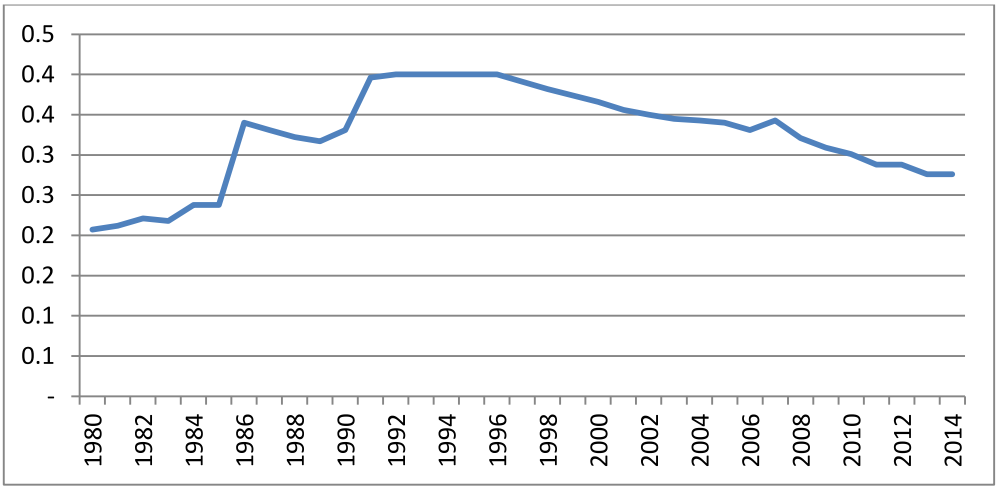
In the baseline forecast, I needed a plausible scenario for the depletion of oil and gas reserves and hence the rate of decline in oil and gas production. Based on BP data on proven reserves, there appear to have been no significant large oil finds to boost the reserves since 2006 (see Figure 7-6). Similarly, there has been no addition to the natural gas proven reserves since 1999 (see Figure 7-7). The government has exercised a conservation policy to prolong the productive capacity, through which no upward trend of production has been observed since 2011 (see Figures 7-8 and 7-9).

Figure 7-6: Brunei's crude oil proven reserves in thousand million barrels



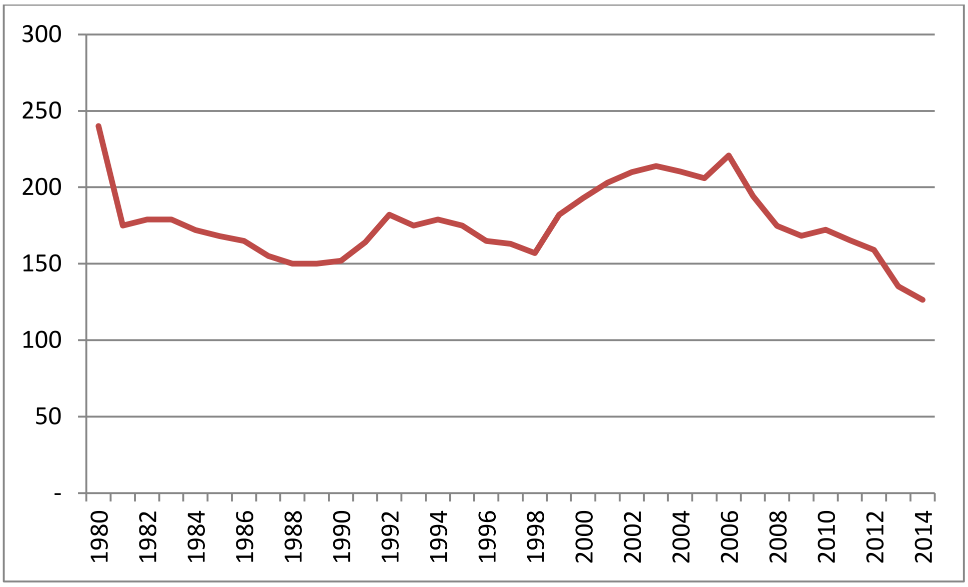
Source: BP (2015)

Figure 7-7: Brunei's natural gas proven reserves in trillion cubic metres



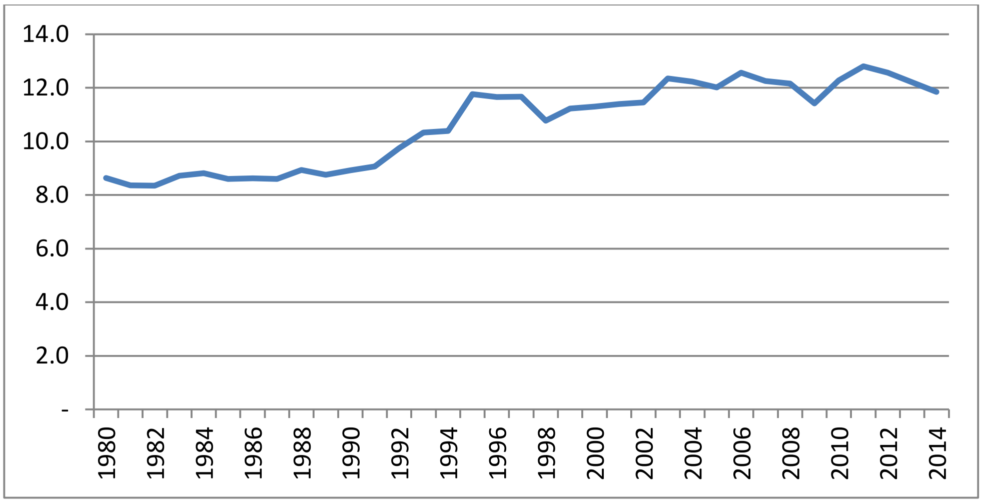
Source: BP (2015)

Figure 7-8: Oil production in barrels per day



Source: BP (2015)

Figure 7-9: Natural gas production in billion cubic metres



Source: BP (2015)

Given that there are no official data on reserves for Brunei, BP data were used for this thesis. As discussed earlier in Section 2.2, based on the level of proved reserves[27]

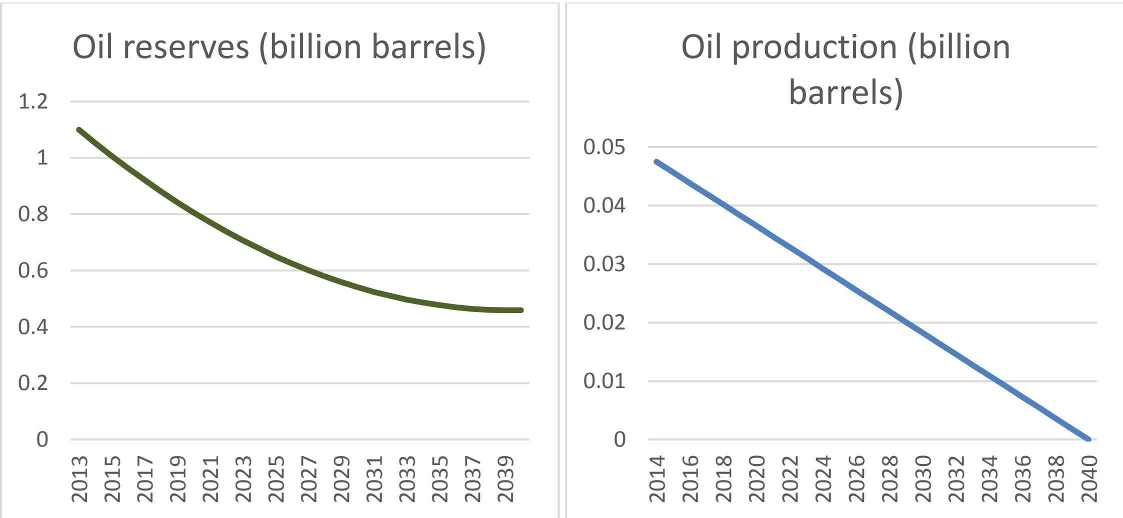
[27] BP defines "proved reserves" of oil as generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and geological conditions.

and rate of production in 2014, oil and gas will not last beyond 2038 without significant new finds.

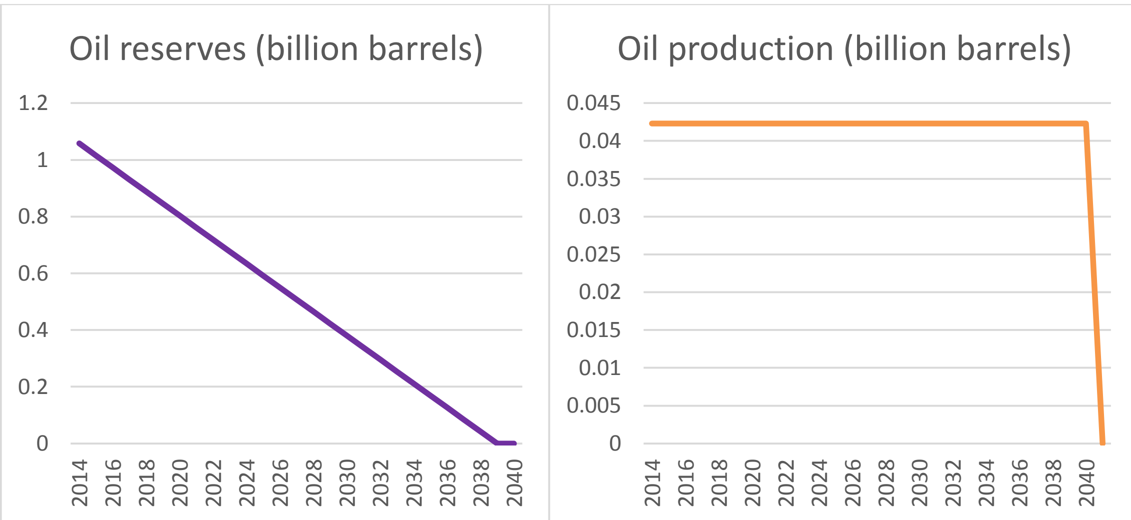
To create depletion for the baseline scenario, I needed to assume the path of hydrocarbon decline for the baseline. As shown in Figure 7-10, the oil production level can decline via different paths, such as declining linearly (Path 1) or geometrically (Path 2). In turn, the choice of path will influence the pattern of oil reserves depletion. The depletion path for natural gas was assumed to be similar to that for oil.

Figure 7-10: Different paths of oil (and gas) depletion

Path 1



Path 2



Path 1 shows a gradual pattern of reductions in production over the years as extraction of oil becomes more expensive due to the increasing difficulty of mining marginal deposits. Path 2 represents constant production until a sudden halt in 2040. Unlike in Path 2, in Path 1 the level of reserves never reach zero. There will always be some reserves remaining in the ground that are not extracted due to technological, geological or economic reasons. From an economic point of view, policymakers may wish to leave some in the ground, whether fully extractable or not, due to high extraction costs. Given the current rate of production, with the government trying to conserve reserves from the maturing oil and gas fields, Path 1 is a more likely scenario for Brunei than Path 2. For the purpose of this thesis, the Path 1 depletion pattern was used and shocks were computed.

To calculate the decline, it was assumed that 5 percent of oil and gas reserves would be left by the year 2040, compared to 2011. An average annual shock of 10 per cent per annum was computed for the simulation period 2012 to 2040 using the Formula (7.10) below, where *g* is the annual growth (or decline) rate, *t* is number of years, and *z* is the final percentage we want to achieve:

$$g = z^{\frac{1}{t}} - 1 \qquad (7.10)$$

In this scenario, the variable *x1lnd* for the use of land or natural resources (as a proxy for reserves) received a negative shock of 10 percent every year from 2012 to 2040.

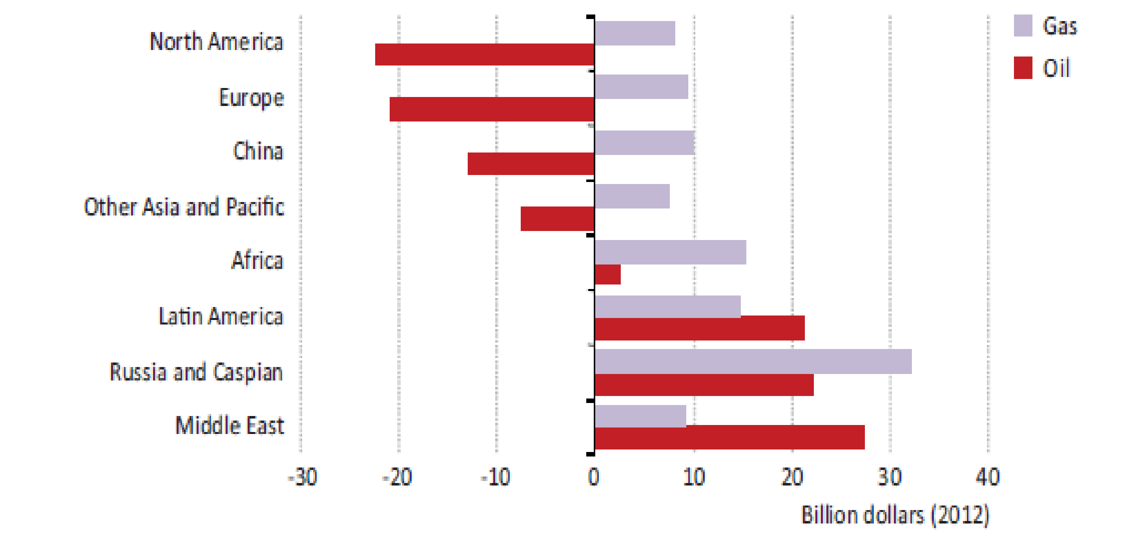
7.2.4 Simulating the fall in investment for the oil and gas sectors

With the oil and gas reserves depletion, it was expected that the overall aggregate investment would also decline over the long term.

If the prospects for the capital intensive oil and gas industries in Brunei were not promising, given the maturing oil and gas fields, no large investments would be likely to occur in the future. This is in line with the trend forecast made by the World Energy Investment Outlook (International Energy Agency 2014), in which the average annual investment on upstream oil projects was expected to tail off for the Asia and Pacific region for the period 2014 to 2035 (see Figure 7-11). On the other hand, upstream natural gas expenditure was expected to increase in the Asia and Pacific regions. In the absence of strong evidence that new oil and gas reserves would be discovered in Brunei, the BP forecast (BP 2015) was used to compute the investment decline in both oil and gas sectoral investments.

In the forecast simulation, investments in oil and gas were assumed to decline over the period 2012-2021, bringing investment levels down to 1 per cent of their 2011 levels by 2021. It was assumed that there would be no further change to investment in the hydrocarbons sector after 2021.

Figure 7-11: Change in average annual upstream oil and gas investment by regions



Note: The figure shows the change in spending between the annual averages for 2014-2020 and 2031-2035.

Source: World Energy Investment Outlook (2014, p. 60)

7.2.5 Oil and gas prices

The main source of forecasts for oil and gas prices is the World Bank Commodity Markets Outlook report (World Bank 2013b, 2015a), which forecasts up to 2025. The Organization of the Petroleum Exporting Countries (OPEC) (2014) has also produced assumptions for oil prices, forecasting a price of US$100 per barrel by 2035 (constant 2013 dollars) and a price US$102 per barrel by 2040.

The World Bank provides forecasts up to 2025. For the period 2026-2040, we assumed that oil prices would decline while gas prices would stabilise at their 2025 levels. Details are provided in Table 7-9.

OPEC does not produce forecasts for gas prices and although they produce forecasts for oil prices for the period 2026-2035, these are not used due to the different base year and methodology applied when compared to the World Bank's forecasts. For consistency of forecast data, in this thesis we used the World Bank's forecast as a single data source for both oil and gas, measured in 2010 dollars. The assumptions for hydrocarbon prices in the later years of the forecast period were derived by taking a few factors into consideration, discussed below.

The World Bank forecasts a declining trend in annual growth rate up to 2025 for oil prices. Our assumptions thereafter simply continued that trend by cutting the growth rate gradually. As for the price of gas (LNG), this was not expected to increase further after the forecast price plateaus in 2025, taking into account supply and demand factors. After producing a vast quantity of fracked shale gas recently, the United States of America (USA) is likely to emerge as a new exporter of LNG (Anderson 2015), thus competing in the global market. On the other hand, there are limited alternatives to gas as a fuel in heating and electricity generation (EIA 2015). Therefore, it is assumed that the supply and demand factors would offset one another, to some extent, leading to little change in LNG prices after 2025.

Table 7-9: Forecast of oil and LNG gas prices in 2010 US dollars

Commodity	Crude oil annual average spot		LNG (Japan) annual average spot	
Real 2010 prices	US$/barrel	% change	US$/MMBtu	% change
2012	87.1	2.96	13.8	15.97
2013	98.1	12.63	15.0	8.70
2014	90.9	-7.59	15.1	0.01
2015	50.3	-44.70	11.4	-24.50
2016	53.1	5.57	11.3	-0.88
2017	55.8	5.08	11.3	0.00
2018	58.6	5.02	11.3	0.00
2019	61.6	5.12	11.3	0.00
2020	64.8	5.19	11.3	0.00
2021	68	4.94	11.3	0.00
2022	71.5	5.15	11.3	0.00
2023	75.1	5.03	11.3	0.00
2024	79	5.19	11.2	-0.88
2025	83	5.06	11.2	0.00
2026*	87.1	5.00	11.2	0.00
2027*	90.6	4.00	11.2	0.00
2028-2040*	n/a	3.00	11.2	0.00

Source: World Bank (2013b, 2015b) for 2012-2025 and author's own calculations based on assumed growth rates of oil and gas prices from 2026-2040

7.2.6 Government accounts

As discussed in Section 2.1, most of Brunei's government revenue is derived from the oil and gas sectors, so the decline in oil and gas production for exports will have a significant impact on the fiscal capacity of the government.

The oil and gas revenues comprise of taxes, dividends and royalties collected from the oil and gas sectors. The oil and gas firms are subject to a 55 per cent corporate tax rate (OBG 2013). Therefore, in the absence of changes to policy, the future growth of the Brunei oil and gas revenues will be linked directly to the size of the oil and gas sectors, as shown in the Equation (3.86) in Section 3.3.8.1. Given the decline in oil and gas production, the associated revenues will also fall.

Another source of government income is the collection of corporate taxes from companies outside the oil and gas sectors. There are three different types of companies in Brunei: sole proprietorships, partnerships and private limited companies in each industry. All three types of companies are liable to pay corporate income tax to the government.

The current non-oil corporate tax rate is low. It was reduced from 27.5 per cent in 2008 to 18.5 per cent in 2015 (see Table 7-10), as stipulated in section 35 of the *Income Tax Act 2013*. Although there is provision in the Act to charge corporate tax on companies, it appears that at present, not all companies in Brunei are paying corporate taxes. The amount of taxes on net income and profits collected from non-oil companies reported in the government revenue accounts (DOS 2012a, 2014a) over the years have been lower than expected, based on the tax rates shown in Table 7-10.

Using 2010 as an example, the non-oil and gas businesses generated a combined operating revenue of B$16.6 billion (DOS 2013a). If we consider generous operating expenses and allowable deductions of say, 40 per cent to derive total taxable income of B$9.96 billion, a 23.5 per cent tax rate should generate an estimated revenue of B$2.34 billion. However, for the financial year 2010/2011, the amount of non-oil corporate tax collected was only B$531.85 million or less than 23 per cent of the expected revenue collection (DOS 2012a). There are several possible reasons for the low collection, which are discussed below.

Table 7-10: Corporate tax rates in Brunei

Year of assessment	Corporate tax rate
2008	27.5%
2009	25.5%
2010	23.5%
2011	22%
2012-2014	20%
2015 onwards	18.5%

Source: Ministry of Finance (2015)

As of 2010, about 97.5 per cent of the total number of active companies in Brunei were SMEs, each hiring fewer than 100 workers (DOS 2013a). In 2012, new thresholds were introduced to reduce the tax liabilities of SMEs further (OBG 2013). It is very likely that many SMEs had annual profits below the tax threshold and hence, they were not paying taxes. The lower than expected level of corporation tax revenue might also be due to the generous tax incentives provided to some companies. The government actively provided long tax breaks of between 5 to 11 years for pioneer status companies (BEDB 2015). Given these observations, the corporate tax revenue was not expected to generate significant income for the government in the years to come. The contribution of corporate tax to total government revenue also grew slowly from 3.2 per cent in 2005/2006 to about 4.9 per cent of total government revenues for 2012/2013.

Therefore, for the forecasting simulations in the short to medium term, it was assumed that there would be no significant changes to the existing tax code. The government was also unlikely to reverse their policy of having low corporate tax rates. With attractive corporate tax rates, the government hoped to encourage the private sector to grow (Koo 2014c), as well as and more FDI, with foreign companies helping to diversify the economy in the longer term.

In BRUGEM, it was assumed that the growth rate of the tax revenues derived would be linked to the growth rate of these non-oil and gas sectors of the economy, as shown in Equation (3.87) in Section 3.3.8.1. Forecasts for other components of government revenue and expenditure were generated by BRUGEM, as explained in Section 3.3.8.1 in Chapter 3.

7.2.7 The stock and interest rate on net foreign assets

In order to track net foreign assets for Brunei, data on the stock of net foreign assets was needed. This was obtained from the Monetary and Financial Statistics published by the AMBD (IMF 2014b). The possible interest rates for future periods were also required. Since there was no published forecast of the rate of interest on net foreign assets (at the time of writing, Brunei had no foreign debt), a conservative 2 per cent[28] annual return on foreign assets was assumed, since the investment portfolio would cover a wide range of assets.

7.3 Developing the baseline forecast

Two baseline forecasts were developed to study the impact of oil and gas depletion on Brunei's economy. In both forecasts, we incorporated the growth rates in population and aggregate employment (Table 7-8) from the forecast discussed in Section 7.2.2. The forecasts in overall technological change (see Section 7.2.1), oil and gas reserves, investment and prices (see Sections 7.2.3 to 7.2.5) were also incorporated. For both baseline forecasts, the government spending was treated as exogenous.

In the first scenario, the government takes no action to stimulate other industries while facing the decline in oil and gas production. The results present the outcome for the Brunei economy in the face of oil and gas reserves depletion with the natural progression of population growth and technical change.

The second scenario was built on the existing policy direction, with the government making an effort to diversify (see Chapter 2 for a detailed explanation). Current diversification efforts include stimulating new industries, such as methanol, petrochemicals, manufacturing, and pharmaceutical industries, as well as boosting physical infrastructure. Since there were no known quantitative studies to track or measure the effects of these efforts, some reasonable assumptions had to be made to

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[28] Since AUD1.00=B$0.99 as of 6/11/15 (www.oanda.com), I chose Australia's interest rate of 2 per cent as a proxy to what can be earned on Brunei's net foreign assets. See http://www.fxstreet.com/economic-calendar/world-interest-rates/ (viewed 11/4/15)

produce this baseline forecast. As per the discussions in Section 2.4, the industries that were too small to contribute GDP growth were excluded from the stimulation.

The development of the two different baseline forecasts are discussed in Sections 7.3.1 and 7.3.2 below.

7.3.1 Baseline Scenario 1 - no diversification policy in place

In the first scenario, it is assumed that the government does nothing in the face of the oil and gas sectors continued decline, as illustrated in the BP forecast.

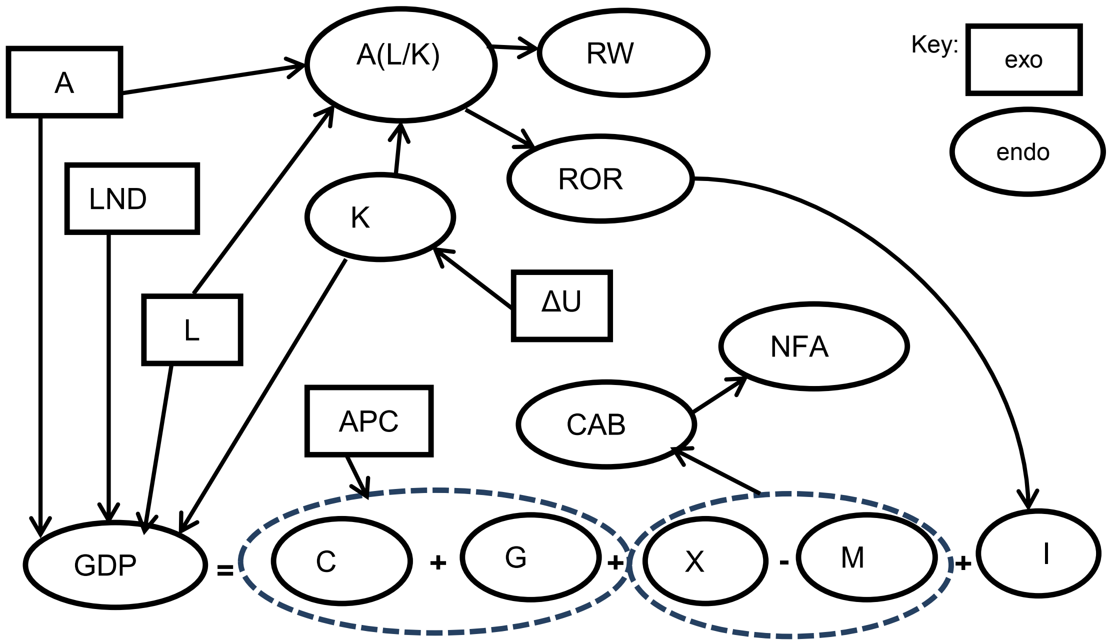
7.3.1.1 Forecast closure and shocks for Scenario 1

Based on the overall simulation design presented in Section 7.1.1 and the discussion on data and value of shocks in Section 7.2, we implemented this forecast simulation using the forecast closure, as shown in Figure 7-12. This forecast closure is similar to a conventional or natural long run closure. The same notations were used as for the BOTE model, shown in Figure 5-3. Additional variables were: the changes in land (LND, which was included in the definition of K in BOTE), net foreign assets (NFA), current account balance (CAB) and *delUnity* (ΔU) to activate capital accumulation. The arrows in Figure 7-12 indicate the direction of change driven by the variables.

The RW and ROR were driven via BOTE Equation (8), as shown in Figure 5-3. ROR in turn drove the aggregate investment via BOTE Equation (7). The average propensity to consumer (APC) variable was exogenous and drove the aggregate consumption function in this closure via Equations (3) and (4) shown in Figure 5-3.

CAB was determined as a residual in the GDP identity equation, which in turn drove the NFA, as defined in Equation (3.172) in Chapter 3. The exogenous macro variables that were shocked were: productivity (A), land (LND) and aggregate employment (L), as explained in earlier sections, as well as the *delUnity* variable. The relationships between these macro variables, as shown in Figure 7-12, are described in the theoretical part of Chapter 3.

Figure 7-12: Year-on-year dynamic forecast closure in baseline Scenario 1



The swap statements that were necessary to facilitate this forecast simulation are shown in Table 7-11.

Table 7-11: Summary of exogenised variables and swaps for the forecast simulation

	Variables to which shocks were implemented (exogenous in forecast closure)	Corresponding structural variables (endogenous in forecast closure)
1	Aggregate employment (determined from population forecast)	Overall wage shifter
2	Overall primary-factor augmenting technological change (determined from expert forecast)	Real GDP (implied)
3	Sector-specific investment for expanding industry and declining industry	Sectoral-specific investment rule shifter
4	Oil and gas export price in foreign currency	Oil and gas export demand price shifter
5	Sector-specific activity level or output for declining industry	Price of other cost tickets shifter for garment sector Land use variable for oil and gas sector

7.3.1.2 Simulation results of Scenario 1

If the government made no effort to diversify and simply let the oil and gas sectors falter away, the expected results would be dire, even if the population and aggregate employment continued to grow at the forecast growth rate. The following paragraphs describe the simulation results.

With the fall in the main exports of oil and gas, real GDP growth declines sharply. Through to 2031, the average annual growth in real GDP would fall by 5.5 per cent per annum. The cumulative fall by 2031 would be 68 per cent. Other components, such as private consumption and investment (see Figure 7-13) would also decline. The government spending did not change since it was treated as exogenous (Section 7.3). Private consumption exhibited a short-lived increase in 2013 due to the strong TOT effect, coupled with real appreciation (see Figure 7-14), with the high oil and gas prices observed that year.

On the supply side, despite a positive population growth, the real wage collapsed by about 20 per cent annually (see Figure 7-15). Within the framework of the model, this scenario shows that aggregate employment would continue to grow despite declining employment opportunities. To accommodate the growth in aggregate employment, the real wage would fall to such an extent that by 2032, it would be close to zero (see Figure 7-15). This result was considered unlikely, as almost certainly aggregate employment would fall via a decrease in population or a rise in unemployment. Any decrease in population would take place via migration. This sets up the justification for an alternative as the baseline forecast - Scenario 2 as described in Section 7.3.2.

Figure 7-13: Real GDP and other expenditure components (Scenario 1)

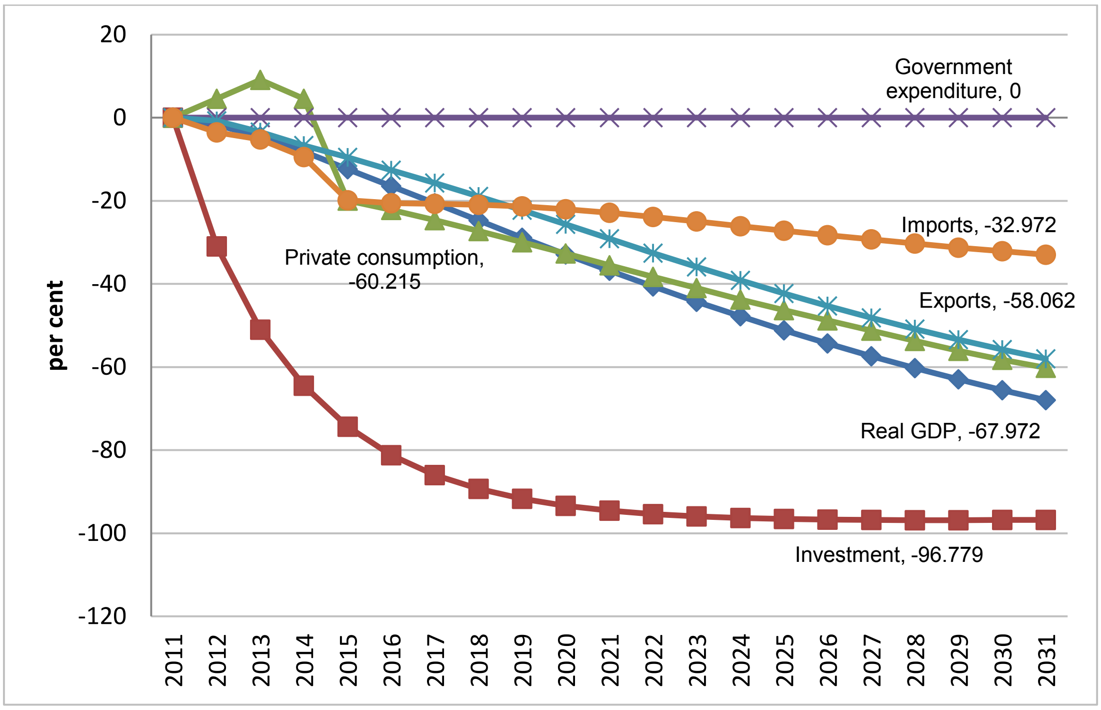


Figure 7-14: Real devaluation and terms of trade (Scenario 1)

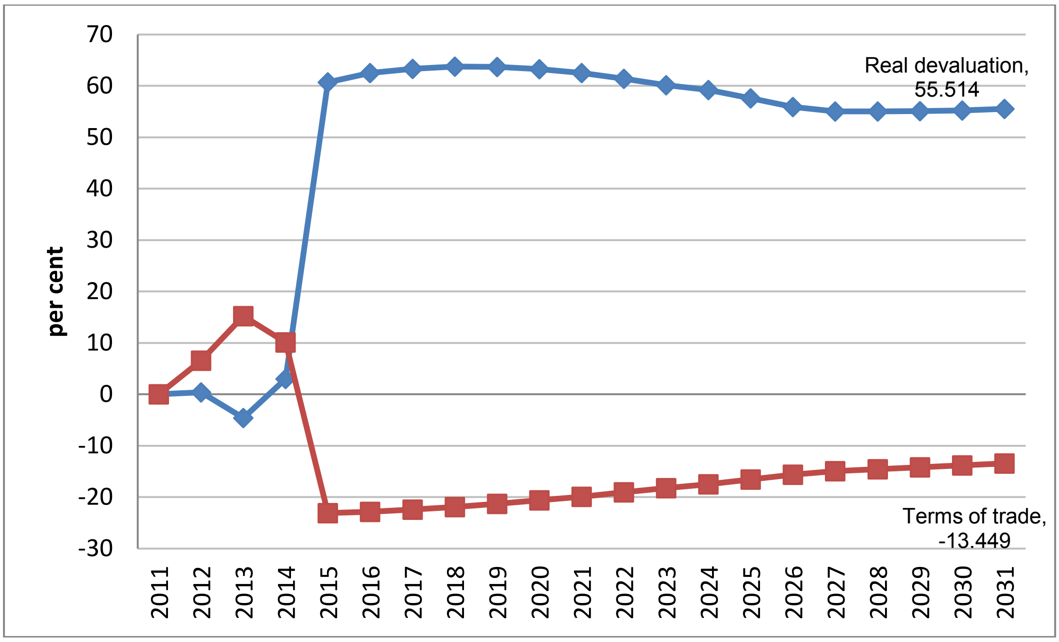
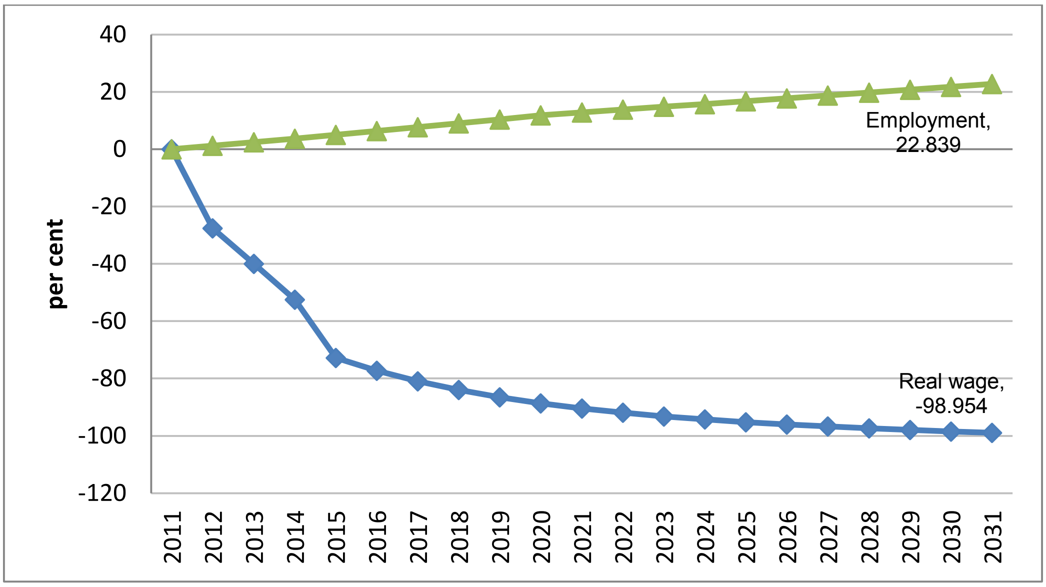
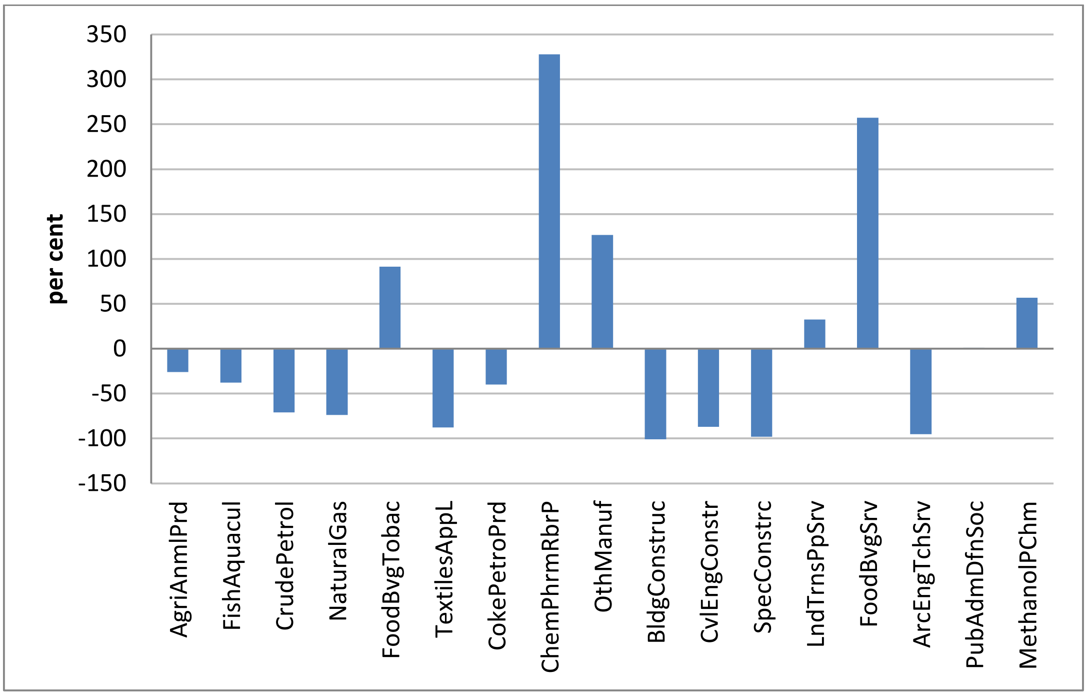


Figure 7-15: Aggregate employment and real wage (Scenario 1)



In terms of activity level by sector (see Figure 7-16), most industries would decline, with the exception of a few that appear to survive the oil and gas adverse shocks. The devaluation of the Brunei currency has helped to stimulate the small amount of exports some industries may have. These industries are chemicals, chemical products, pharmaceuticals, other manufacturing, food and beverage, textiles, and electrical equipment manufacturing. Industries that performed badly in the forecast are the construction of buildings, civil engineering and specialised construction industries, impacted as investment and capital stocks fall. In summary, the fall in the real wage benefits labour intensive industries and puts the capital intensive industries at a disadvantage. Export-orientated industries, such as land transport and pipeline services, would benefit from the real devaluation of currency.

Figure 7-16: Selected sectoral industry outputs in 2031 (Scenario 1)



7.3.2 Baseline Scenario 2 - some actions taken to offset the decline

Unlike Scenario 1, Scenario 2 was built on the inclusion of some diversification efforts, with a slight modification to closure and shocks. This is explained in Section 7.3.2.1.

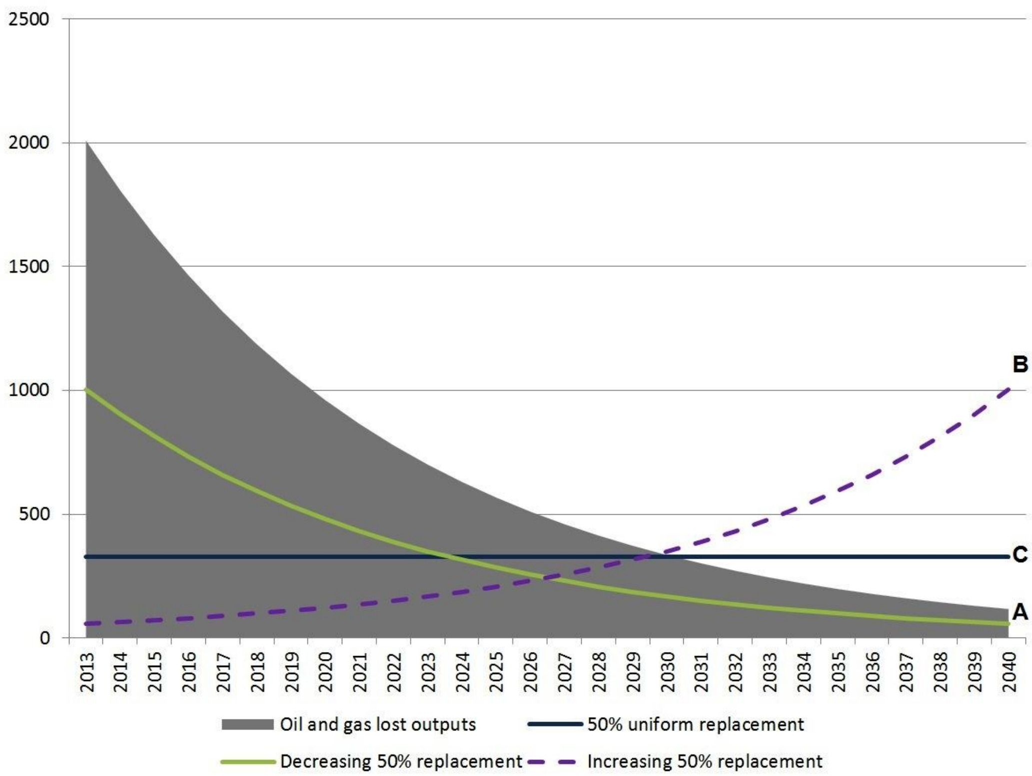
Based on current on-going development projects, eight selected industries, including the government sector, were given demand side stimulus as part of Brunei's diversification efforts. The lost output from oil and gas, based on a decline of 10 per cent per annum, would be around B$19,044 million from 2012 to 2040. It was assumed that half of the oil and gas outputs in dollar value would eventually be replaced by the selected industries between 2012 and 2040, with an allocated replacement value as shown in Table 7-12. The stimulus was accommodated in the modelling via demand side shifts relating, in part, to government demand.

Table 7-12: Replacement industries for the lost output from oil and gas sectors

Code	Industry	Replacement value (B$ mil)
CokePetroPrd	Manufacture of coke and refined petroleum products	948
ChemPhrmRbrP	Manufacture of chemicals, chemical products, pharmaceuticals, rubber and plastic products	38
BldgConstruc	Construction of buildings	1518
CvlEngConstr	Civil engineering	1138
SpecConstrc	Specialised construction activities	1138
ArcEngTchSrv	Architectural and engineering activities, technical testing and analysis	948
PubAdmDfnSoc	Public administration and defence, compulsory social security	2276
MethanolPChm	Methanol and petrochemicals	1518
	Total	9522

After determining the replacement values, I needed to consider how the replacement would take place in the simulation design. This would enable the appropriate shock values to be calculated. Figure 7-17 shows the three possible replacement paths of the stimulated industries. Path A shows that most replacement would take place in the beginning and then decrease towards the end of the forecast period. Path B represents the opposite, with most replacement taking place in later years. Path C indicates uniform shock across the years 2012 to 2040 where each year the selected group of industries has an equal likelihood of replacing the lost output. All three paths would achieve the same outcome of 50 per cent replacement of the lost outputs from oil and gas.

Figure 7-17: Alternative replacement paths of lost oil and gas outputs



The decreasing replacement Path A was not considered plausible because of the existing state of diversification and the lack of empirical evidence to suggest a high replacement ratio. The increasing replacement Path B was also not considered achievable given that the selected industries for diversification, such as the methanol and petrochemicals industries, rely heavily on oil and gas as inputs that would deplete over time. It is highly unlikely that more of these outputs would be produced unless Brunei imported oil and gas in order to keep these downstream industries growing. Therefore, a uniform replacement Path C was considered the most plausible option as it would allow diversification to take place over the same period with equal likelihood occurring in any year.

The government sector was stimulated because it was expected to grow in terms of expenditure. In the past, the government has assisted its people by providing subsistence allowances (Malai Hassan 2012). Should the standard of living fall drastically as the hydrocarbon sectors decline, it is likely that the government would step in to assist. As discussed in Sections 2.5 and 2.5.1, the government has a large pool of financial assets and reserves through various funds, including SWF. Therefore, the hypothetical case was modelled in such a way that government expenditure would continue to increase into the future in several plausible forms. This would consist of cash transfers to households; expansion of government services; continued extensive subsidies; skills retraining programs to equip the local workforce with the right skills in the new industries; cash incentives to encourage more take-up of private sector jobs through various schemes, such as the Training and Employment Scheme (Haris 2015); building more infrastructure for better connectivity between Brunei and its trading partners; and building more industrial parks or developing industrial zones to create new economic activities.

To simulate the expected increases in the government's future expenditure, in the Scenario 2, the government demand shift variable, which was exogenous, was given a positive shift outwards. This represents an increase in government expenditure on public services. Uniform annual shocks on the other seven industries (see Table 7-12) were implemented by exogenising a miscellaneous other demand variable (proxied by inventory demand in Table 7-13) and shifting demand out to accommodate the necessary expansion in output of the targeted industries.

7.3.2.1 Forecast closure and shocks for Scenario 2

In view of the simulation results discussed in Section 7.3.1.2, which show an unrealistically sharp decline in the real wage, an alternative baseline forecast was developed with a controlled fall in the real wage. The closure was the same as that shown in Figure 7-12, with two additional swap statements (see Table 7-13) to control the real wage decline and create a demand side shift for diversification efforts. This was achieved by exogenising the real wage and endogenising population, which is free to move via net migration. The real wage was targeted to decrease by 1 per cent annually. In this scenario, the eight selected industries were stimulated with the appropriate sectoral shocks, as shown in Table 7-12. These industries would replace the lost output from the oil and gas sectors by about half.

Table 7-13: Swap statements for Scenario 2 baseline forecast

	Previously exogenous		Newly exogenous
Swap	*Aggregate employment*	=	*Overall wage shifter*
Swap	*Sector-specific inventory rule shifter*	=	*inventory demand (proxy for demand side factors)*

For the oil and gas sectors, the supply side shocks were revised with resources depleted at 10 per cent per annum for the period 2012 to 2025 and at 5 per cent per annum for 2026 to 2040. This was based on the assumption that the government would control the extraction rate to prolong hydrocarbon production. The associated investment shock values were also halved for the later periods. The yearly oil and gas price shocks were also included and it was observed that oil and gas prices had dropped, in real terms, by an average of 45 per cent and 25 per cent respectively in 2015. The export price variable in foreign currency for oil and gas was exogenised to accommodate the price shocks (see Table 7-11) by swapping with the price shifter in the oil and gas export demand schedule. Both the oil and gas sectors were given zero productivity shocks by ensuring that their all-factor augmenting technological change variables were exogenous with zero value.

The magnitude of the real wage shock was increased to 10 per cent as a “one-off” in 2015 to complement the sudden large negative oil and gas price shocks. The year 2014 was given a negative real wage shock of 2.5 per cent as the oil price had declined sharply toward the second half of the year.

In this scenario, to help stimulate the export-oriented industries, the overall export demand shift variable was given a boost of 3 per cent per annum and a uniform small increase of 1 per cent per annum was given to import prices in foreign currency. This was designed to assist the import competing industries.

The simulation was run until 2040 to produce results based on the existing policy direction. These results are discussed below.

7.3.2.2 Simulation results of Scenario 2

As shown in Figure 7-18, real GDP declined, on average, by 1.8 per cent per annum. While this is still significant, the decline is not as sharp as that observed in Scenario 1. The same temporary increase in private consumption was also observed in 2013 due to the TOT effect and real appreciation of currency (see Figure 7-19). Note that in this scenario government consumption was stimulated, unlike in the first scenario where real government consumption was held at zero change.

The magnitude of the decline in aggregate exports was slightly higher in Scenario 2 than in Scenario 1 as some oil was diverted to stimulate the domestic production of refined petroleum products. Similarly, gas was diverted from export to stimulate the growing domestic methanol and petrochemicals industry. This was based on the assumption that domestically produced oil and gas would be used for the production of these two categories of commodities, since they are readily available.

In the short run, aggregate investment would fall due to the declining oil and gas sectors, which made up 80 per cent of total investment and 80 per cent of total capital stock in the initial database. Aggregate investment would recover gradually in the long run (see Figure 7-18).

Figure 7-18: Real GDP and other expenditure components (Scenario 2)

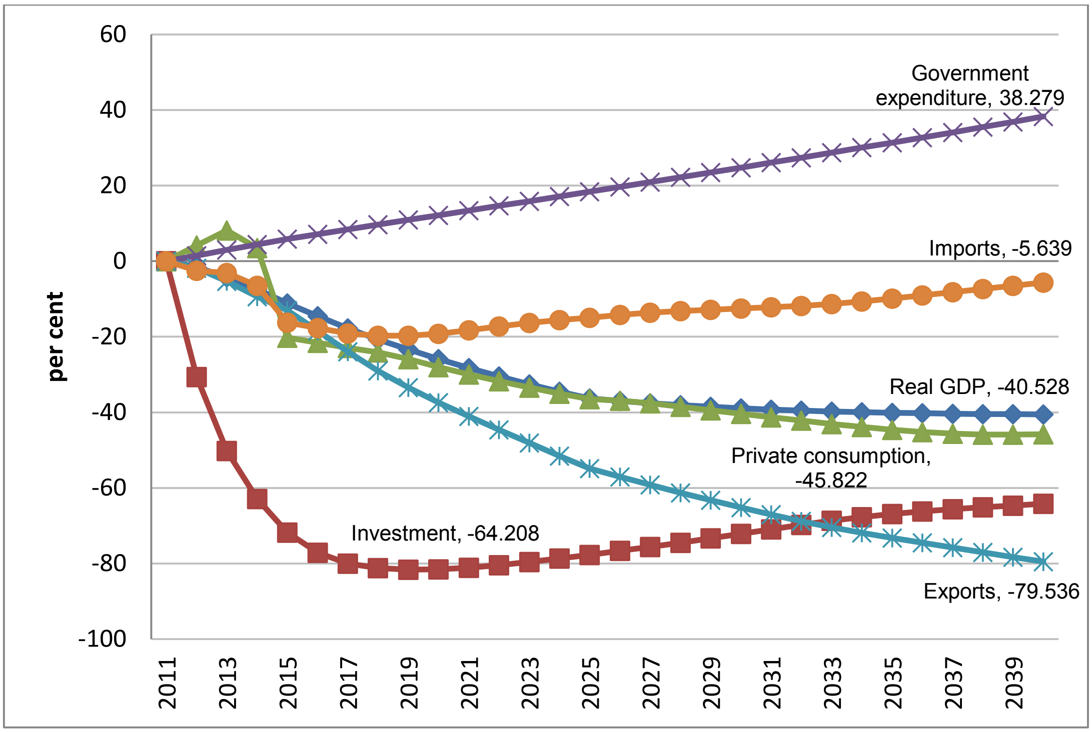
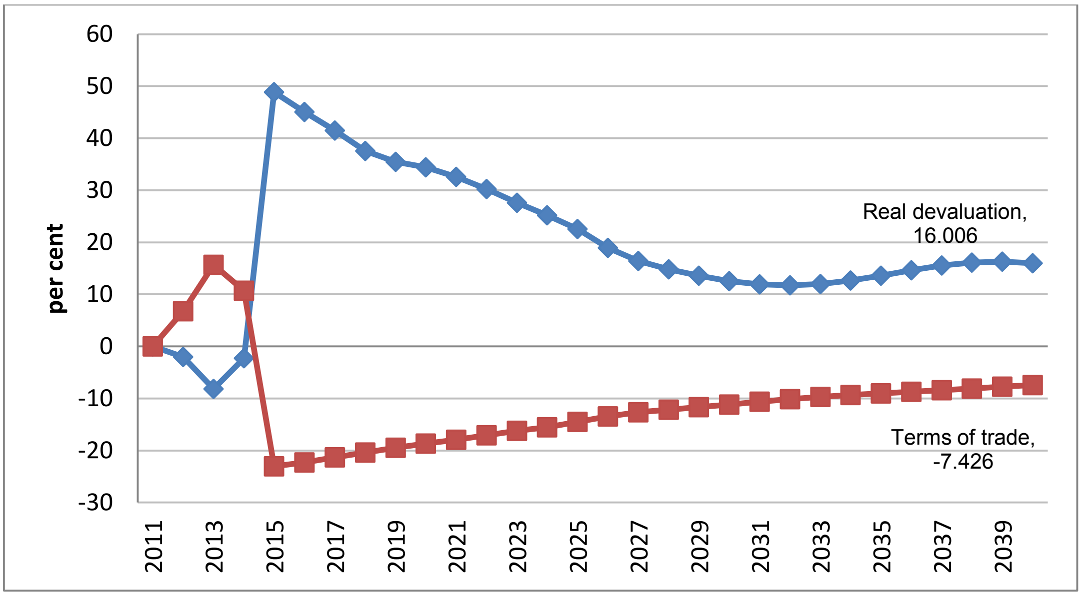
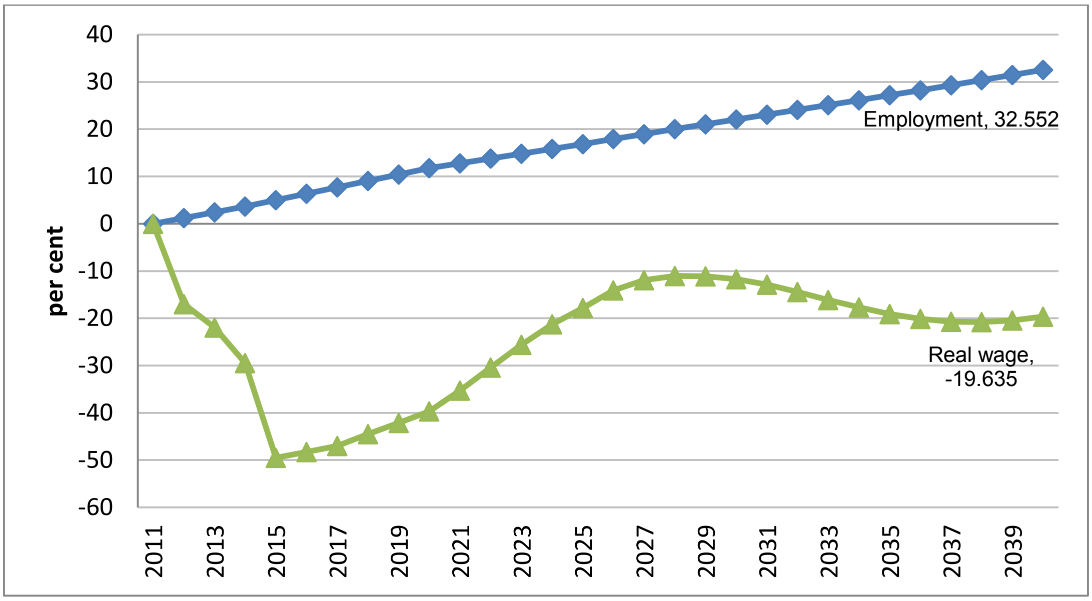


Figure 7-19: Real devaluation and terms of trade (Scenario 2)



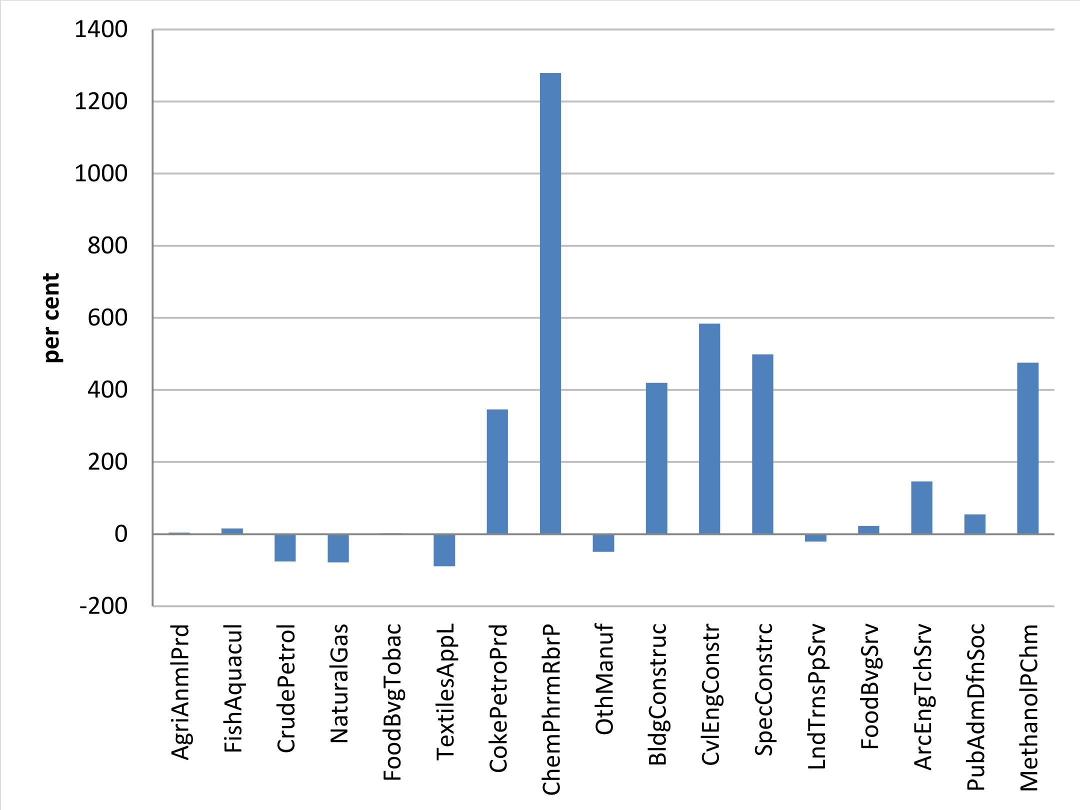
With the controlled decline in the real wage and fixed unemployment, as explained in Section 7.3.2.1, employment would increase in the long run (see Figure 7-20). Four of the stimulated industries - building construction, specialised construction activities, architectural engineering activities and public administrative services - are labour intensive and would absorb more labour as they expanded.

Figure 7-20: Aggregate employment and the real wage (Scenario 2)



Similar to the sectoral results in Scenario 1, in this scenario, real devaluation would benefit industries that export commodities, such as methanol and petrochemicals, chemicals and pharmaceutical products. With the fall in the real wage, labour intensive industries such as agriculture, animal products, fisheries and aquaculture, food and beverages, and architectural engineering would benefit while capital intensive industries would be adversely affected (see Figure 7-21).

Figure 7-21: Selected industrial outputs in 2040



7.4 Conclusions

This chapter has elucidated future scenarios for Brunei's economy. These have been developed in the context of depleting oil and gas resources accompanied by falling real wages and GDP as expected for an economy heavily dependent on hydrocarbons. Two baseline forecasts were developed. In the first scenario, the government implemented no diversification efforts and real GDP declined by 5.5 per cent annually and the real wage by 20 per cent per annum. Although decreases in real wages could boost employment, realistically, as indicated by the Scenario 1 results, significant falls in the real wage were not plausible and the government would be unlikely to do nothing and simply let the standard of living erode. The population would be unlikely to grow with this deterioration in the standard of living, which could lead to migration.

Scenario 2 provides an alternative baseline forecast where the real wage was allowed to fall in a controlled manner. As seen in the Scenario 2 results, the decline in real GDP would be attenuated by the partially successful diversification of the stimulated industries. However, it would not completely reverse the downward trend. These results indicate that more needs to be done.

The main purpose of the forecast simulation was to create a baseline forecast. It was concluded that Scenario 2, based on existing policy directions, was a more plausible baseline forecast. This was therefore used as the reference case to study the impact of policy simulations, as discussed in Chapter 8.

Chapter 8: Scenarios and policy analysis for Brunei's post-hydrocarbon era

A key research objective of this study, as stated in Chapter 1, was to examine the impacts of various policy options designed to prepare Brunei for the post-hydrocarbon era.

As depicted in Figure 3-1, a policy simulation deviated from the baseline path of the economy due to the implementation of new policies or changes to existing policies. Chapter 7 presented two baseline scenarios: one without any diversification efforts being implemented in the face of hydrocarbons depletion and the other with some diversification efforts. For the computations reported in this chapter, we chose the more realistic second scenario to be the counterfactual baseline; given the existing policy direction.

In this chapter, we consider two different policy options. The first policy simulation examines the impact of an overall improvement in productivity, calibrated to create an additional 1 percent real GDP growth from the counterfactual baseline. The second policy simulation considers the effects of additional stimulus by increasing the demand of the products produced by the eight selected industries listed in the second baseline scenario.

Section 8.1 contains a discussion of some of the considered policy options. Section 8.2 examines the impact of introducing productivity improvement with a discussion on the model closure and the simulation results. If existing diversification and policy directions could yield better results in terms of achieving higher levels of replacement for oil and gas lost outputs, we could examine the effects of this as another policy simulation. This is discussed in Section 8.3. Finally, Section 8.4 summarises the discussion on policy options and simulation results.

8.1 Policy options

For the period 2005-2011, Brunei enjoyed an improving TOT and strong productivity growth at 4.62 per cent per annum for the non-mining sector. However, with the reduction of oil and gas outputs, technical regression was observed in the oil sector. For the future, based on the second of the two baseline scenarios reported in Chapter 7, overall productivity was forecast to improve slightly by an average of 0.07 per cent per annum in the medium term (see Table 7-5). In the longer term, productivity growth was forecast at between 0.33 and 0.96 per cent per annum (see Figure 7-4).

Within this context, we considered the government's vision for Brunei's economic future, as explained in the National Vision 2035 statement (see Section 2.2). Based on National Vision 2035 goals, there were three possible avenues that could lead to long run sustainable growth: (1) by increasing productivity, (2) by stimulating exports and (3) by increasing the skilled labour force pool. These options are described in more detail in the following sections.

8.1.1 Productivity improvement

The policy option to grow the economy would be achieved through TFP improvements. There are two main components to TFP: technological progress and technical efficiency change (Färe et al. 1994, Han et al. 2004). Technological progress relates to innovation and changes in technology that shift the technology frontier over time. One example was the introduction of fibre-to-optic broadband to homes around the country, encouraging innovation and productivity through better access to newer ICT. Technical efficiency change relates to the efficiency in the application of the inputs, where more output is produced with the same level of input or less input is required to produce the same level of output. Overall, TFP growth causes an economy to be more productive and more efficient, leading to long term economic growth by raising the potential output.

The link between macroeconomic performance and productivity is widely recognised in the literature (Jorgenson (1991, p. 21) provides a list references). This includes the frequently cited Solow growth model, which predicts that technological progress is necessary for sustainable increase in living standards (Solow 1957). However, no single policy can address this multi-faceted issue of improving TFP productivity to raise economic growth. There are various avenues for improving the efficiency of investment through quality of capital inputs and infrastructure; innovation and knowledge transfer to enhance workers' skills; and implementing microeconomic reforms on institutional and regulatory frameworks to eliminate impediments to productivity and to improve efficiency. However, some factors complement one another and some exist as a pre-condition. For example, Borensztein et al. (1998) pointed out that for a host country to benefit from higher productivity FDI, it must have a minimum threshold stock of human capital, in terms of education level, in order to contribute to economic growth via the FDI channel. It appears that some measures do need to go hand in hand to be effective.

The intention to improve productivity was explicitly stated in Brunei's Tenth National Development Plan, launched in April 2012 (Haji Apong 2013). The government has been working on several productivity-related initiatives, especially in the non-energy sector (Shahminan 2012, Too 2012a). These initiatives include fibre-to-optic broadband to homes in Brunei, as mentioned earlier; building better infrastructure such as roads, bridges for greater connectivity and time-saving; exploring more capital intensive and high value-add types of industries due to the small labour force pool; and investing in human resources for skilled workers and increasing research activities with high commercial values. Some initiatives target technological progress while others seek to improve the efficiency aspect. There are also general measures to provide an enabling environment for these changes to take place.

One such measure is the improvement in technological change through the infrastructure for the financial sector in Brunei. The AMBD has implemented a series of projects, including modernising the national Payment and Settlement System (PSS). The first Real Time Gross Settlement System (RTGS) was launched on 7 November 2014 to enable safe and real-time large-value interbank fund transfers to be carried out between financial institutions (AMBD 2014b). This helps to mitigate settlement risk and improve the liquidity management of financial institutions. Businesses rely on an efficient and safe PSS to carry out financial transactions.

Brunei is attempting to improve its productivity via the second component of TFP, that is, to achieve better efficiency by reducing red-tape and streamlining procedures for businesses. Bureaucracy is often cited as an obstacle to Brunei's progress (Bhaskaran 2007, Crosby 2007, Monitor Group 2003, Voon 1998).

The impact of economy-wide productivity improvement on the economy is examined in Section 8.2.

8.1.2 Stimulation of exports

The second platform for growth is export stimulation. Export-led growth is a policy option that many countries have pursued. There are several econometric studies on the causality of exports and GDP growth (studies such as Balassa 1978, Jung & Marshall 1985, Michaely 1977 cited in Ahmad 2001). A rise in exports should increase the level of GDP but the direction of causality is inconclusive, as pointed out by Ahmad (2001). He concluded that the empirical support for export-led growth in both developed and developing countries was considerably weaker than had been the case in earlier studies. This was due to the observation that the transmission of growth impulses from the export sectors to the rest of the economy is either absent or insufficient to boost overall GDP growth.

As discussed in Section 2.4, Brunei has looked at creating and stimulating alternative exports outside oil and gas, but this has been challenging. Manufactured exports such as methanol are yet to grow sufficiently to counter the declining hydrocarbon exports, while other export-orientated industries, such as manufacturing of chemicals, pharmaceutical products and petrochemicals, remain insignificant.

The economy cannot be expected to grow via increased exports until Brunei has established alternative large exports outside of oil and gas. This is examined in Section 8.3, with the same industries selected in the baseline forecast given a further boost to simulate greater production and therefore more exports.

8.1.3 Increase the skilled labour force pool

Another policy option is to increase the pool of skilled workers. Labour is an important primary factor input for production. As pointed out by the UN (2004), Brunei has a favourable demographic structure for economic growth. Since 2005, Brunei has had a large working age population relative to the number of dependents, with a natural population growth of 1.6 per cent in 2013 and 1.4 per cent in 2014. However, the population is increasing at a declining rate.

Koh (2011) estimated that a labour force growth of 1.3 per cent over the period 2010-2035 would be required to produce economic growth of 3 per cent per annum. Koh (2011) used the assumption that the oil and gas sector would continue to grow at 2.5 per cent and the non-oil and gas sectors at 3.5 per cent per annum in the future. In his analysis, he concluded that if the non-oil and gas growth was greater than 2 per cent per annum, the growth in labour demand would outpace labour supply and Brunei would need to import more foreign labour. Growth in the labour force could help to grow the economy, provided employment could be found.

The unemployment rate was 9.3 per cent in 2011 and declined to 6.9 per cent in 2014 (DEPD & ILO 2015) indicating some growth in employment. However, it was noted that the unemployment rate amongst citizens and permanent residents might have been higher, as temporary residents in the labour force were nearly 100 per cent employed (OBG 2014).

Brunei's economy growth has been supported by the influx of foreign workers over the last few decades, especially when there were mega projects in place to incite new activities. However, most of these people are temporary workers, transient in nature and project-based. As of 2014, temporary residents made up about 27.6 per cent of the total labour force, compared to 36.9 per cent in 2001. With a strict immigration policy and stringent criteria for citizenship and permanent residency in place, it is unlikely that this pool of skilled foreign workers will remain in the country for the long term.

Due to the length of time it takes to train the existing labour force, in some countries, targeted migration policies are put in place to address the shortage of skilled labour and to grow the economy. Singapore, a country without natural resources, relies heavily on its human resources and productivity through the improvement of the quality of its labour force, to maintain competitiveness. It is one case study of success with talented skilled foreigners encouraged to settle as permanent residents (Chia 2001). This may not be the path that Brunei wishes to follow, although the country has embarked on an industrialisation strategy that requires skilled labour. Nevertheless, the Brunei government is not prepared to relax its immigration policy yet, although it has allowed a certain number of residency and citizenship applications every year (Wong & Kassim 2015). The government is concerned about the socio-cultural effects of having too many foreigners in the country and them benefitting from the heavily subsidised utilities, fuel and selected food items (Kamit 2014).

As the government continues its efforts in human resource development and capacity-building for the locals, it is likely that the population will not increase at any rate higher than its existing natural population growth rate. The number of non-local workers may not increase significantly unless there is an increase in the number of new projects that require foreign skilled labour.

An increase in labour force may raise GDP but not necessarily income per person, unless there are accompanying productivity gains. The policy aim should be to improve economic welfare, which is often measured by income per person. Given this observation, for the purpose of this thesis increasing the labour force was not considered a feasible policy option.

8.2 Policy 1 simulation – increase productivity

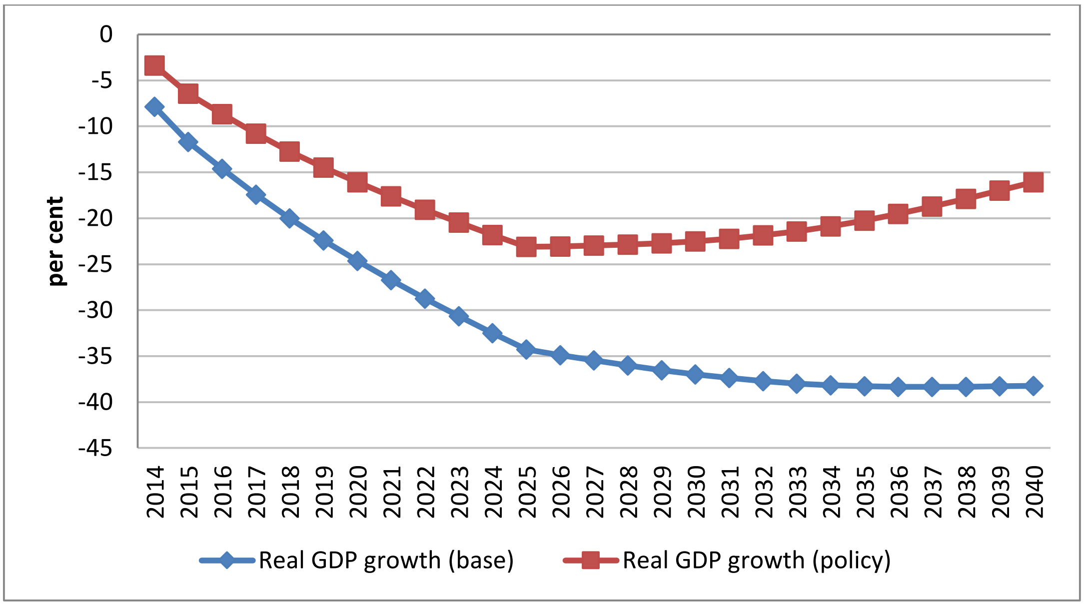
Given the existing national focus on using productivity to boost economic activities and growth, a simulation on overall productivity improvement was implemented. For the purpose of this simulation, the economy-wide all-factor productivity or technical change variable was used, irrespective of whether productivity improvements were derived from technological progress or improved efficiency through less bureaucratic arrangements. The terms all-factor productivity and technical change were used interchangeably in the context of this simulation.

8.2.1 Model closure and the BOTE model

The policy closure is similar to decomposition closure (Dixon & Rimmer 2002) in which naturally endogenous macro variables, such as GDP, aggregate investment and aggregate consumption, stay endogenous and are allowed to respond to the policy introduced. Similarly, naturally exogenous and typically unobservable variables, such as average propensity to consume, taste or preference for imports and technical change, remain exogenous. If there is no policy shock, a policy simulation should generate the same results as the baseline forecast in the forecast simulation (Dixon et al. 2013). Therefore, any differences in the solutions between the policy simulation and baseline forecast are due to the policy shocks implemented.

Since there was no forecast of the expected overall productivity that could be achieved from the on-going activities and microeconomic reforms described in Section 8.1.3, the shock to all-factor augmenting technological progress was calibrated to achieve a modest real GDP growth of an additional one per cent per annum, in addition to the baseline forecast for the GDP. In the baseline, real GDP falls at an average annual rate of 1.8 per cent. Thus in the policy case, real GDP falls at an average annual rate of 0.8 per cent for the whole period from 2014-2040. Figure 8-1 shows the improvement brought about by productivity with steadily increasing deviation in real GDP growth from the baseline.

Figure 8-1: Base case and policy paths of real GDP growth (cumulative per cent)



A BOTE model similar to the equations shown in Figure 5-3, but expressed in percentage form, can help us interpret the simulation results. The stylised BOTE model is described in Appendix 6-2 (see Figure 3), with variables in lowercase representing percentage change. This represents a simplification of the underlying dynamic model. It omits most of the details of BRUGEM, including the dynamic relationships and land (or natural resources). For reference, the same BOTE model shown in Figure 3 (see Appendix 6-2) is reproduced here in Figure 8-2. The associated closure for this policy simulation is shown as the year-on-year closure after the BOTE model in Figure 8-1 and illustrated at macro variables level in Figure 8-2.

When the BOTE model was used to analyse the impacts of the policy under question, we used a year-on-year closure in which capital stock and labour were exogenous. The remaining six exogenous variables were: technical change, average propensity to consume, income tax rate, nominal exchange rate, import price in foreign currency and real government expenditure (see Figure 8-2 closure).

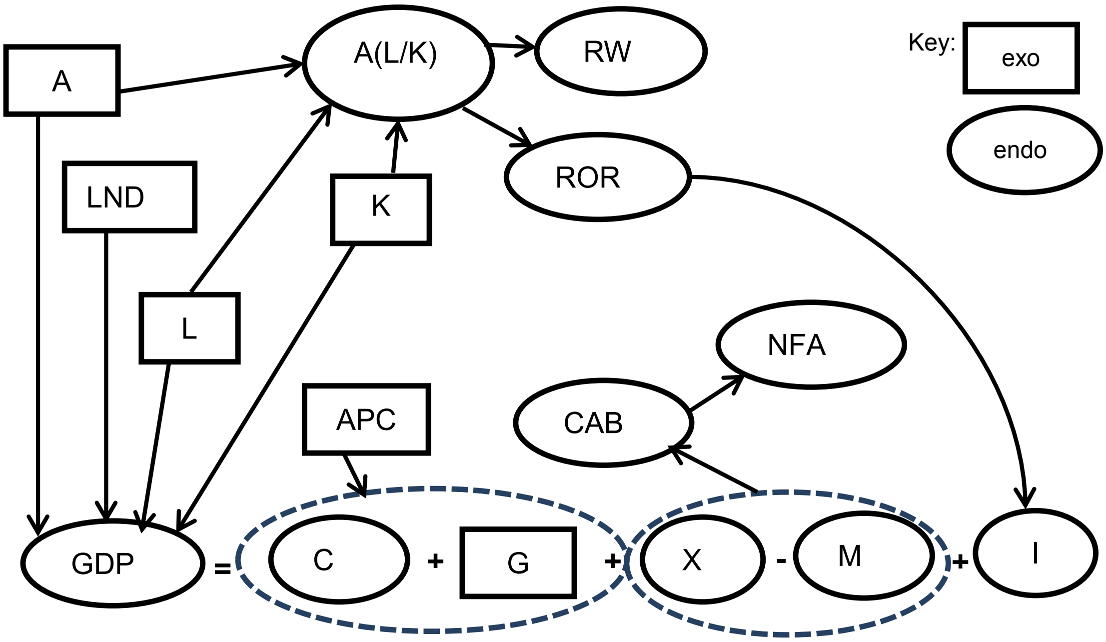
The required ROR on capital was endogenous. In terms of closure, for this policy simulation the aggregate employment was tied down, assuming the real wage was sufficiently flexible. The real wage was made endogenous with the aggregate employment exogenised as in a typical long run closure. This is consistent with the theory of NAIRU. The government expenditure is set exogenously as explained in Section 7.3. Both trade balance and private consumption were determined as residuals in this set up, with most of the export side tied down due to the specific oil and gas shocks (the main exports) implemented. This is shown in Figure 8-3.

Figure 8-2: BOTE equations and closure for analysis (Policy 1)

GDP expenditure	$y = S_C^Y c + S_I^Y i + S_G^Y g + S_X^Y x - S_M^Y m$	(8.1)
GDP supply	$y = S_L^Y l + S_K^Y k - a$	(8.2)
Zero pure profit condition	$p = S_L p_L + S_K p_K + a$	(8.3)
CES production function	$l - k = -\sigma(p_L - p_K)$	(8.4)
Nominal consumption function	$c + p_c = y - t + p + apc$	(8.5)
CPI price index	$p_C = S_D^C p + S_M^C (p_M + \phi)$	(8.6)
Imports	$m = y - \alpha(p_M + \phi - p)$	(8.7)
Exports	$x = -\varepsilon(p - \phi)$	(8.8)
Rate of return	$p_K - p = \xi$	(8.9)
Investment as a function of rate of return and GDP	$i = y + \xi$	(8.10)
Real wage	$rw = p_L - p_C$	(8.11)

Variable	Description	year-on-year closure
l	labour	Exo
k	capital	Exo
a	technical change	Exo
p_L	nominal wage	Endo
p_K	nominal rental cost of capital	Endo
t	income tax rate	Exo
ξ	gross rate of return	Endo
ϕ	nominal exchange rate (numeraire)	Exo
p	domestic price level	Endo
p_c	consumer price	Endo
p_M	import price in foreign currency	Exo
rw	consumer real wage	Endo
apc	average propensity to consume	Exo
c	real private consumption	Endo
i	real investment	Endo
g	real govt expenditure	Exo
x	real exports	Endo
m	real imports	Endo
y	real GDP	Endo

Figure 8-3: Year-on-year dynamic policy closure for Policy 1 simulation



8.2.2 Simulation results

Results were reported as percentage (or change) deviations from baseline (the second baseline as reported in Chapter 7).

The macroeconomics results starting with the immediate (i.e., short run) effects in year 2015 of improved productivity are provided in Table 8-1.

In the short run, there is negligible change to the capital stock (K). Aggregate employment (L) is fixed. Thus, all of the change in real GDP (Y) is driven by technological improvements (see BOTE Equation (8.2)). In the first year, to achieve the necessary 1 per cent improvement in real GDP, technological improvement of 1.02 per cent is required.

Table 8-1: First year macroeconomic results (percentage deviation from the baseline)

Real GDP (gdp)	1.00	GDP price index (p_{GDP})	-1.37
Real GNE (gne)	0.23	GNE price index(p_{GNE})	-2.30
Employment (l)	0	Factor cost index (p_{prim})	-0.39
Capital (k)	-0.01	Average capital rental (p_K)	0.28
All factor augmenting technical change (a)	-1.02	Effective price of labour (p_L)	-5.74
Consumer real wage (rw)	-4.62	Consumer price index (p_C)	-1.17
Rates of return (ror)	2.03	Investment price index (p_I)	-1.72
Real private consumption (c)	0.80	Government price index (p_G)	-3.52
Real aggregate investment (i)	-0.27	Export price index (p_X)	-0.06
Real government expenditure (g)	0	Import price index (p_M)	0
Exports (x)	1.25	Terms of trade (tot)	-0.06
Imports (m)	0.55	Real devaluation	1.38

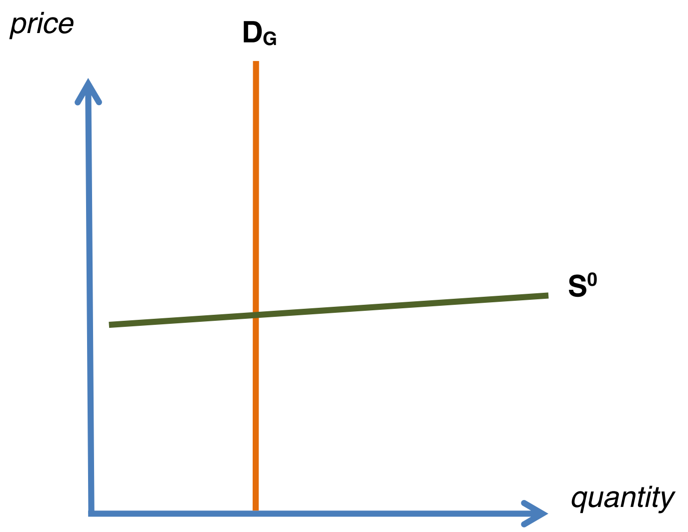
In this simulation, aggregate employment was exogenous and set to zero change from its baseline trajectory. To accommodate the exogenous setting for employment, the producer real wage must adjust. According to the results shown in Table 8-1, the producer real wage rate declined by 5.35 per cent (equal to the percentage deviation in nominal wage rate less the percentage deviation in the factor cost index). The fall in the consumer real wage rate was 4.62 per cent (see Table 8-1). Thus, we concluded that in the short run, with factor inputs held fixed, real wage declines. Why does real wage fall with productivity improvement? The answer lies in the strong compositional effect arising from fixing demand for, and hence output of, the government sector.

According to BOTE Equation (8.2), shown in Figure 8-2, with no change in labour and capital (including natural resources), the percentage change in real GDP should equal the cost savings arising from the 1.02 per cent TFP improvement (i.e., $y = -a$). From BOTE Equation (8.4), with labour and capital fixed, the percentage change in price of labour was equal to the percentage change in cost of capital (i.e., $p_L = p_K$). Therefore, from BOTE Equation (8.3), the real cost of labour should rise in line with the technological improvement (i.e., $p_L - p = -a$). It follows that the real cost of capital would also rise in line with the technological improvement (i.e., $p_k - p = -a$ *).* Yet, this was not the result simulated by BRUGEM.

The BOTE provides a useful guide to understanding simulation results when compositional effects are of little importance. However, in this simulation, compositional effects are important. For the real wage, a key factor is how the government sector is allowed to respond to the technological improvement. The government sector employs about 50 per cent of the total labour force. In this simulation, we fixed government consumption at its baseline level. This severely limited the extent to which the government sector could adjust its production. Even with the technological improvement, the supply schedule of the government sector has little movement to the right due to its fairly flat slope[29] as shown in Figure 8-4. Since it faces an almost infinitely inelastic demand schedule (D_G), its production cannot change.

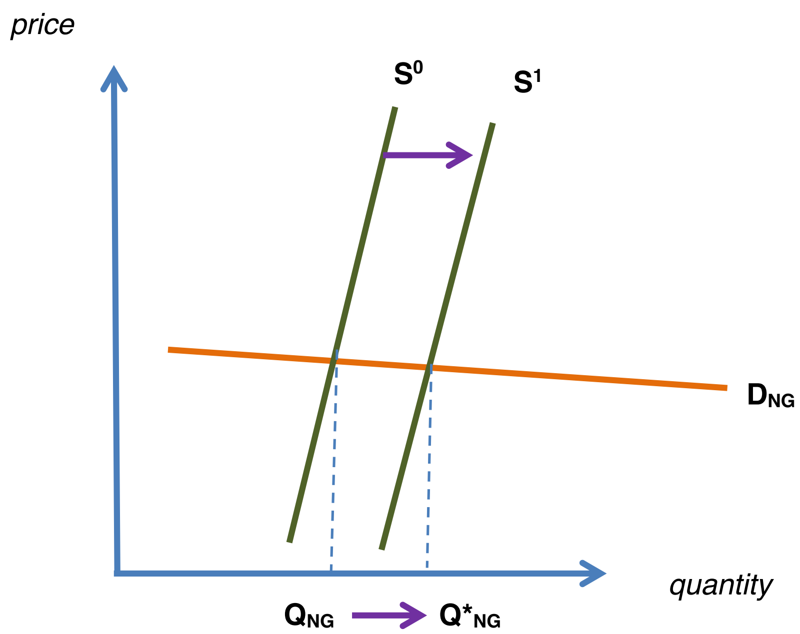
[29]The slope of the industry supply schedule depends on the labour to capital ratio and the share of materials in its production. The supply schedule is more elastic (or flatter) the higher the labour to capital ratio or when there is a higher share of intermediate inputs (see Appendix J in Horridge 2003). Government sector is labour intensive and has a flat supply schedule.

Figure 8-4: Supply and demand schedules of the government sector



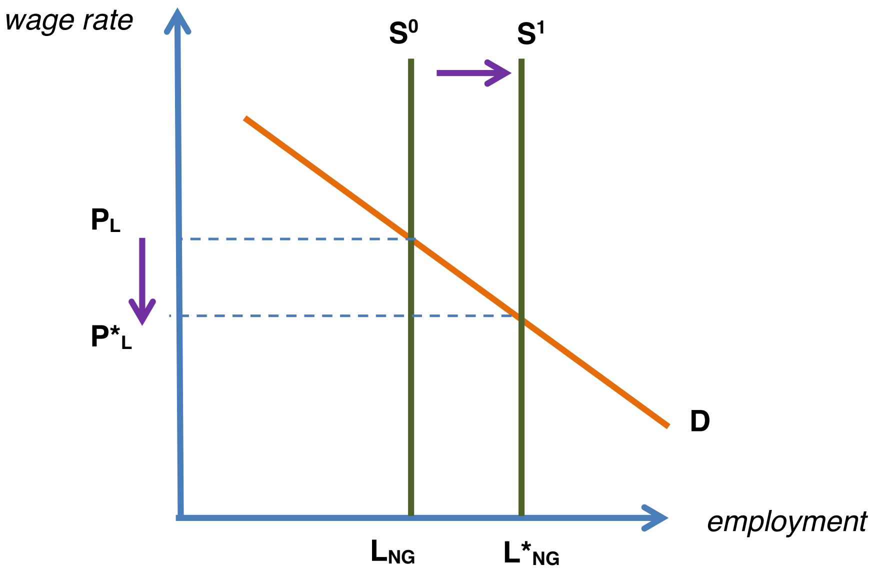
On the other hand, the other non-government sector faces a fairly elastic, nearly flat demand curve (D_{NG}) shown in Figure 8-5. Compared to the government sector, the supply curve for non-government sector is steeper with relatively low labour to capital ratio as it includes the oil and gas sectors which are capital intensive. With the improvement in productivity, the non-government sectors are able to produce more with output increasing from Q_{NG} to Q^*_{NG} in Figure 8-5. There is little change to the price level due to the elastic demand curve.

Figure 8-5: Supply and demand schedules of non-government sectors



With fixed industry-specific capital, government employment (working at a higher level of productivity) must fall. With fixed national employment, those previously employed by the government sector must be employed elsewhere. Labour force is released to the non-government sector causing the rightward shift of the labour supply schedule from S^0 to S^1 in Figure 8-6. To absorb this excess labour into the non-government sectors, the price of labour must fall, leading to the declines in real wage rates from P_L to P^*_L , as illustrated in Figure 8-6 and the results in Table 8-1. Appendix 8-1 examines this issue more in details, the effect of how an improvement in productivity can cause the decline in producer real wage when the government demand is fixed. The difference between the capital to labour ratio of the government and non-government sectors can influence the direction of producer real wage. In this case, it leads to decline in real wage with improvement in productivity.

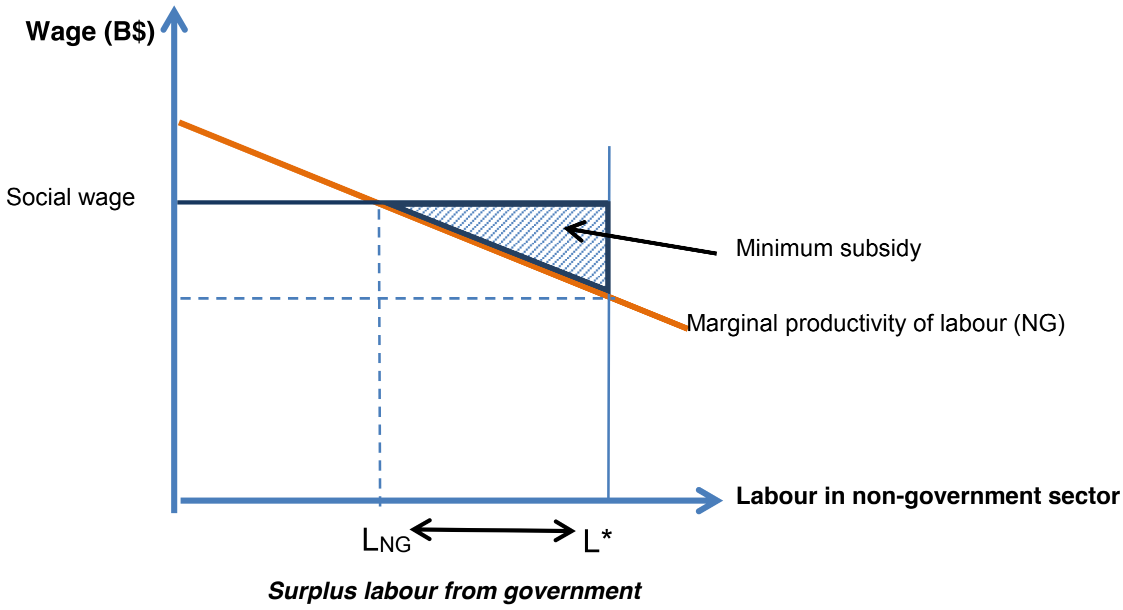
Figure 8-6: Supply and demand of labour in non-government sector



A fall in consumer real wage is undesirable as it affects the purchasing power of households. In terms of policy, the budget savings from hiring less labour into the government sector could be channelled to compensate for this fall in consumer real wage. This result supports the idea of a private sector employment subsidy as proposed by Tisdell (1998) and Duraman et al. (1998) in addressing the wage gap and imbalances between public and private sector employment. Without the minimum subsidy, only L_{NG} amount of labour force will elect to take up private sector jobs (see Figure 8-7).

Tisdell (1998) and Duraman et al. (1998) suggested that in order to maintain a social wage (see Figure 8-7), the government could provide an employment subsidy to incentivise private sector employment. This might result in greater domestic production. They argued that this subsidy would be desirable on the grounds of productivity. The surplus labour from the government sector could remain unemployed or take a wage cut and be employed by non-government sectors, as shown in the simulation results.

Figure 8-7: Employment subsidies in the private sector



Source: Adapted from Tisdell (1998) and Duraman et al. (1998)

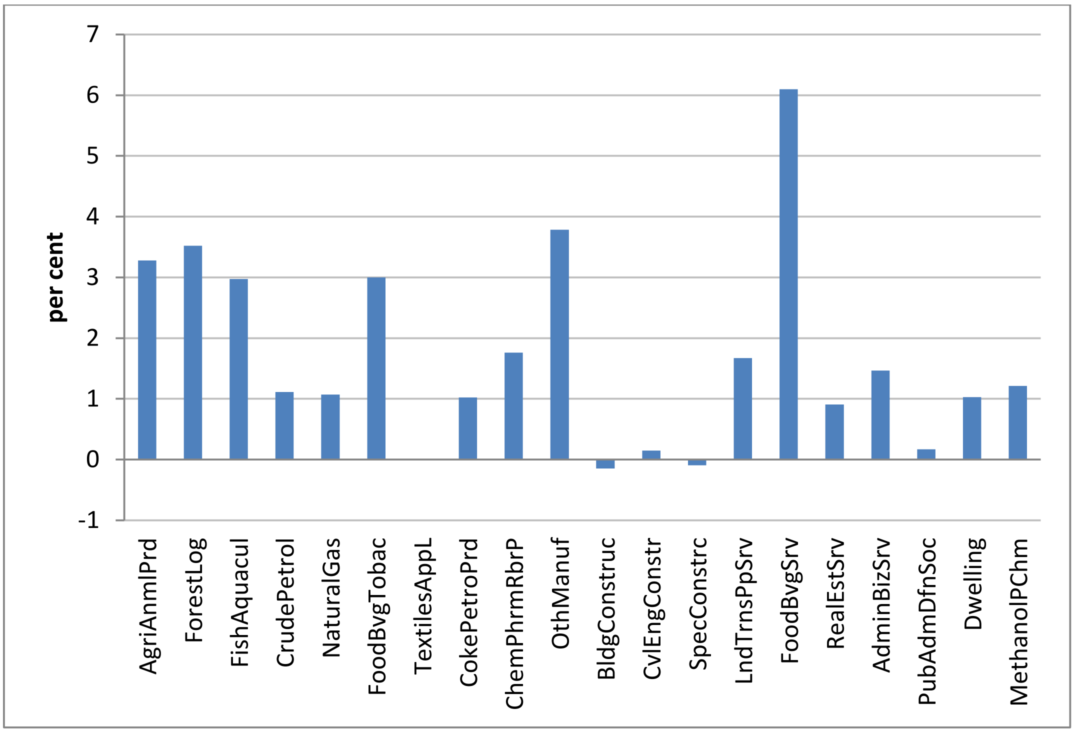
Previously, we examined the mechanism behind the fall in real wage with productivity improvement. With technological improvement, this resulted in a real devaluation of currency (see Table 8-1). Real devaluation makes exports more competitive, with the export volume increasing in the short term by 1.25 per cent (see BOTE Equation (8.8)). Since the import price was exogenous, the TOT deteriorated by

0.06 per cent with the fall in the export price index. In addition, since imports are a function of GDP (see BOTE Equation (8.7)), as GDP increased by 1 per cent, so imports also increased by 0.55 per cent.

At a sectoral level, the overall productivity improvement benefits most industries, except those capital industries related to construction. The increased capital rental cost in the short run put them at a disadvantage with their decline in output, as shown in Figure 8-8. The oil and gas industries are the exceptions here as, despite also being capital intensive, their outputs increased. The main difference lies in the fact that these two industries own natural resources as a fixed factor in their production and they benefit from the overall all-factor augmenting productivity growth. Therefore, the oil and gas industries perform well in the short run. The methanol sector also gains from productivity improvement. These three export-orientated industries also benefit from the real devaluation of currency in the short run.

The labour across sectors is mobile even though overall employment is fixed. Labour intensive industries, such as agriculture, fisheries, food and beverage, and other manufacturing, administration and business services, can take advantage of the lower producer wage to hire more labour and thus increase their output or activity level (see Figure 8-8). Although the government sector is labour intensive, its increase in output is negligible due to its inelastic demand schedule and it cannot vary its production to any great extent.

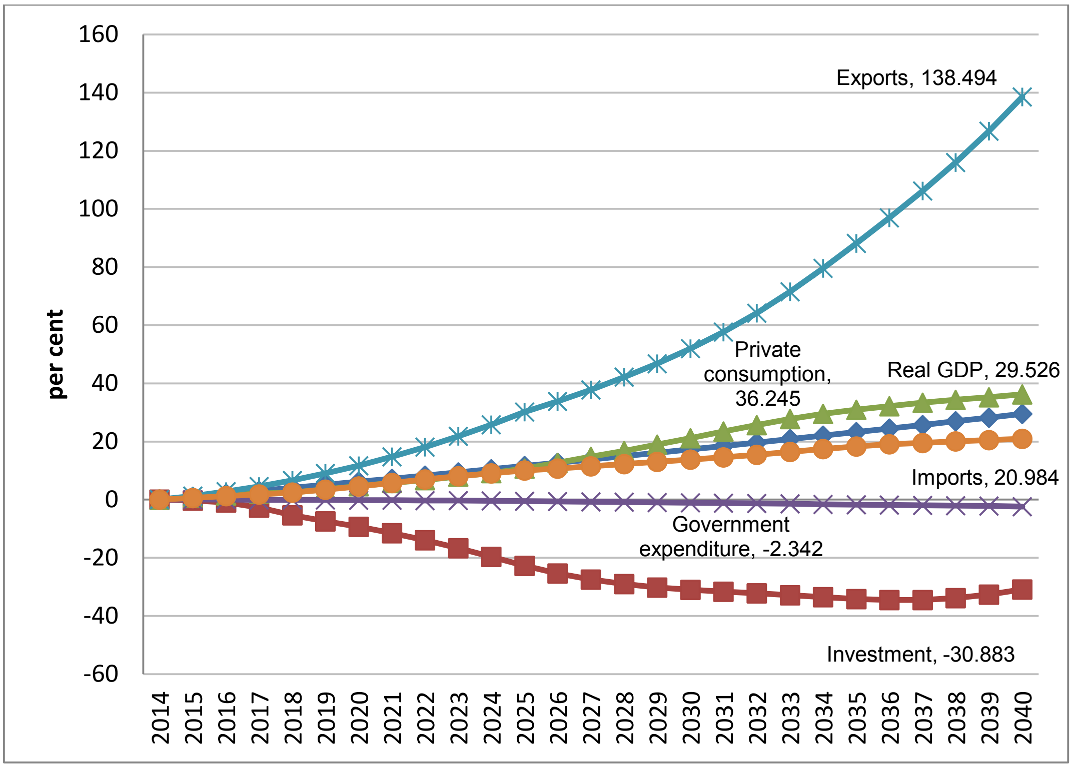
Figure 8-8: Selected industrial outputs for 2015 (percentage deviation from baseline forecast)



This brings to a close our discussion of the immediate short run effects of the technological improvement. We turn now to the longer run (2040) deviations.

In the long run, TFP improvement stimulates the economy relative to its baseline path. As shown in Figure 8-9, all expenditure components expand relative to baseline values, except for aggregate investment. The increase in real household consumption is 36.25 per cent relative to its baseline level. The largest gains, however, are in areas focused on exports. By 2040, the volume of exports has been forecast to rise by almost 140 per cent relative to its baseline level. The fall in investment accompanies a fall in capital employed. This is discussed below.

Figure 8-9: Real GDP and its components (percentage deviation from the baseline forecast)



Real GNE (C + I +G) falls relative to real GDP (Y), implying an improvement in the net volume trade relative to baseline values. This is shown in Figure 8-10.

Figure 8-10: Real GDP and real GNE (percentage deviation from the baseline forecast)

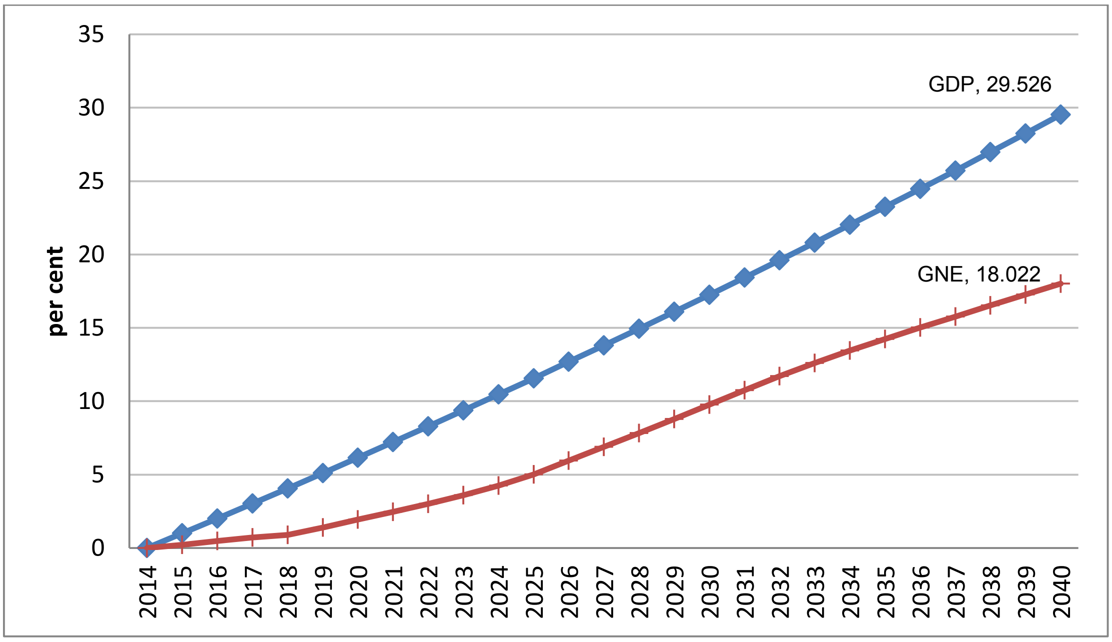


Figure 8-11 shows percentage deviations in the key labour market variables – aggregate employment and the real wage rate. By the end of the period, the real wage rate is down 86 per cent relative to its baseline level, while employment does not change by assumption. Over the period, in the policy simulation the real wage rate falls at an average annual rate of 6.5 per cent.

The reason for the fall in the real wage rate, as explained above, was due to a compositional effect. The same effect persists through the forecast period, since real government consumption is held at its baseline level. Hence, the real wage contraction persists, and indeed intensifies, as the technological improvements continue.

As the real wage rate falls, so does the real cost of labour. This encourages producers to substitute labour for capital. Since employment is fixed, capital must fall. Figure 8-12 shows percentage deviations in real GDP, employment and capital. By 2040, real GDP is up 29.6 per cent, employment is unchanged and capital is down 19.5 per cent. As can be seen, the only positive contributor to the increase in real GDP is technological progress, which proceeds at a rate necessary to increase annual growth in real GDP by 1 per cent relative to its rate of growth in the baseline.

Figure 8-11: Labour market (percentage deviation from the baseline forecast)

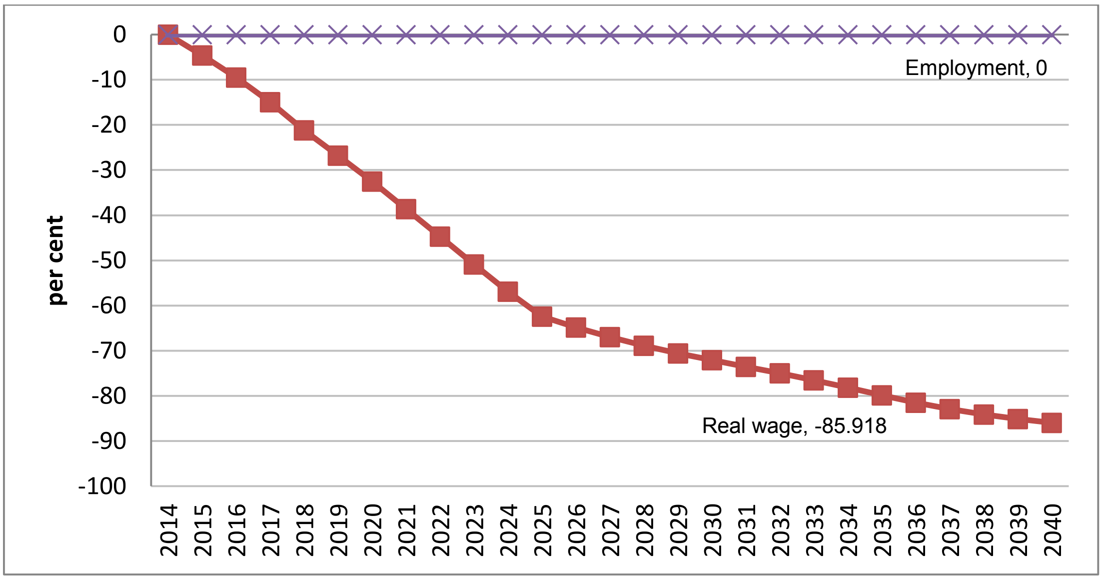
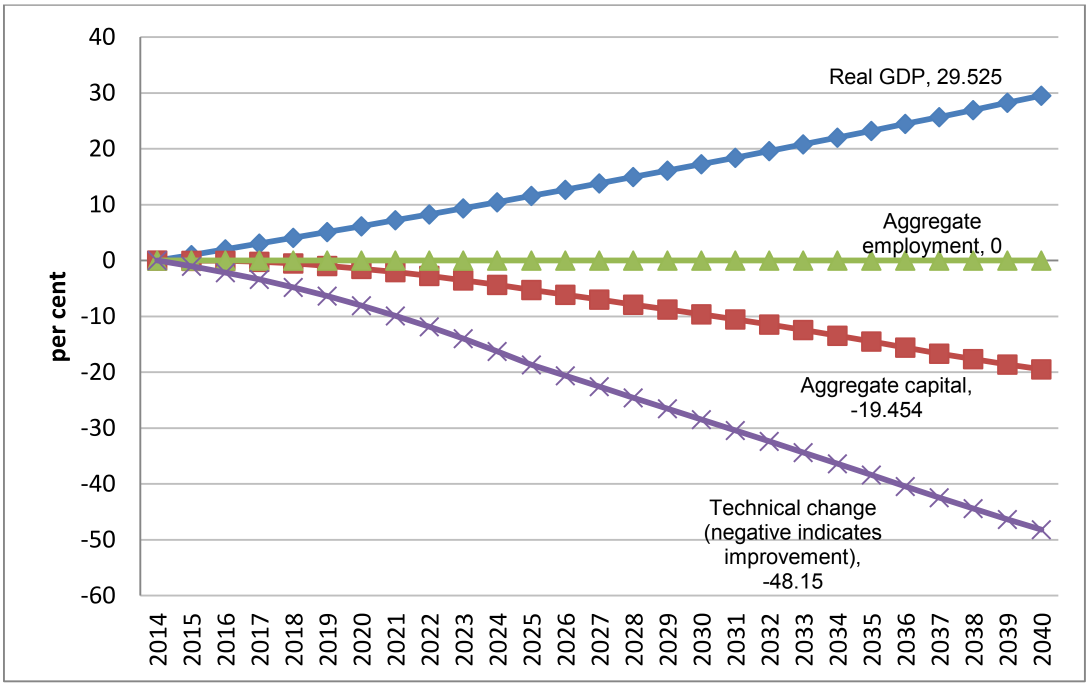


Figure 8-12: Real GDP and factor inputs (percentage of deviation from the baseline forecast)



Generally, productivity improvement is regarded as good for the economy. But, in the results presented so far, particularly in the long run, it is difficult to see where those benefits lie. Certainly real GDP is up, but the increase was mitigated somewhat by a reduction in capital stock. Employment is, by assumption, unchanged. In addition, the real wage rate has fallen dramatically. Most of the good news appears in a variable not yet reported – the real return to the key fixed factor, natural resources. Relative to its baseline value, the ROR for natural resources was forecast to increase by 165 per cent accumulatively for oil and 169 per cent for gas by 2040. Essentially, the owners of the natural resources are the main beneficiaries of the productivity improvements in the longer run.

As mentioned earlier, with real GDP up relative to real GNE, the net volume of trade must improve. To facilitate this, real devaluation of the currency is required (see Figure 8-13).

Figure 8-13: Macro trade variables (percentage deviation from the baseline forecast)

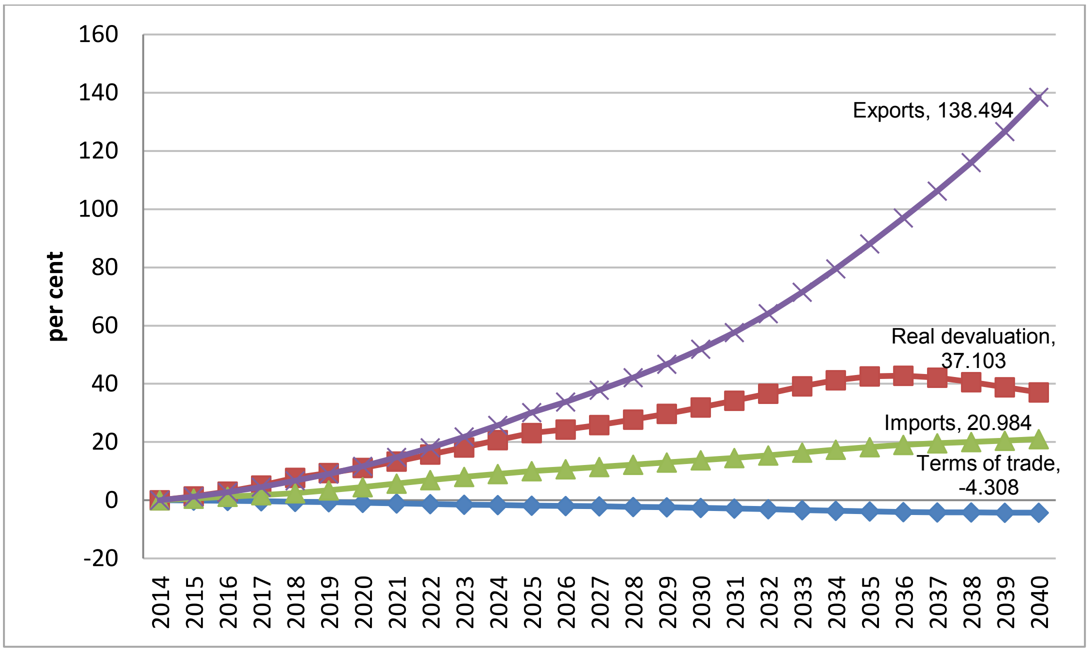


Figure 8-14 shows a comparison between the baseline and policy paths for the balance on current account and Brunei's stock of foreign assets. In Figure 8-15, the same information is provided for the government's fiscal balance. At the time of writing, Brunei has no foreign debt and a sizeable pool of net foreign assets (NFA, excluding SWF). It was assumed that these assets would be well managed to generate a conservative return of 2 per cent per annum (see Section 7.2.7). Based on the equations blocks presented in Section 3.4.4, NFA will accumulate over time and help offset the current account deficit brought about by the excess of imports over exports. The current account balance in the policy simulation was improved relative to its baseline value.

In the baseline, as oil and gas deplete, the balance on current account will weaken and NFA will start to fall (see Figure 8-14). The government will run into budget deficits very quickly as income from oil and gas declines (see Figure 8-15). With the improvement in productivity, Brunei could continue to enjoy a current account surplus and the build up its NFA, as well as a budget surplus for the government.

Figure 8-14: Policy results for current account balance and net foreign assets (Policy 1)

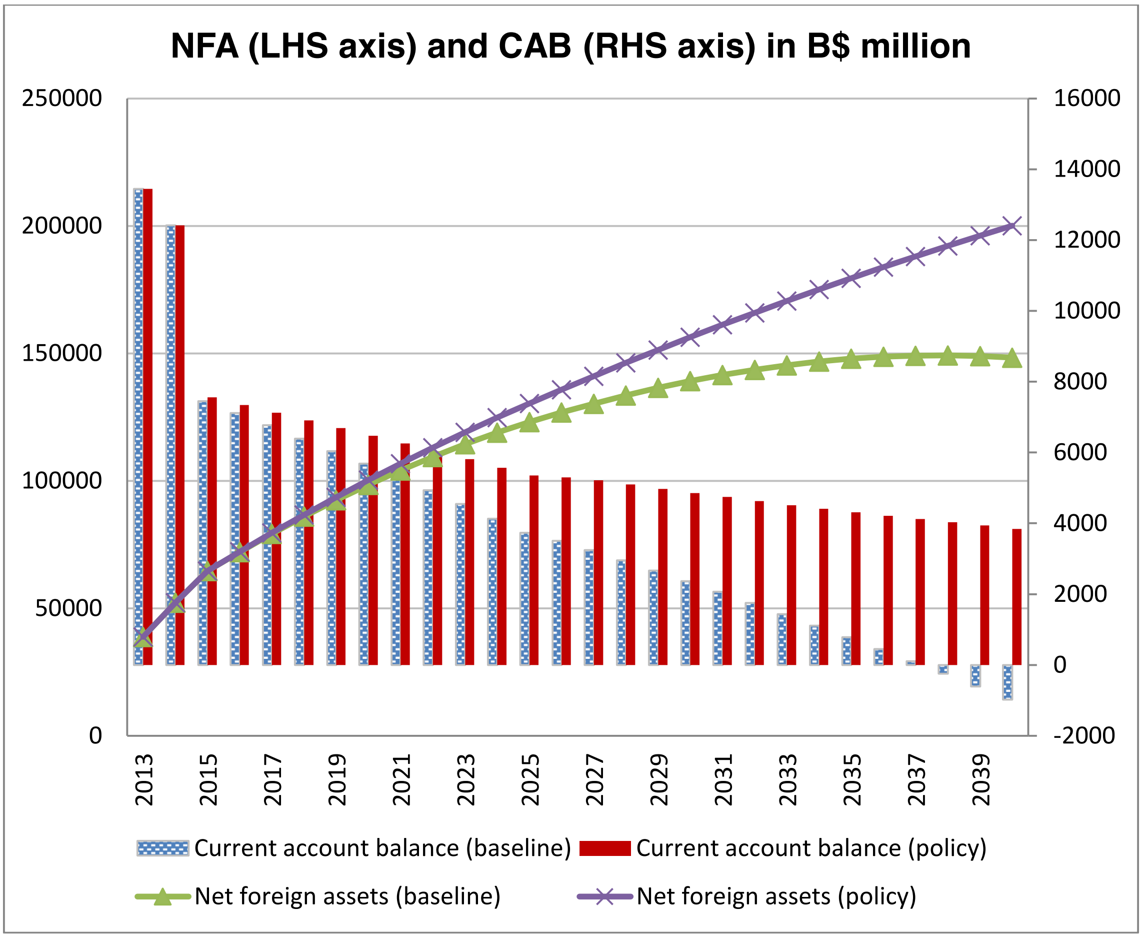
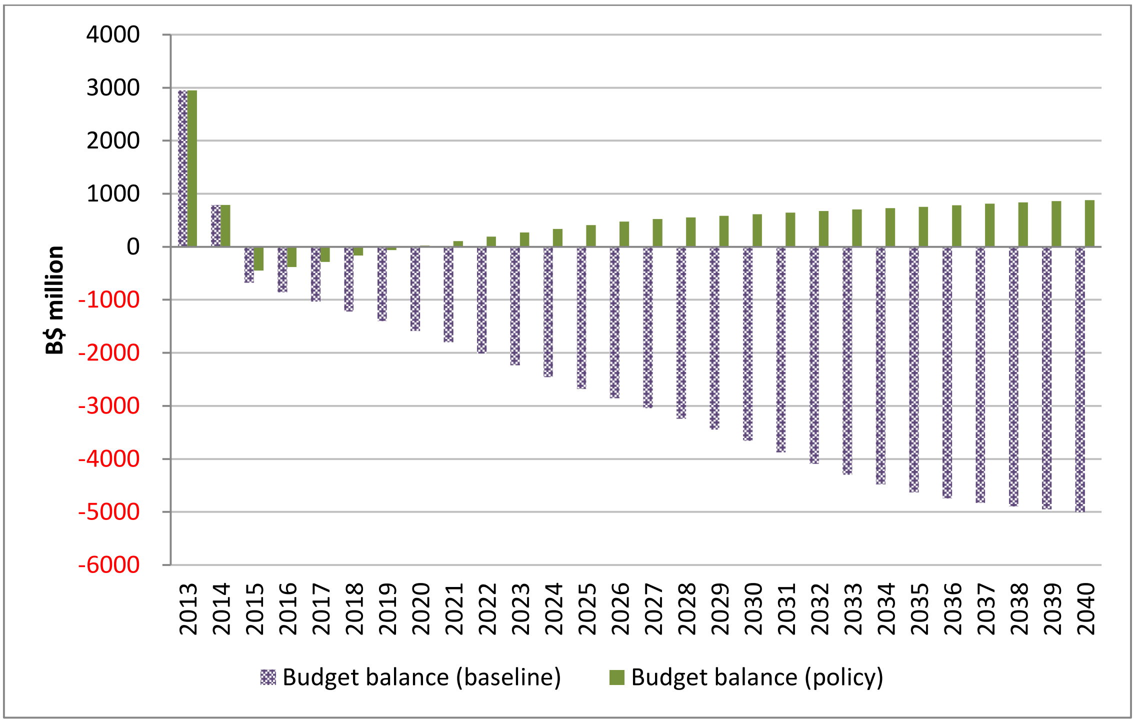


Figure 8-15: Government budget balance pre-policy and policy scenario with productivity shock

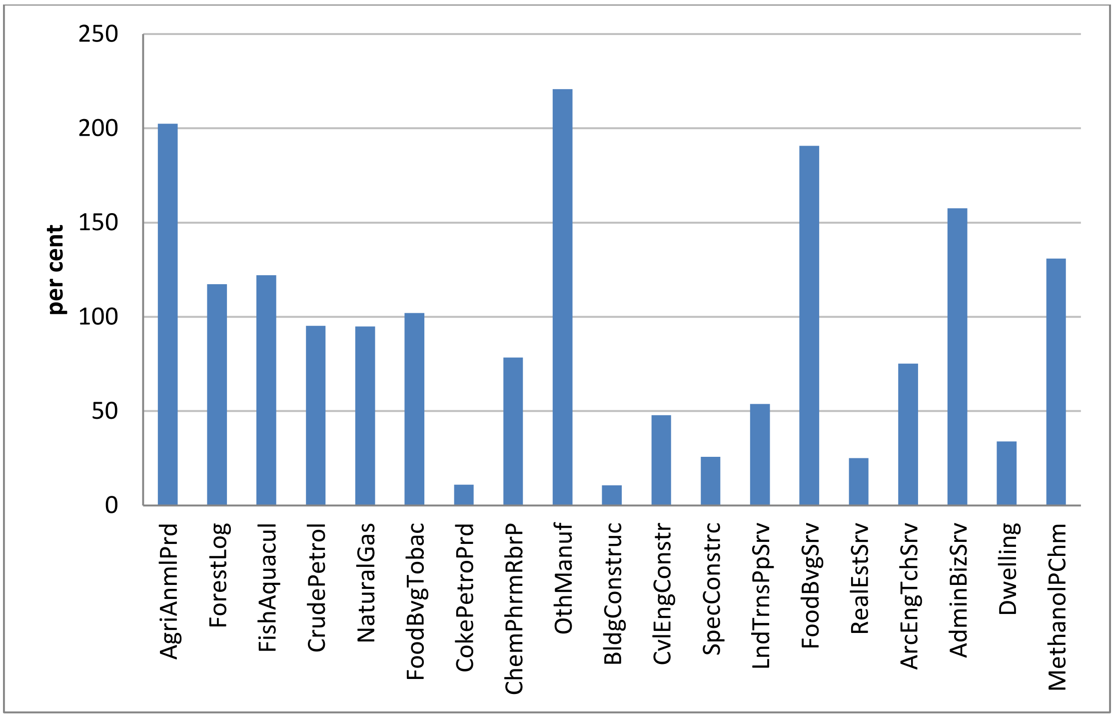


At the industry level, in the long run, sectoral outputs increased with the productivity improvement (see Figure 8-16). However, it was found that not all industries would benefit equally, depending on the factor intensity and sale structure. The forecast showed some increased activity levels for the oil and gas industries in 2040 and this had to be qualified. This increased activity was due to the lower depletion rate implemented from 2026 onwards, as explained in Section 7.3.2.1. This implies that the oil and gas sectors would still benefit from the productivity shock and therefore deliver a positive deviation from the baseline.

The better performing industries are those that are relatively more labour intensive, such as food and beverage, office administrative activities, agriculture, animal products, fisheries and aquaculture, furniture and other manufacturing industries. This is because labour is cheaper than capital as a primary factor input into production. Those who sell mainly to households also benefit, since private consumption (see Figure 8-9) increases with the productivity improvement.

Industries that are export-orientated will benefit from real devaluation of currency. Besides oil and gas, the land transport and transport via pipeline services industry (the fourth largest industry in terms of market sale share), and the methanol industry are amongst the better performers (Figure 8-16).

Figure 8-16: Sectoral outputs under improved productivity in 2040 (percentage deviation from the baseline forecast)



8.3 Policy 2 simulation – additional stimulus to selected industries

This scenario simulates the effects of stimulating the eight selected industries, as shown in Table 7-12, beyond what was assumed in the second of the two baseline simulations. The additional stimulus was imposed via a shift in demand for the products of these industries.

8.3.1 Model closure and shocks implemented

In this simulation, further demand side stimulus to the identified eight industries, including the government sector was implemented.

Table 8-4 shows each industry's contribution in replacing the oil and gas production lost in the baseline. Uniform shocks were imposed on demand to achieve 85 per cent replacement of the total lost hydrocarbon output of B$19,044 million by 2040.

Since the baseline already included a simulated 50 per cent replacement, an additional shock of 35 per cent was implemented in this simulation to achieve the outcome.

The year-on-year dynamic macroeconomic closure used was similar to that presented in Figure 8-2 for Policy 1, except with the following swaps in Table 8-2 to endogenise the aggregate employment which is no longer held fixed. The corresponding overall wage shifter was made exogenous to achieve this. As with the forecast simulation for the second baseline scenario, the sector-specific inventory demand variable, while not a policy variable, was used as a proxy to model sustained increase in the miscellaneous demand side shifts. Another difference with Policy 1 was real public consumption, which remained exogenous but not set to zero change and a positive shock was implemented. Table 8-2 summaries the swaps to facilitate the Policy 2 simulation. The closure used is presented in Table 8-3

Table 8-2: Swap statements for Policy 2 simulation

	Previously exogenous		**Newly exogenous**
Swap	*Aggregate employment*	=	*overall wage shifter*
Swap	*Sector-specific inventory rule shifter*	=	*inventory demand (proxy for demand side factors)*

Table 8-3: Closure for Policy 2 simulation

Variable	Description	year-on-year closure
L	labour	Endo
K	capital	Exo
A	technical change	Exo
p_L	nominal wage	Endo
p_K	nominal rental cost of capital	Endo
T	income tax rate	Exo
ξ	gross rate of return	Endo
ϕ	nominal exchange rate (numeraire)	Exo
P	domestic price level	Endo
p_c	consumer price	Endo
p_M	import price in foreign currency	Exo
apc	average propensity to consume	Exo
C	real private consumption	Endo
I	real investment	Endo
G	real govt expenditure	Exo
X	real exports	Endo
M	real imports	Endo
Y	real GDP	Endo
rw	consumer real wage	Exo

Table 8-4: Replacement of lost oil and gas output under Policy 2 simulation

Code	Industry	Replacement value (B$ mil)
CokePetroPrd	Manufacture of coke and refined petroleum products	1612
ChemPhrmRbrP	Manufacture of chemicals, chemical products, pharmaceuticals, rubber and plastic products	64
BldgConstruc	Construction of buildings	2580
CvlEngConstr	Civil engineering	1935
SpecConstrc	Specialised construction activities	1935
ArcEngTchSrv	Architectural and engineering activities, technical testing and analysis	1612
PubAdmDfnSoc	Public administration and defence, compulsory social security	3869
MethanolPChm	Methanol and petrochemicals	2580
	Total	16187

8.3.2 Simulation results

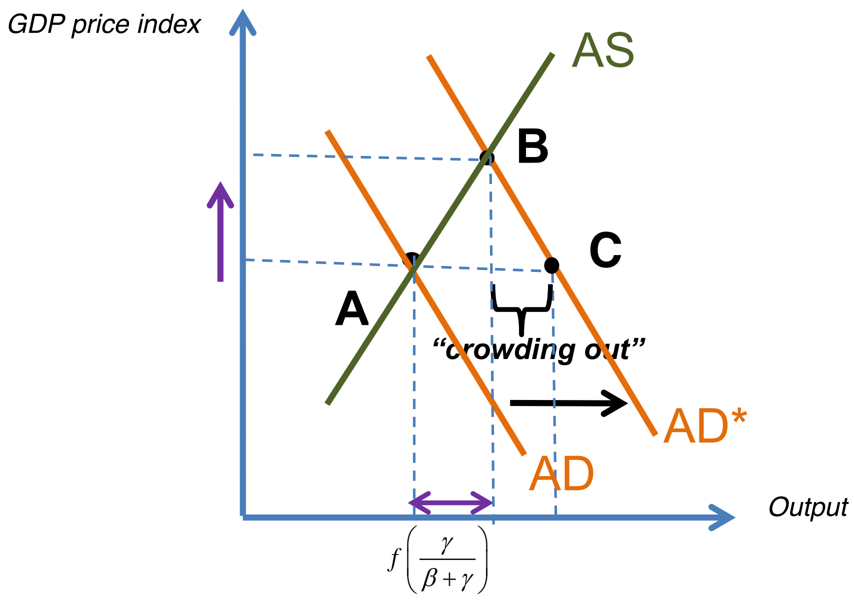
In the short run, additional demand stimulation of the eight identified industries created a small increase in real GDP growth relative to its baseline level. As shown in Table 8-5, real GDP rose by 0.42 per cent in the first year. Comparing the results in Table 8-5 with those in Table 8-1 under the first policy simulation, the sources contributing to the GDP change are different. In the short run, for Policy 1, productivity drove the real GDP from the supply side since labour is fixed and capital hardly changes. In Policy 2, real GDP growth came from the strong increase in aggregate employment in the supply side, since this variable was endogenous. On the GDP demand side, Policy 2 was stimulated through government demand and investment growth. On the other hand, for Policy 1, export-led growth was observed with the real devaluation of currency.

Table 8-5: First year macroeconomic results (percentage deviation from the baseline)

Real GDP (gdp)	0.42	GDP price index (p_{GDP})	1.01
Real GNE (gne)	2.48	GNE price index (p_{GNE})	2.13
Employment (l)	2.49	Factor cost index (p_{prim})	1
Capital (k)	0.01	Average capital rental (p_K)	1.51
All factor augmenting technical change (a)	0	Effective price of labour (p_L)	1.24
Consumer real wage (rw)	0	Consumer price index (p_C)	1.24
Rates of return (ror)	-2.57	Investment price index (p_I)	4.19
Real private consumption (c)	0.2	Government price index (p_G)	1.32
Real aggregate investment (i)	0.4	Export price index (p_X)	0.1
Real government expenditure (g)	1.35	Import price index (p_M)	0
Exports (x)	-0.59	Terms of trade (tot)	0.1
Imports (m)	0.91	Real devaluation	-1

Figure 8-17 shows the general direction of effects on GDP volume and price arising from the demand stimulation. In the short run, volume and price both expand as the economy moves from point A to point B. If aggregate supply (AS) schedule were perfectly elastic, indicating unlimited resources, then the stimulus would move the economy from point A to C. However, with some constraint on supply, illustrated by the upward sloping AS schedule, crowding out occurs.

Figure 8-17: Impact of further expansion of the selected industries



The BOTE model shown in Figure 8-1, along with the new closure shown in Table 8-3 can help to understand the results a little better. In this simulation, the shock entered through the demand side of the GDP expression given in BOTE Equation (8.1). In the context of the BOTE model, it was convenient to think of the stimulus as an increase in government consumption *g.* Initially, the demand stimulus was expected to increase GDP with growth in government consumption. On the supply side, with capital and technology fixed in the short run, the only way for real GDP to expand was via an increase in employment. BOTE Equation (8.2), $y = S_L l$, indicates that the increase in GDP due to the demand stimulus must be matched by an increase in employment multiplied by the share of labour in primary factor inputs.

From BOTE Equations (8.3), (8.4) and (8.11), we could develop expressions for employment and real GDP in terms of prices (the capital and technology variables are zero), as follows:

$$l = -\sigma(p_L - p_K)$$

$$l = -\sigma\left[S_D p - \left(\frac{1 - S_L S_D}{S_K}\right)p\right]$$

$$l = -\frac{\sigma}{S_K}\left[S_D S_K - 1 + S_L S_D\right]p$$

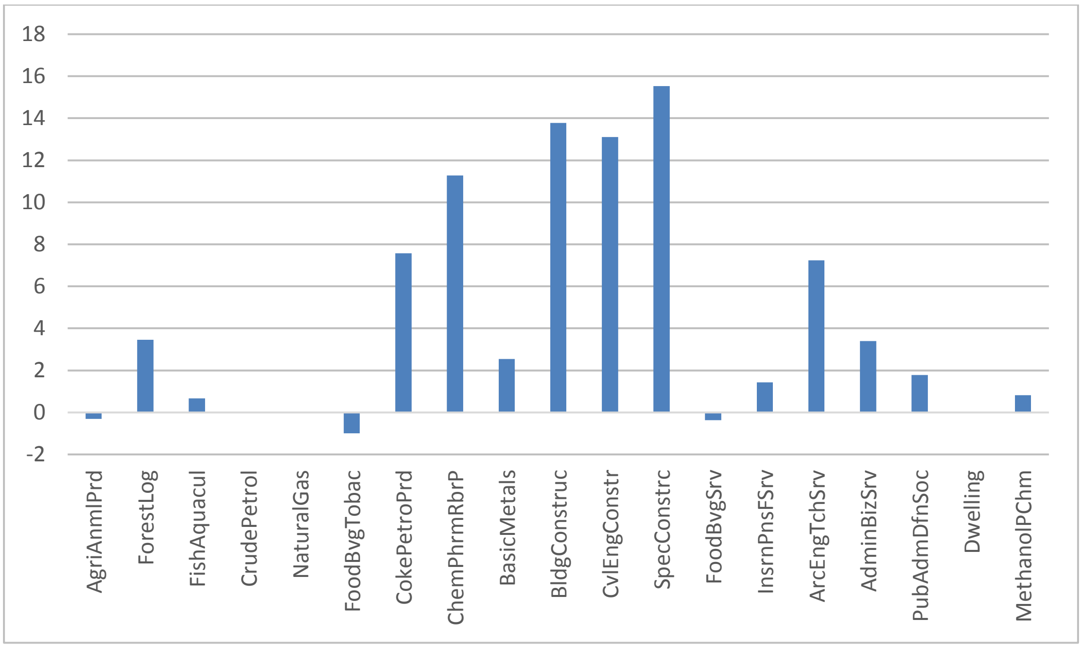
$$l = \frac{\sigma}{S_K}\left[1 - S_D\right]p \qquad (8.12)$$

$$y = S_L l = \sigma\frac{S_L}{S_K}\left[1 - S_D\right]p = \gamma p \qquad (8.13)$$

Equation (8.12) above explains the percentage change in employment as a function of the percentage change in GDP price. Equation (8.13), which is similar to the employment equation, explains the percentage change in real GDP. Note that γ is the positive elasticity of supply. An elasticity of demand of β (a negative, but finite number) was assumed. As depicted in Figure 8-17, a demand stimulus would boost real GDP, but not proportionally. This is because there was an element of crowding out, measured by the factor $\left(\frac{\gamma}{\beta + \gamma}\right) < 1$.

Figure 8-18 shows the short run effects of the demand stimulation for production of selected industry sectors. The expansion of the government sector, absorbed most of the labour and crowded out other labour intensive industries, such as agriculture, manufacturing of food and beverage. The increased outputs in the construction-related, refined petroleum products, chemicals and pharmaceutical, and methanol industries were due to the targeted demand side stimulus. Similarly, the public sector, which was stimulated, also showed increased output. There were barely any noticeable changes in the oil and gas outputs compared to the baseline.

Figure 8-18: First year selected industrial outputs (percentage deviation from the baseline forecast)



Next, is to look at the dynamics in order to arrive at the results for 2040. These results are referred as "long run", but they were not truly so in a comparative-static sense. A comparative-static long run refers to a state of the economy, different from the initial state, in which equilibrium has been restored following a one-off shock. Here, even for 2040, shocks were imposed exogenously to the model. Accordingly, for 2040 the economy is still seen in transition.

In the longer run, even though there was no productivity shock, the second simulation showed strong growth in employment and aggregate capital stock (see Figure 8-19). These were driven by the stimulation of both capital intensive construction related industries and the labour intensive public sector. The total aggregate investment also increased (see Figure 8-19). As shown in Figure 8-20, the exports fell by 32.54 per cent over the whole forecast period due to the real appreciation of the currency. This made exports less competitive in the medium term before the real devaluation took place.

Figure 8-19: Real GDP and its components (percentage deviation from the baseline forecast)

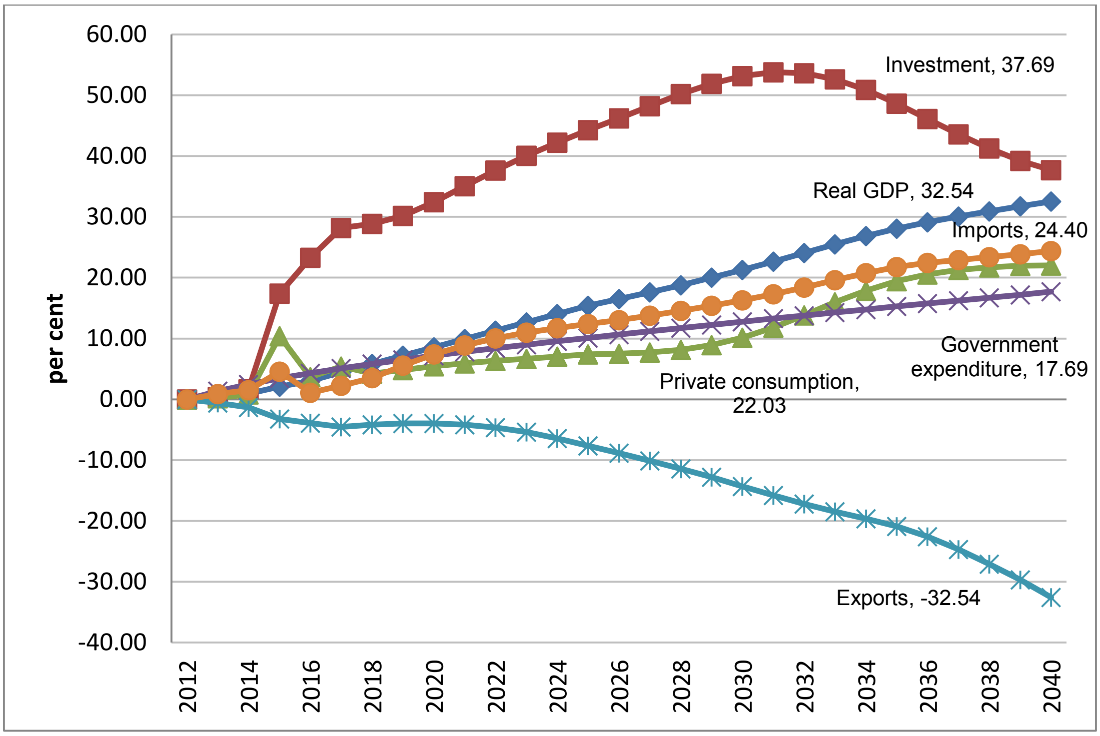
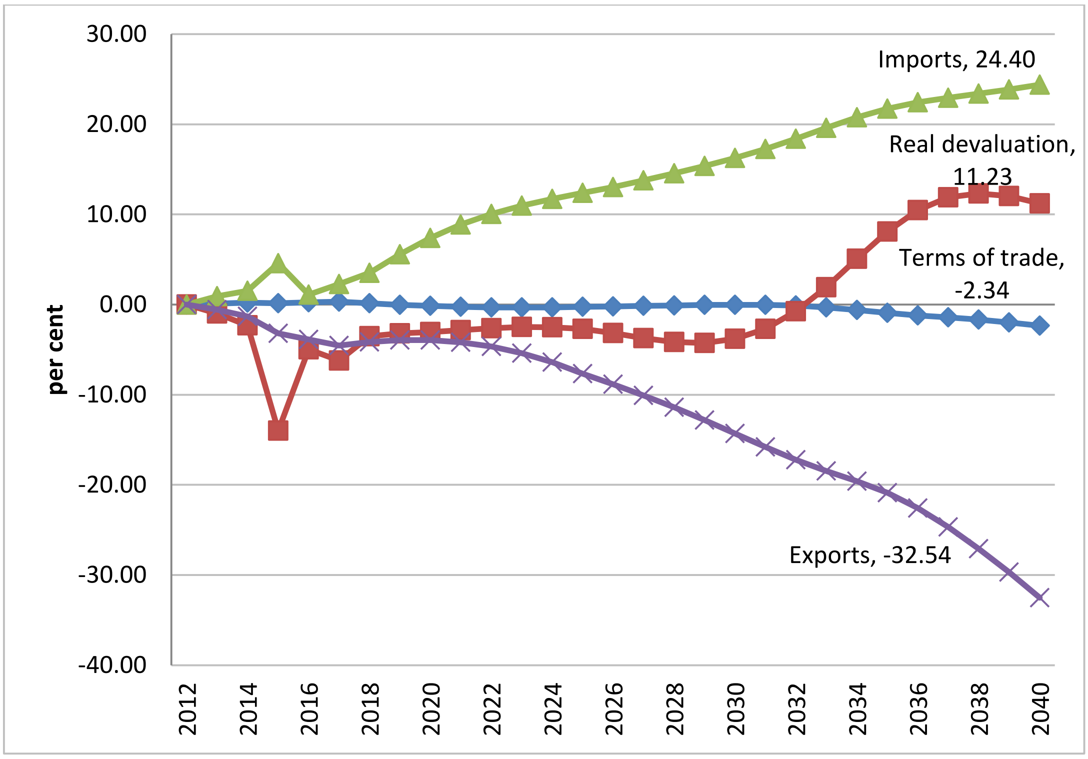


Figure 8-20: Macro trade variables (percentage deviation from the baseline forecast)



This economic growth was led, to a great extent, by government and construction. Out of the eight stimulated industries, as shown in Table 8-4, only three were expected to generate more exports for Brunei. These are the industries producing methanol, petrochemicals, pharmaceuticals and refined petroleum products. Despite the additional stimulation, overall, the aggregate exports still fell, as shown in Figure 8-19, because the methanol and petrochemicals industries rely on oil and gas as inputs and these declined over time. The real appreciation of currency in the short to medium term, as shown in Figure 8-20, made domestic production uncompetitive, reducing exports and fuelling more imports in Figure 8-19. There was an increase in aggregate investment but at a declining rate in the long run (see Figure 8-19). This additional diversification does not contribute much to the TOT effect as was expected (see Figure 8-20), due to the composition of the stimulated industries.

Table 8-6: Macroeconomic results for 2040 (cumulative percentage deviation from the baseline)

Real GDP (gdp)	32.54	GDP price index (p_{GDP})	-10.11
Real GNE (gne)	39.03	GNE price index (p_{GNE})	-3.05
Employment (l)	28.25	Factor cost index (p_{prim})	-10.42
Capital (k)	31.18	Average capital rental (p_K)	-7.36
All factor augmenting technical change (a)	0	Effective price of labour (p_L)	-2.37
Consumer real wage (rw)	0	Consumer price index (p_C)	-2.37
Rates of return (ror)	-8.28	Investment price index (p_I)	1.00
Real private consumption (c)	22.03	Government price index (p_G)	-0.73
Real aggregate investment (i)	37.69	Export price index (p_X)	-2.34
Real government expenditure (g)	17.69	Import price index (p_M)	0
Exports (x)	-32.54	Terms of trade (tot)	-2.34
Imports (m)	23.39	Real devaluation	12.33

In this policy simulation, the closure used (see Table 8-3) was a little unusual, with both labour and capital regarded as endogenous while real wage and rate of return were exogenous. It appeared that there was no quantity variable of the primary factor endowment being set as exogenous (where some quantity variables are required to be exogenous, as explained in Section 3.5). This was not the case, however, because of the presence of a third factor endowment – natural resources. This was fixed throughout the simulation.

Unlike other non-resource based economies, due to the prominence of natural resources in production within Brunei's economy, we needed to introduce land as a fixed primary factor denoted by n. Both labour and capital were classified as the variable primary factors denoted collectively by v. Land endowment, as the quantity variable, was set as exogenous for the model to solve. Some of the BOTE equations shown in Figure 8-2 were rewritten as follows, expressed in terms of variable and fixed primary factors:

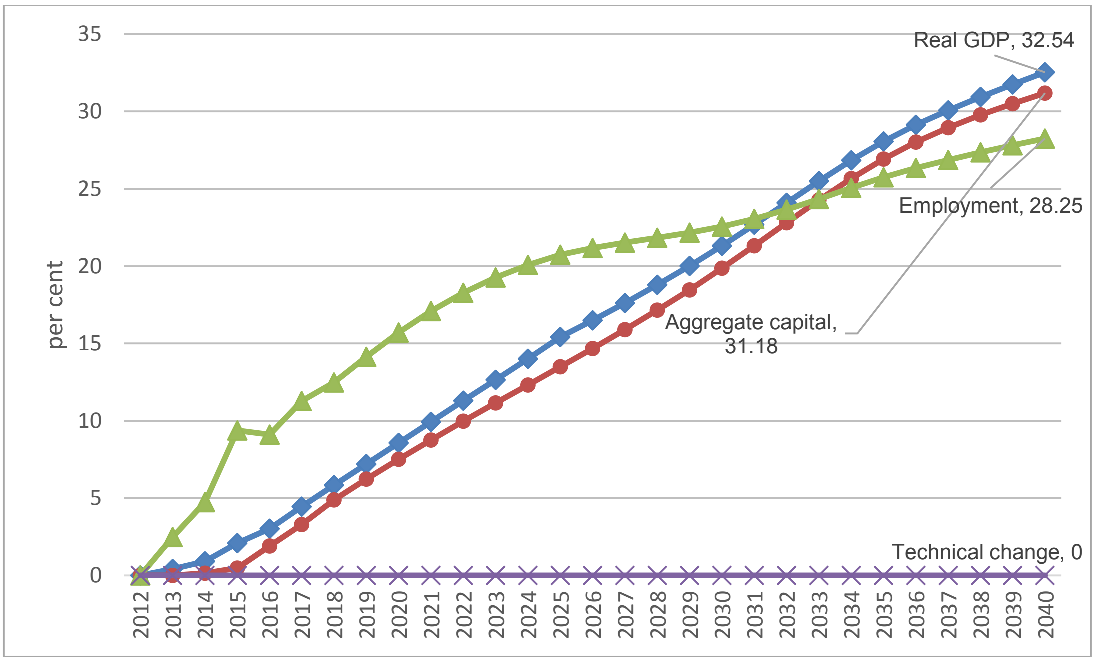
$$y = S_V v + S_N \overline{n} \quad (8.14)$$
$$p = S_V p_v + S_N p_N \quad (8.15)$$
$$v - \overline{n} = -\sigma(p_V - p_N) \quad (8.16)$$
$$p_K - p = \overline{\xi} \quad (8.17)$$
$$\overline{rw} = p_L - S_D p \quad (8.18)$$
$$y = -\beta p + \overline{f} \quad (8.19)$$

From Equation (8.15), with the depletion of oil and gas, S_N would become smaller and smaller leaving approximately $p_V = p$. Using this we could reduce Equation (8.16) by substitution through Equations (8.14) and (8.15):

$$v - \overline{n} = -\sigma(p_V - p_N)$$
$$v = -\sigma(p - p_N)$$
$$v = -\sigma\left[p - \frac{1}{S_N}(p - S_V v) \right]$$
$$v\left[1 + \sigma \frac{S_V}{S_N} \right] = -\sigma p \left[1 + \frac{1}{S_N} \right]$$
$$v = -\sigma p \left[\frac{S_N + 1}{S_N + \sigma S_V} \right]$$
$$v = \sigma \left[\frac{S_V}{S_N + \sigma S_V} \right] p \quad (8.20)$$

From Equation (8.20), the percentage change in the use of the variable primary factor (consisting of both labour and capital) v would increase with the fall in the share in natural resources S_N. As demand in the economy expands, the scarcity value of the fixed factor (natural resources) increases. This drives up the real cost of those resources, causing the real cost of the variable factors of production (capital and labour) to fall. Thus, the economy substitutes away from the fixed to the variables factors of production causing real GDP to rise. To understand this last point, consider BOTE Equation (8.2), with natural resources made explicit. Its quantity remains unchanged but labour and capital rise. Thus, real GDP must increase. The long run increases in aggregate capital and employment are shown in Figure 8-21 and Table 8-6.

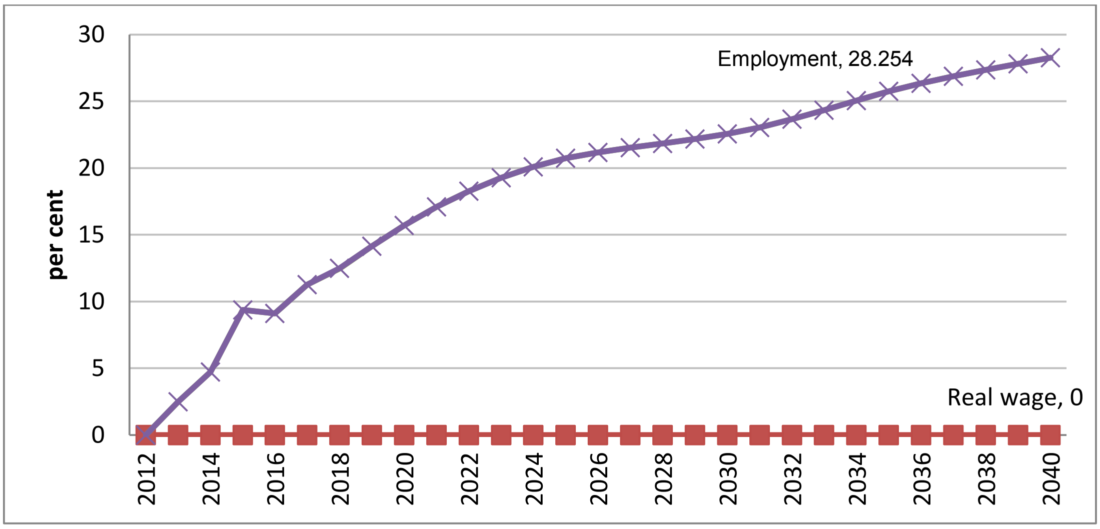
Figure 8-21: Real GDP and factor inputs (percentage deviation from the baseline forecast)



The large increase in aggregate capital stock drives the rates of return down as shown in Table 8-6, although this is not quite the long run result. As noted earlier, in a typical long run result, there is no additional policy shock to the economy for several years (at least five years) and the model results will eventually settle down, especially for the economy-wide rate of return. The negative deviation from the base result for this rate of return was just a point in a cyclical movement since the shock was implemented every year, creating results that were not quite long run by definition. The investment elasticity value of ALPHA in Equation (3.162) was assumed to be 2 (see Section 3.4.2), which could lead to over-reaction of investment to changes in the rates of return. This could explain the cyclical behaviour instead of a monotonic return to “normal”. As seen in Figure 8-19, investment peaked around 2030, creating an over abundance of capital leading to the fall in rates of return in subsequent years.

Unlike the earlier productivity shock simulation, in this policy simulation, the aggregate employment was not tied down and remained endogenous, while the corresponding real wage was exogenous. Employment grew in line with population growth (see Figure 8-22).

Figure 8-22: Labour market (percentage deviation from the baseline forecast)



Interestingly, despite the increase in real GDP growth, this policy of creating more stimulus in the eight selected industries did not improve the current account balance, net foreign assets (see Figures 8-23) nor government budget balance (see Figure 8-24). With the deterioration of the current account balance, net foreign assets would start to decline, as shown in Figure 8-23. In the long run, the government would run budget deficits, although at smaller amounts compared to baseline.

This indicates that this policy would not be effective in keeping both the current account and budget balance in surplus. Further stimulation of the construction and government sectors did not create more exports to help the current account balance. The further expansion of downstream industries would come at the cost of further reduction of oil and gas exports, which could have generated more export earnings for the government coffers.

The expansion of the government sector also supports Anaman's (2004) conclusion that a large government, in terms of sectoral GDP, can impede economic growth. In the policy simulation, large export growth could improve the long run economic growth rate. Using multiple regression analysis, Anaman (2004) suggested that Brunei's large government impeded the long term economic growth. He found the optimal size of government expenditure to GDP ratio to be 27.5 per cent. In this simulation, the expansion of the government sector had an adverse effect on other sectors.

Figure 8-23: Policy results of additional stimulus to selected industries (Policy 2)

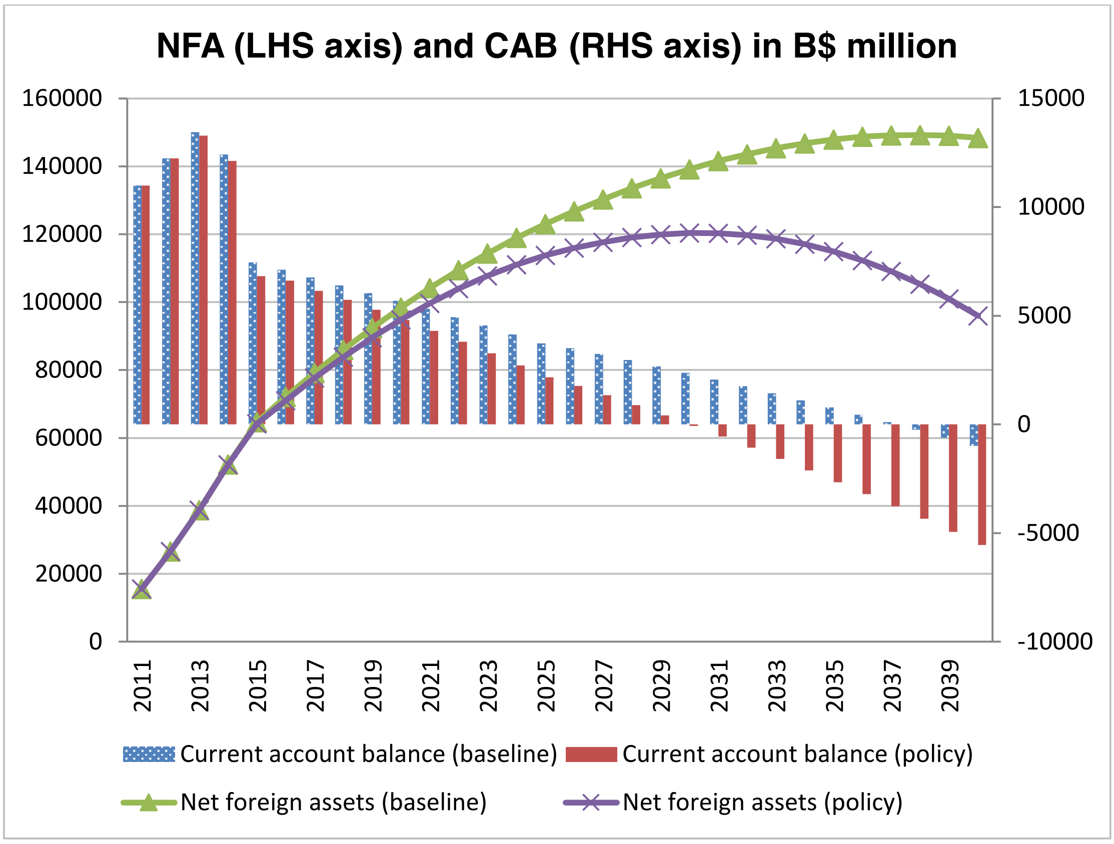
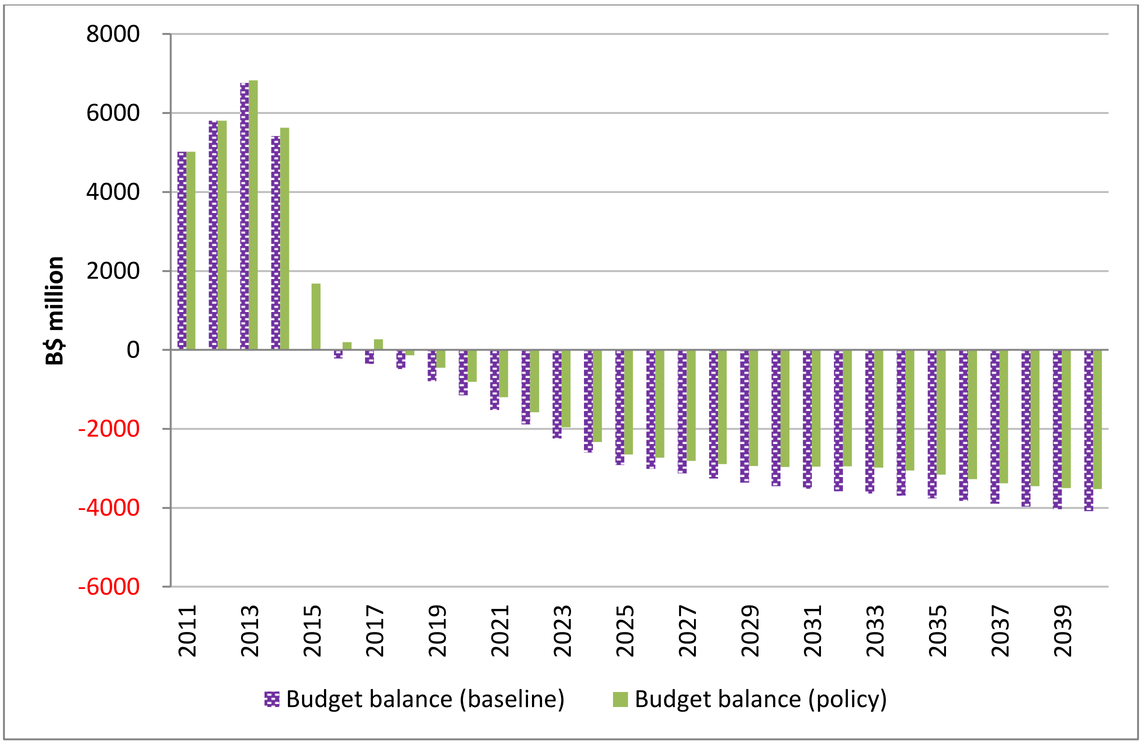


Figure 8-24: Pre and post policy results of the government budget balance (B$ million)



The sectoral results (see Figure 8-25) also showed some improvement in the activity level of certain labour intensive industries. Industries that produce goods and services as inputs to the stimulated industries will benefit; such as basic metals industry selling to building construction related industries and insurance service selling to civil engineering industry. However, as discussed earlier, the exports of selected export-orientated industries (methanol and petrochemicals) would deteriorate (see Figure 8-26) due to their dependency on oil and gas as inputs. Therefore, in the long run, there would be no expansion in new exports from downstream industries unless imported oil and gas were used to replace dwindling domestic varieties.

Figure 8-25: Sectoral outputs in 2040 under further stimulation of the selected industries (percentage deviation from the baseline forecast)

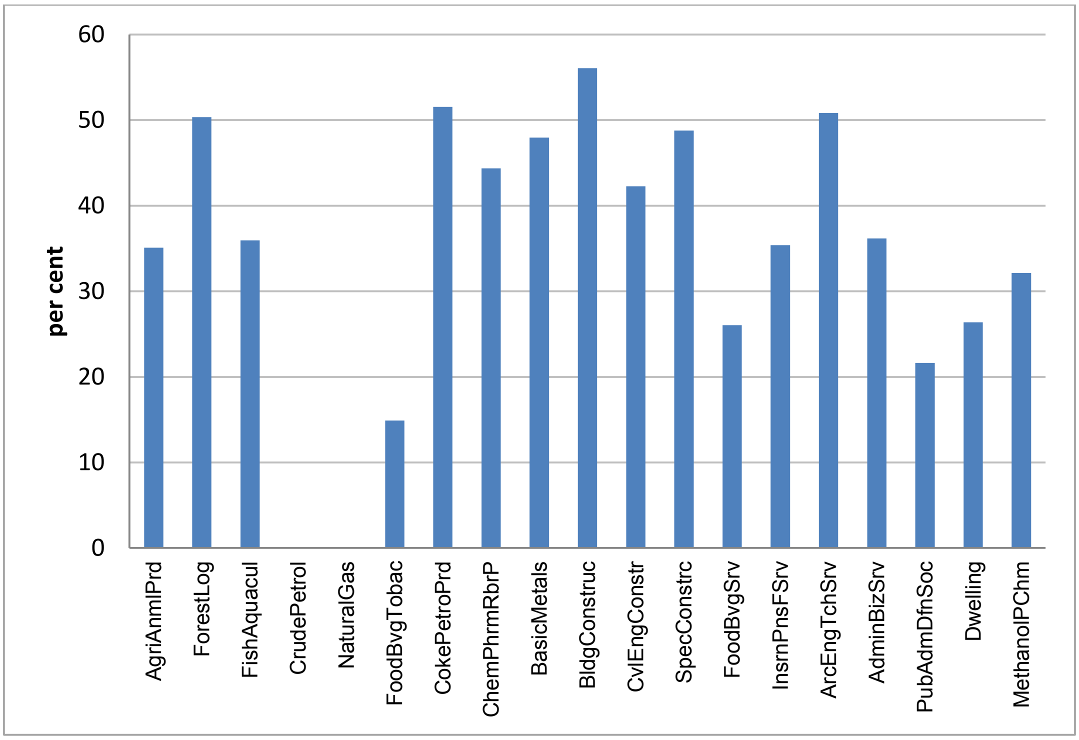
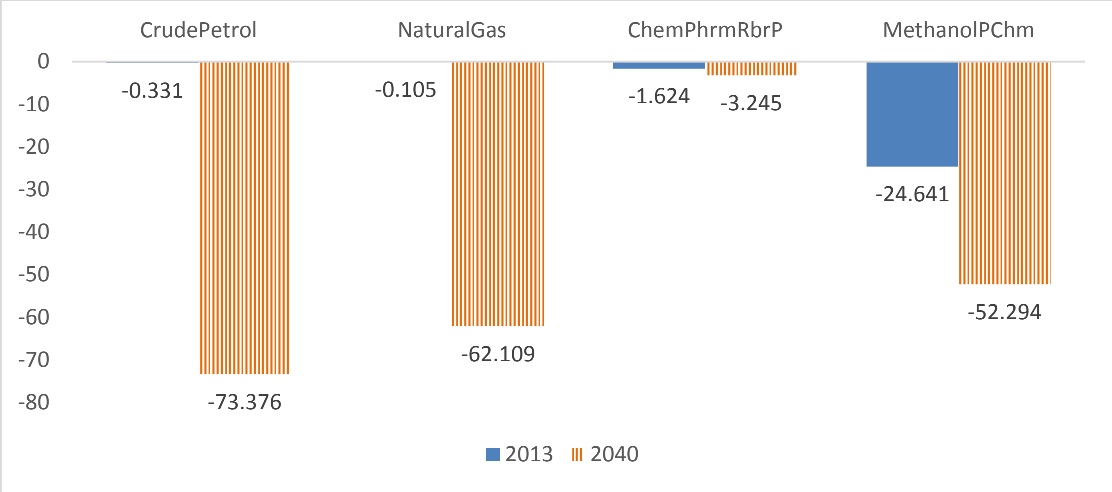


Figure 8-26: Sectoral exports of the stimulated industries (percentage cumulative deviation from the baseline forecast)



8.4 Conclusions

Our modelling shows that a positive stimulus to the economy of either a productivity shock or an increase in the intensity of diversification of selected industries, will generate an increase in real GDP. The key difference between the types of stimulus applied was whether the economic growth would be sustainable - that is growth not driven by depletion of natural resources or increasing debt.

In the first policy simulation, improvement in productivity created additional exports. By contrast, the second policy simulation generated negative growth in exports relative to the baseline. This was due to real appreciation of currency, which led to erosion in the competitiveness of exports. In the face of depletion of oil and gas reserves, this stimulation would not be sustainable unless alternative industries could create substantial outputs to replace the lost oil and gas outputs.

However, due to the rigidity on the demand side, which was dominated by the government spending and held as exogenous, the positive impact of productivity improvement in Policy 1 was muted. The simulation results showed that improved productivity crowds out employment (by driving wages down) and capital stock (as rental costs go up). Who would benefit from this productivity shock? It appears that some labour intensive exporters might gain in this simulation. Households would fail to benefit due to the decline in real wages. However, they would enjoy cheaper goods and services provided by the public sector as the government price index fell across the forecast period. To maintain the standard of living, householders would need to be compensated.

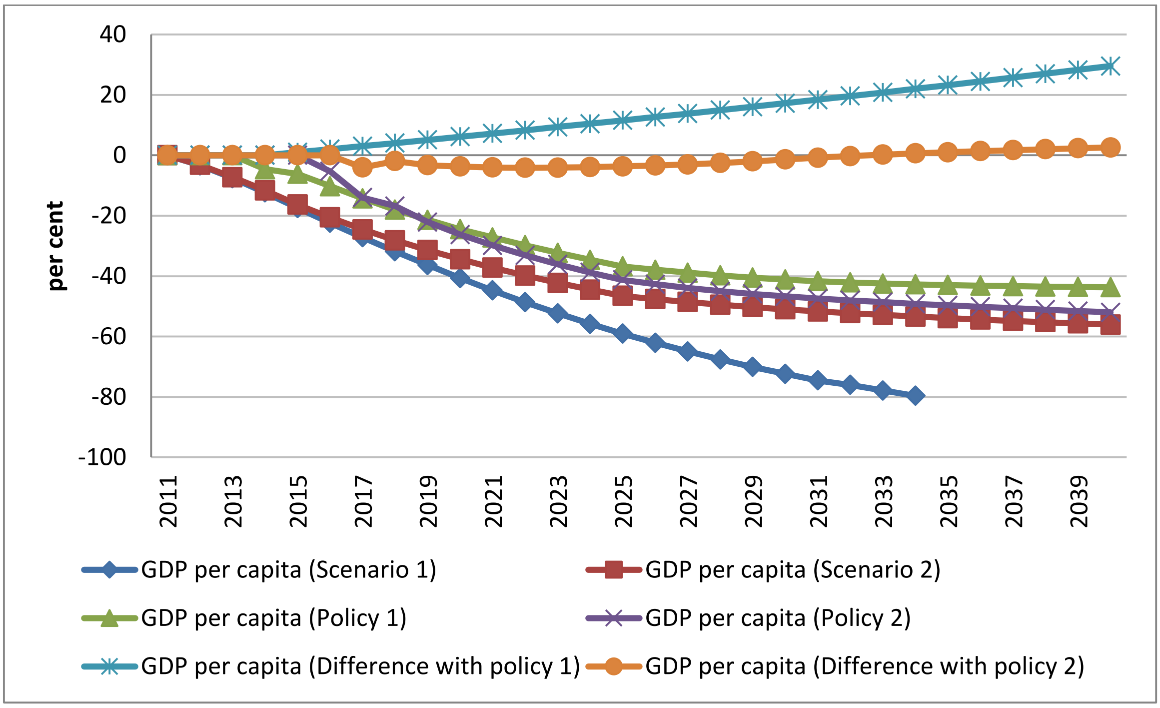
The second policy option relies more on the domestic stimulus and increased construction-related activities to generate growth, which may not be sustainable in the long run. Construction activities would reach a saturation point and the government's revenues would decline with the fall in hydrocarbon revenues, which could not be expanded further. Construction-related industries would not produce any outputs for exports in exchange for export earnings.

It is clear that out of the two simulations, the significant demand stimulus to selected industries was less effective than an improvement in technical change or productivity. Although improvement in all factor-augmenting technical change could generate a positive effect on economic growth and exports, it is not always a viable policy option because it can be difficult to implement. Nevertheless, simulation results show that in order to create an additional 1 per cent of real GDP growth per annum on top of the baseline forecast, 1.02 per cent of annual productivity growth would be required. This productivity growth would also lead to the improvement of real GDP per person by about 1 per cent per annum (Figure 8-27).

The GDP per capita growth rate, as a measure of welfare, was compared under four scenarios - Scenario 1 without any action, Scenario 2 with some diversification efforts, Policy 1 with overall productivity improvement and Policy 2 with further stimulation of the eight selected industries. Despite the overall decline due to the depletion of the hydrocarbon sectors, it was observed that the percentage change in

GDP per capita could be significantly improved in the long run with productivity growth (see Figure 8-27). The difference due to the policy itself is represented by the line sloping upwards in Figure 8-27, above the horizontal axis. Even without productivity growth, improved GDP per capita could be obtained with further success in diversifying the economy, although at a much lower rate and one that would only improve only in later years.

Figure 8-27: GDP per capita growth rate under different scenarios



The literature focussed on the link between fiscal policy and economic growth remains inconclusive (Mencinger et al. 2015). The demand side stimulus needs to be funded either by incurring more government debt or by running down the net foreign assets, if the government is not borrowing. Either way, the effects of fiscal stimulus will only be temporary and not sustainable. The only way to achieve sustainable long run economic growth is through technical change or productivity (Solow 1957). Productivity improvement coupled with demand stimulus will be more effective than individual policies implemented in isolation.

The remaining issue to address here is the declining aggregate investment associated with the shrinking of the oil and gas sector seen in the simulation results (see Figure 8-9). Putting new investments into the economy to generate productive activities would help offset this decline. Besides looking at effective public investment, the government should also continue its efforts to attract more FDI and to provide a business-friendly environment to entice potential investors and businessmen alike. Brunei can offer several attractive features to potential investors or business owners, such as existing favourable tax incentives, low corporate tax of 18.5 per cent (Koo 2014c), one of the lowest utilities rates in the region, and good infrastructure. Despite the limited pool of skilled workers, as long as it remains relative easy and convenient to employ foreign workers to fill this labour shortage, this would not represent an obstacle for developing new industries.

Policymakers must be mindful of their choice of industries to stimulate. The downstream methanol and petrochemicals industries could help broaden the export base in the short term. However, their production depends on the oil and gas inputs and while currently these are cheap and readily available, this may not be the case in the long run. Without proper management of intermediate inputs, risk can arise and threaten the survival of these downstream industries in the future. These downstream industries need to maintain competitive pricing in the global market. If too much focus and emphasis is placed on developing these downstream and related industries, another concentration and correlation risk will arise as oil and gas resources deplete.

In view of the simulations results, policymakers should focus on productivity growth and continue to implement microeconomic reforms across the board. They must also keep track of the progress of these initiatives. A productivity improvement strategy could be more successful if combined with demand stimulus. This could be funded from excess savings instead of channelling all savings overseas to increase net foreign assets.

Policymakers might also wish to reassess current strategies and take a long term view of the future viability of the downstream industries because, unlike the GCC economies, the life span of Brunei’s oil and gas resources are limited to continue supporting these industries.

Chapter 9: Concluding remarks and future directions

This chapter summarises the main findings and conclusions of the thesis. The limitations with regard to the database and model are identified, followed by suggestions for improvement. The chapter concludes with a discussion of some potential policy applications and an extension of this study.

9.1 Main findings

In this thesis, we described the construction of an IO database and dynamic CGE model of the Brunei economy. We then used that model to assess issues associated with diversification and declining oil and gas sectors. The recursive dynamic model called BRUGEM was developed for this thesis and is based on the ORANIG-RD model, with modifications and additions made to suit the thesis research objectives. New equations with regard to government and foreign accounts, the labour market, the current account balance and net foreign assets were included.

Brunei is in a preparation phase and the government has been looking into various options to diversify, with some strategies already implemented. To date, the diversification progress has been slow and has shown no significant results.

Following the oil and gas industries, which make up 64 per cent of total nominal GDP, the government sector is the next most important sector as it contributes 10 per cent of total GDP. Some industries, such as agriculture, aquaculture and tourism, have been identified as having growth potential, but little progress has been achieved in developing these sectors due to constraints on raw materials and resources. Instead, the current policy direction is focussed on downstream oil and gas industries, such as methanol, refineries and petrochemicals for broadening the industry base.

In this thesis, we assessed two policy options directed at achieving sustainable growth for an economy with declining oil and gas sectors. The first consisted of a suite of undefined policies designed to generate productivity improvement. The second, again based on a suite of undefined policies, allowed for further expansion of eight selected industries (downstream energy and construction-related), and the expansion of the government sector for diversification.

Before the policy effects could be studied, a more up-to-date IO database was created. A baseline forecast was also constructed, taking into account known policies and likely developments, against which the alternative policy intervention scenarios could be compared to.

There were challenges in the construction of the IO database due to inconsistencies in the published data and the lack of availability of some key data. This meant that a number of adjustments had to be made. The DOS also published two different sets of national accounts for the same years, using different methodologies and base years. This posed a challenge in harmonising the two sets of data due to large differences in the expenditure component shares of GDP, as well as extensive statistical discrepancies. As a consequence, the IO database was only updated from 2005 to 2011. Through the techniques explained in the thesis, challenges were overcome to create a functional database and a working model.

9.1.1 Assessment of the policy options

Without any actions being put in place, the modelling of the baseline scenarios, as reported in Chapter 7, point to dire consequences in the face of declining oil and gas reserves. In the first baseline scenario, real GDP falls at an average annual rate of 5.5 per cent and the real wage falls by 20 per cent annually. However, the first baseline was considered to be unrealistic, as the government would certainly take action to diversify.

This leads to the second baseline forecast. The results in this scenario showed that with some effort, the fall in GDP could be cut to an average rate of 1.8 per cent per annum, with falls in the real wage rate limited to 1 per cent per year. This was the baseline forecast against which the policy simulations were compared.

9.1.1.1 The first policy simulation with productivity improvement

For the first policy option, it was assumed that policies would be put in place to allow the economy to replace about half of the total lost output from oil and gas sectors over the forecast period of 2012 to 2040. The policies were aimed at improving all-factor productivity. This improvement would generate additional GDP growth of 1 per cent relative to baseline growth. To achieve this, the positive productivity shock was about 1.02 per cent per annum.

Overall, as real GDP growth improved by additional 1 per cent from the baseline forecast, growth in aggregate exports improved by an average of 3.4 per cent per annum, with growth in imports up by 0.7 per cent per annum. The average annual growth of private consumption increased by 1.2 per cent, and there was no change in government expenditure due to it being exogenous with zero change. The aggregate investment growth declined by 1.4 per cent per annum as the oil and gas industries faltered away. In the long run, aggregate investment would recover as more capital is built up with time.

An important assumption made for the first of the policy simulations was that aggregate employment cannot change from its baseline path. In the baseline, employment is essentially unchanged. Thus as the economy collapses, the real wage rate falls. In the first of the policy simulations, even though the economy collapses less, the real wage rate still falls significantly at a rate of 6.5 per cent per annum.

In the baseline, with the decline in oil and gas income, the current account balance would start to turn into a deficit when export earnings and net receipts on net foreign assets are no longer sufficient to cover the imports. Net foreign assets will fall in the long run. However, the productivity improvement in the policy simulation would help to reverse the declining trend and Brunei was projected to experience surpluses on its foreign current account and domestic fiscal account throughout the projection period.

Sectoral results indicated that those labour intensive industries and those selling to households would gain from productivity improvements. Those improvements would lead to more a competitive exchange rate, so traded goods industries would also experience gains in the policy simulation relative to the baseline.

9.1.1.2 The second policy simulation with expansion of selected industries

In this second policy simulation, there was no additional productivity boost. The same baseline forecast was used, with selected industries stimulated further to achieve 85 per cent replacement of the lost oil and gas outputs (increased from 50.2 per cent). The further expansion of the selected industries yielded mixed results. Relative to growth in the baseline, average annual growth in real GDP increased by 1 per cent, private growth in private consumption increased by 0.7 per cent, growth in government expenditure increased by about 0.6 per cent, and growth in aggregate investment increased by 1.2 per cent. Growth in the volume of exports, however, fell by about 1.4 per cent due to real appreciation of the currency, while growth in import volumes was up 0.8 per cent.

The current account balance and budget balance deteriorated further, relative to baseline levels. In this policy simulation, real GDP growth was driven mainly by government expenditure and investment growth due to the boost in construction-related industries. The demand side stimulus needs to be financed either through incurring debts or, in the case of Brunei, by running down the net foreign assets.

Currency appreciation adversely affects export-orientated industries. Aggregate exports fall as the directly stimulated industries have little impact on overall exports. The methanol and petrochemicals industries rely on oil and gas inputs that otherwise would be sold to export.

Sectoral results indicate that businesses that sell to construction-related industries and the government would benefit under this demand side stimulation policy. However, the expansion of the government sector has absorbed most of the labour and has crowded out other labour intensive industries, such as agriculture, manufacturing of food and beverage products. The increased outputs in construction-related industries, refined petroleum products, chemicals and pharmaceutical, and methanol are due to the targeted demand side stimulus.

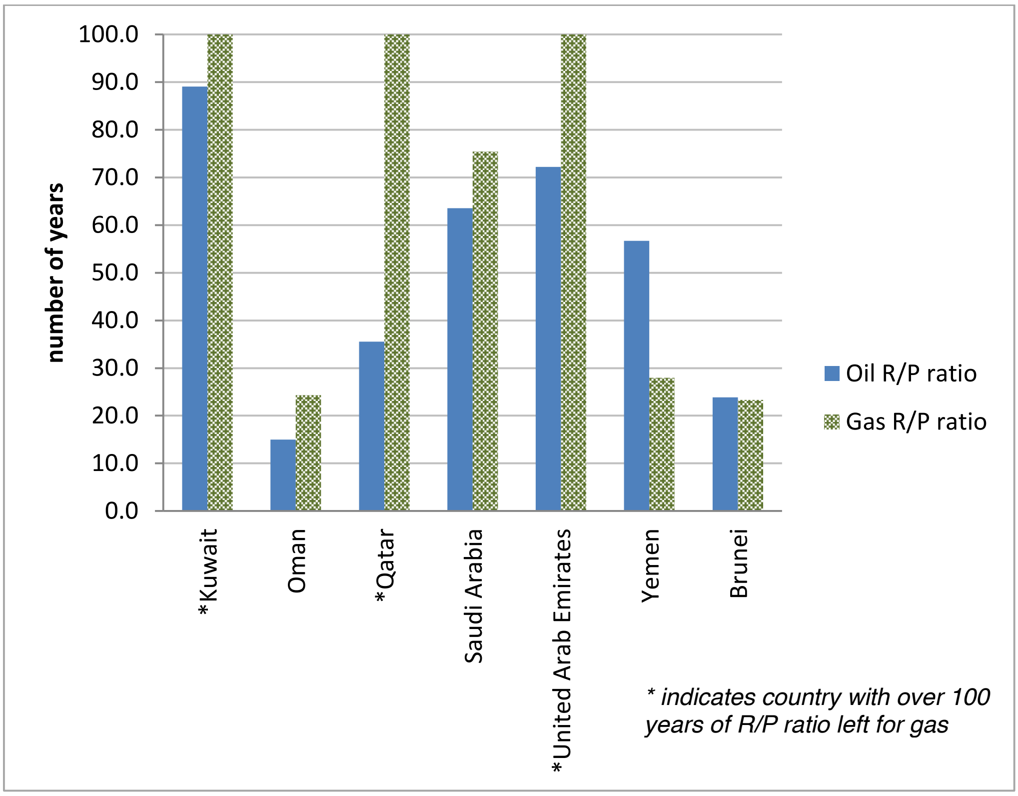
9.1.2 Conclusions from the simulations

In the second baseline forecast, results show that current diversification strategies can help to reduce the magnitude of decline in overall GDP as oil and gas deplete. This was simulated with half of the declining oil and gas output replaced by the targeted industries over the period 2012-2040. However, this is not sustainable into the future, as eventually the downstream industries will be adversely affected by the depletion of domestic oil and gas. The construction and government sectors are not contributing much in terms of generating productive activities that can boost the government revenues or export earnings. Further stimulation of these industries to replace lost oil and gas output by 85 per cent will aggravate this adverse outcome in the long run as shown in the Policy 2 results.

Brunei may be following in the footsteps of GCC countries that have established downstream energy industries. But why is this strategy not working as well as anticipated for Brunei?

Comparing the selected countries in the GCC and the Middle East, Brunei has a relatively shorter time span before its oil and gas reserves run out (see Figure 9-1). Most GCC countries have embarked on diversification programs well ahead of their oil and gas resources depleting. So being a late starter in this diversification strategy might disadvantage Brunei's economy in the long run.

Figure 9-1: Oil and gas reserves to production (R/P) ratio for selected countries in 2014



Source: BP (2015)

Given the dire situation implicated by the modelling results, policymakers may have to rethink their strategies and implement any positive changes. This might improve the standard living of its people, as well as economic growth.

The Brunei government may wish to maintain its downstream industries in the long term by starting to import the necessary intermediate inputs once its own reserves run out. However, this will expose these industries to the risk of uncertain commodity prices in the world market and they may not be able to produce and export at competitive prices.

Diversifying into the petrochemicals industries may work for countries like Saudi Arabia, which holds abundant oil and natural gas reserves and where gas offers a considerably strong advantage as a feedstock for production (Yamada 2011). Saudi Arabia is one of the main petrochemicals producers and in 2008, was the largest methanol producer and second largest ethylene producer in the world (Yamada 2011). Saudi Arabia has gone through industrialisation for more than four decades to achieve that share of global production and by 2008, it had successfully created employment for 3.8 per cent of its population through its petrochemicals sector (Yamada 2011).

In 2014, Saudi Arabia held 15.7 per cent of total oil reserves, which are predicted to last another 63.6 years at current reserves-to-production ratios, and 4.4 per cent of the world's natural gas reserves, predicted to last another 75.4 years (BP 2015). In contrast, Brunei has less than 24 years of remaining oil and gas reserves (BP 2015). In addition, at the current low commodity market prices, no large investments are expected to pour in for further exploration unless there are convincing data of potential large finds to entice investors. The cost to extract the marginal deposits from maturing oil and gas fields cannot be justified in the face of low commodity prices, as many oil and gas companies have scaled down their operations in recent years. For a medium-sized field, Brunei is the most expensive in the Southeast Asia region in terms of the breakeven price for oil firms to operate (Xu 2015).

Besides methanol and petrochemicals, Brunei is also looking at other potential export products. Projects include the setting up of an aluminium smelting plant with the help of a Korean company (Bandial 2014a), and a potential steel manufacturing plant (Shahminan 2013b). These are industries that utilise large amounts of intermediate inputs, such as electricity, which is relatively cheap in Brunei since it is mainly generated by gas. At the time of writing, neither of these two industries has commenced production.

In short, the idea of diversification is on the agenda but execution of industrialisation plans has come a few decades too late. This is despite the fact that frequent mentions of economic diversification have been made in the five-yearly national development plans developed since 1984 (Siddiqui et al. 2012). Several industries have been identified as having to potential to assist in diversification but there has been no major progress and most projects appear to start strong and then plateau in progress. The lack of aggressiveness in strategy and a sense of “complacency” during the heyday period of high oil prices have stalled economic diversification efforts. There was little incentive to diversify when there were abundant oil and gas resources. On the positive side, fiscal management has been prudent and this has helped Brunei to weather several budget deficits in the past.

The government has also continued to invest the hydrocarbon income in human capital and infrastructure to improve the living standards of its people, and to save through SWF managed by the BIA. Although the details of BIA’s investment are not disclosed, it is believed they are well diversified into different asset types, continuing to generate income for the country. This SWF income has been acting as a buffer to cushion fiscal deficit, as these funds are required to keep up with government expenditure without resorting to the issue of sovereign debts.

Without effective diversification in place to generate alternative income streams from productive activities, Brunei can continue to finance its budget and imports using the returns from foreign financial assets. This, however, would not be feasible in the long run since the financial returns would be exposed to investment risks. Without published information on the SWF fund size, it is uncertain how long can Brunei depend on its SWF without creating other productive activities to generate economic growth.

Successful industrialisation of a country can take decades to develop before an impact on the economy can be seen. Since the 1970s, Bahrain has embarked on an aggressive diversification program and its finance sector contributed 17 per cent to its total GDP in 2013 (Bahrain Economic Development Board 2013). In comparison, Brunei's finance sector grew slowly from 3 per cent in 2006 to 4.3 per cent in terms of the share of total GDP in 2014 and remains underdeveloped.

Brunei's close neighbours, Singapore, embarked on industrialisation from the 1960s and Malaysia has been building aggressive export-led industrialisation since the 1980s (Athukorala & Menon 1997). In 2013, these industrialisation efforts resulted in GDP contributions of 19 per cent and 24 per cent in these respective countries' manufacturing sectors (World Bank 2013a).

Currently, Brunei's industrial sector remains predominantly oil-based, with 95 per cent in mining and manufacture of LNG and methanol (DOS 2014a). If Brunei were to diversify away from oil and gas, it would have to achieve phenomenal growth in the non-oil manufacturing and services sectors to replace the value-added oil and gas industries.

The policy simulation with productivity improvement might prove more viable in the long run in terms of creating economic growth. Microeconomic reform is mentioned frequently in the economic growth literature (Adams & Parmenter 1994). However, implementation takes time and time is not on Brunei's side. This calls for urgent well-coordinated microeconomic reforms designed to improve productivity on all levels in order to grow Brunei's economy. The government must also look into issues of increasing aggregate investment as investment in the hydrocarbon sector declines.

However, the policymakers have to be aware of other factors that may affect FDI. Despite the incentives to attract investment that are in place, the recent implementation of Syariah law did not receive a favourable perception[30], especially internationally. Maierbrugger (2015) suggested a hard time ahead for Brunei's economy with the little diversification progress and that the Syariah law has undermined investors' confidence.

Brunei cannot afford to be complacent in handling diversification issues and in attracting new FDI. Productivity has to improve significantly to generate sustainable growth into the future. The success of these productivity reforms will depend on the political will and unwavering commitment of relevant parties in preparing for a smooth transition into the post-hydrocarbon era.

9.2 Contributions of this thesis

The main contribution of this thesis is to the limited pool of literature on Brunei, especially in quantitative research and in the field of CGE modelling. This thesis documents an operational dynamic CGE model for Brunei called BRUGEM, which captures government and foreign accounts data in order to track adjustment paths as oil and gas deplete. It has presented quantitative evidence on the future, elucidating the impacts of oil and gas depletion for Brunei.

BRUGEM was used to assess and measure the effectiveness of current diversification effects and to analyse their impact on the economy. With the inter-dependencies captured in BRUGEM, it was possible to analyse in more detail both the macro economy and "winners and losers" at sectoral levels. This makes BRUGEM a useful tool for policy formulation, as illustrated in Chapter 8.

[30] Some viewed this implementation harshly, believing it would be detrimental to economic growth ('All pray and no work' 2015). Whether it will be adversely affecting growth in labour force, tourism and FDI is yet to be seen.

This thesis also described the development of a new CGE database based on the published IOTs, with the appropriate adjustments. The challenges of inconsistent or unavailable data, necessary for CGE modelling, have also been addressed. The methods explored in the thesis may be used as a reference for other researchers who are facing similar challenges in terms of data limitations.

9.2.1 Limitations and directions for further research

The dynamic CGE model BRUGEM, developed in this thesis, opens up opportunities to conduct further research on many economic issues of interest. Modifications or further enhancement of BRUGEM may be required to address the issues of concern for each study subject. Nevertheless, the development of BRUGEM sets the foundation for more research to come, with the use of CGE as a tool for policy analysis.

9.2.2 Ways to improve the BRUGEM theory and database

9.2.2.1 Addressing statistical discrepancies

Statistical discrepancy is often used as an indicator of the reliability of national accounts. Several authors, as list in Bajada (2001), have shared growing concerns about the quality and accuracy of national accounts in general that have been undermined by extensive and volatile statistical discrepancy. In the case of Brunei, based on the published data from statistical yearbooks and recent key indicators, the statistical discrepancy has shown significant changes in magnitude and volatility for the period 2005 to 2013, swinging from a positive to negative share of total GDP, as shown in Table 9-1. The discrepancy is explained as the difference between measurement of the GDP obtained by production and expenditure approaches.

Table 9-1 Nominal and real GDP by expenditure approach for 2005-2013 (base year 2000)

Nominal GDP (B$ million)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Personal Consumption	3,563.20	3,610.40	3,722.00	3,608.00	3,803.00	3,908.60	4,088.90	4,333.20	4,492.10
Government Consumption	2,920.40	3,291.90	4,175.40	3,496.40	3,635.50	3,780.70	3,566.60	3,659.40	3,691.80
Capital Formation	1,803.20	1,902.40	2,396.80	2,788.00	2,740.80	2,678.30	2,750.40	2,880.60	3,087.00
Exports	11,131.60	13,072.40	12,524.60	15,971.14	11,362.40	13,736.60	16,726.00	17,237.30	15,351.40
less: Imports	-4,329.20	-4,595.90	-5,149.50	-5,632.80	-5,587.20	-5,544.70	-5,994.50	-6,609.30	-6,548.20
Statistical discrepancy	774.80	944.60	789.20	166.80	-343.40	-1,692.10	-141.10	-316.10	83.50
Total	15,864.00	18,225.80	18,458.50	20,397.54	15,611.10	16,867.40	20,996.30	21,185.20	20,157.70
% Share of GDP	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Personal Consumption	22%	20%	20%	18%	24%	23%	19%	20%	22%
Government Consumption	18%	18%	23%	17%	23%	22%	17%	17%	18%
Capital Formation	11%	10%	13%	14%	18%	16%	13%	14%	15%
Exports	70%	72%	68%	78%	73%	81%	80%	81%	76%
less: Imports	-27%	-25%	-28%	-28%	-36%	-33%	-29%	-31%	-32%
Statistical discrepancy	5%	5%	4%	1%	-2%	-10%	-1%	-1%	0%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%
Real GDP (B$ million)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Personal Consumption	3,485.50	3,615.50	3,687.90	3,752.70	3,939.90	4,010.80	4,157.90	4,375.50	4,499.20
Government Consumption	2,872.20	3,240.70	3,751.70	3,722.50	3,919.00	4,055.20	3,907.10	3,987.00	4,029.00
Capital Formation	1,717.30	1,741.40	2,203.70	2,494.00	2,486.30	2,398.30	2,448.40	2,521.20	2,661.30
Exports	7,485.70	7,760.40	7,012.50	6,576.60	6,229.90	5,744.10	6,700.40	6,462.40	5,931.80
less: Imports	-4,251.50	-4,425.50	-5,010.30	-5,559.80	-5,515.20	-5,500.40	-6,129.70	-6,909.10	-6,804.30
Statistical discrepancy	154.50	35.30	340.70	767.80	496.50	1,138.50	1,168.70	1,932.00	1,835.40
Total	11,463.70	11,967.80	11,986.20	11,753.80	11,556.40	11,846.50	12,252.80	12,369.00	12,152.30
% Share of GDP	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Personal Consumption	30%	30%	31%	32%	34%	34%	34%	35%	37%
Government Consumption	25%	27%	31%	32%	34%	34%	32%	32%	33%
Capital Formation	15%	15%	18%	21%	22%	20%	20%	20%	22%
Exports	65%	65%	59%	56%	54%	48%	55%	52%	49%
less: Imports	-37%	-37%	-42%	-47%	-48%	-46%	-50%	-56%	-56%
Statistical discrepancy	1%	0%	3%	7%	4%	10%	10%	16%	15%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: DOS (2007, 2011, 2012a, 2014b)

The statistical discrepancy is much more significant in real GDP numbers, which were as high as 10 per cent in 2010 and 2011, and a 16 per cent share of GDP in 2012. This large discrepancy cannot be ignored. Although real GDP provides a more meaningful comparison of economic activities over time without the price changes, the level of statistical discrepancy shown in Table 9-1 would definitely have an impact on the correct measurement of real growth rate for each aggregate. In the case of Brunei, as far as I am aware, no research or publication of findings has been conducted to determine from where the source of discrepancy comes. The statistical discrepancy is there as a "balancing item" in Brunei's national accounts, to match the GDP figures by a production approach as the sum of value-add in various industries. Therefore, the DOS in Brunei had taken the stance that measuring the GDP by production was more accurate than obtaining the GDP by an expenditure approach. As explained in Section 4.4, the statistical discrepancy was scaled across all the expenditure aggregates based on their share in the GDP. It is not surprising that the outcome of the simulation showed different GDP numbers by aggregates to those in the national accounts.

It is generally costly, in terms of resources, to obtain nationwide data and information in order to compute GDP numbers. Some methods, based on surveys, rely on the understanding and truthfulness of respondents and can be prone to errors due to misinterpretation of data requirements. Further estimation and extrapolation may be necessary for any missing or incomplete data. It is not an easy process to obtain highly accurate numbers. In the case of Australia, Bajada (2001) estimated that three-quarters of the measurement errors in the national accounts came from the mis-measurement of private investment expenditure. He argued, however, that the public investment and public consumption expenditure and the international trade data on imports and exports were reasonably well measured and contributed fewer measurement errors.

In analysing US data published by the Bureau of Economic Analysis, Beaulieu and Bartelsman (2006) identified "problem" industries that caused statistical discrepancy. This was due to differences in value-added and mis-measurements of private fixed investment numbers, which were not reliably reported. They also suggested that an optimal dataset is a combination of expenditure side and income side GDP data, weighing more to the income approach than the expenditure approach.

In Brunei, for many years the DOS has been producing GDP by expenditure and production approaches. More recently, a GDP by income approach (DOS 2014c) has been applied. This represents an improvement in data coverage and GDP estimation. Producing good national accounts data is a common challenge faced by many countries. Whether a developed nation or a developing country like Brunei, it is nevertheless important to have accurately measured economic data. This is necessary for proper assessment of the economy and for policymaking decisions. Consequently, agencies should continue to strive to improve data quality.

A better set of national accounts and more accurate data would be useful for researchers to conduct further studies. Given the limited time frame, this study analysed only the data that was made available. Using the same methodology of database creation, any improved dataset available at later dates could be incorporated easily into this model and simulations rerun in BRUGEM to obtain new sets of results for future research work.

9.2.2.2 Addressing data inconsistencies

BRUGEM's IO database was created for 2005 using data for that year. It was updated to 2010 using national accounts data for that year, based on prices of the year 2000. National accounts with 2010 as their base year were released in 2015, including revisions back to 2010. Although major data work had already been completed in this study by the time this new data series was released, efforts were made to harmonise and update the IO database using the new data. Unfortunately, this attempt failed because of significant changes in the shares of the expenditure components to total GDP, as well as the extensive statistical discrepancies, as explained in Section 5.5. An improved and updated IO database could be produced if the statistical discrepancy in the national accounts is addressed by the statistical office.

9.2.2.3 Availability of more data

BRUGEM has one representative household and one representative occupation in its core database. This could be improved. The distributional effects of macroeconomic policies are often of interest to policymakers. A policy that may work well at the macroeconomic level may not have the same beneficial effects on households and industries. There will always be winners and losers in any implemented policy. Trade-offs are generally unavoidable and policymakers need to weigh the pros and cons before an informed decision can be reached. That process would be improved if the underlying modelling were to provide outcomes across households of different income-types and across occupations with different skills/training characteristics. Once the detailed labour market data and information are available from the ILO (an on-going project with DEPD), the model could be extended to capture more details of the labour market by occupation, industry and wage rates.

9.2.2.4 Improvement to the model theory

Besides the database, one of the main objectives of this thesis was to produce a well-functioning model. Improvement to BRUGEM from a theoretical perspective could be carried out. In BRUGEM, several assumptions had to be made as to how government income and expenditure develops over time. If more details pertaining to a further breakdown of the revenues and expenditure items were available, these equations could be improved to give a more accurate picture of the government accounts.

Without comprehensive and reliable BOP data, the analysis is limited. The role of the SWF is important to Brunei's economy. However, due to the lack of data and transparency on how the SWF interacts with the economy, as well as government's fiscal position, it was not modelled explicitly in BRUGEM. If more information were available on the transmission mechanism of the SWF to Brunei's economy, combined with good data on BOP, better forecasting results might be obtained as Brunei transitions to a post-hydrocarbon era.

9.2.3 Other policy applications of BRUGEM

There are many potential policy applications for using BRUGEM. One could use it to study the impact of an increase in investor confidence; an injection of new gross fixed capital formation; or the introduction of new tax, such as GST, or even income tax to improve fiscal position. These are just a few of the policy applications.

BRUGEM could also be extended to undertake work in other areas not traditionally thought of as especially suited to CGE modelling. At present there are a few finance-related industries in the IO database but BRUGEM, like other conventional CGE models, does not include specific equations to model the financial sector of a country. In BRUGEM, the interest rates are set exogenously and the nominal exchange rate is set as the numeraire, as a yardstick to measure the relative price movements in the economy. As demonstrated by Dixon et al. (2014) in the case of Papua New Guinea (PNG), a financial module could be developed to link to the core CGE model. Dixon et al.'s financial module was developed to investigate the impact of monetary policy for PNG. It included equations describing the accumulation of financial assets held by agents; how domestic and foreign agents decide on which assets to hold at the end of the year; how funds are made available to domestic agents to acquire net assets; and how the rates of interest for the different assets are determined. This financial model was linked to the core CGE model of PNG via three conditions. First, the current account deficit was equal to the net inflow of capital. Second, the government's fiscal deficit was equal to the new acquisition of domestic bonds. Third, the investment in industry *i* was set as equal to the new acquisition of assets *j* in industry *i* by agents *z*. The financial agents and assets covered in Dixon et al.'s (2014) research are shown in Table 9-2

Table 9-2: List of financial agents and assets in financial CGE model

Agents (z)	Assets (j)
(1) Households (2) Foreigners (3) Government (4) Commercial banks (5) Non-bank financial institutions (NBFI) (6) Superannuation funds (7) Industries	(1) Business assets (equity and credit), industry 1 to n (2) Bank deposits (3) Domestic bonds (4) Foreign bonds (5) Deposits with central bank (6) Loans to domestic households (7) Deposits and equity in NBFI (8) Superfunds deposits

Source: Dixon et al. (2014)

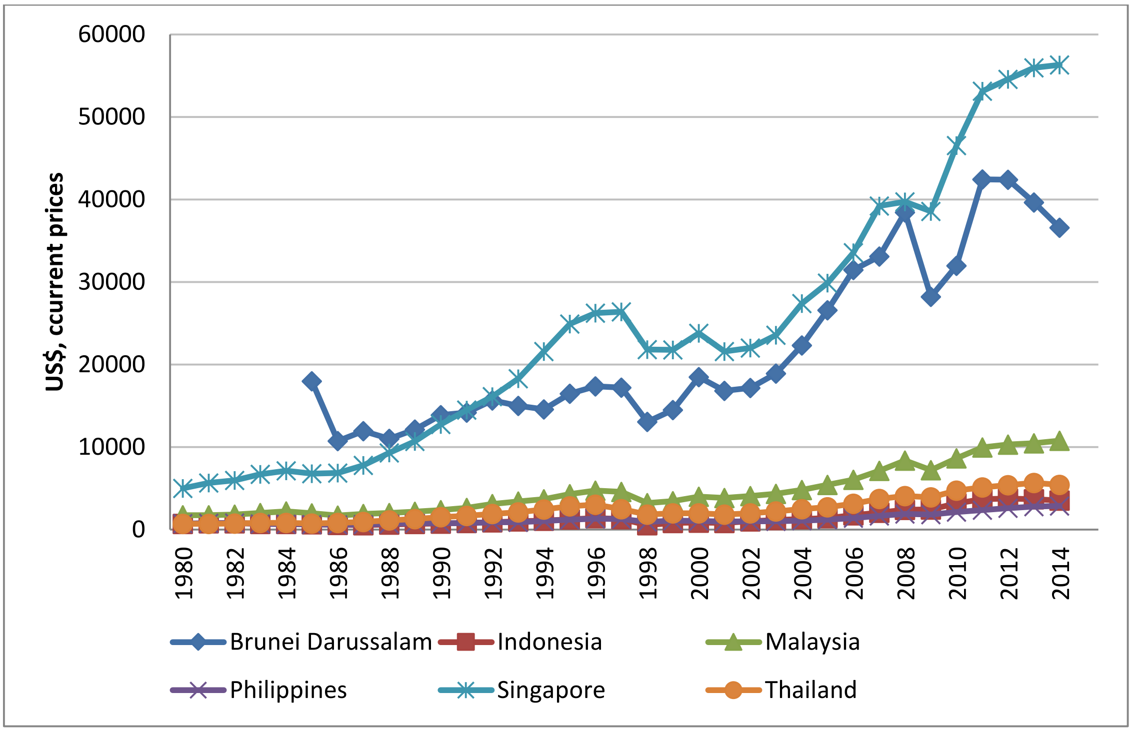
Therefore, if the monetary authority of Brunei (AMBD) were interested in modelling the economy to capture explicitly the behaviour of financial agents, this would be possible by adding a financial module to BRUGEM. This is particularly useful considering Brunei has already issued its domestic Islamic bonds and is looking at issuing more financial instruments in the future, as the capital market develops. A key challenge is to obtain all the necessary data and information. Greater coordination will be needed between AMBD and the main statistical agencies, such as DEPD and the MoF, which also holds the Tabung Amanah Pekerja (employees trust fund) (TAP) and supplementary contributory pension (SCP) on behalf of households.

Another application that may be of interest to the MoF is the effect of increasing the compulsory contribution rate to the TAP and/or SCP on households. The contributed funds in TAP and/or SCP are intended to ensure that some forced savings are available as retirement income. In some aspects, this is similar to the superannuation funds in Australia, but there are differences. The superannuation sector in Australia is made up of different types of superannuation funds and, unlike Brunei, Australian households are able to designate a super to which contributions are made. Dixon et al. (2015) has modelled the Australian superannuation sector within a financial CGE model of the Australian economy. They provided explicit treatment of financial intermediates and the agents with whom they interact; financial instruments describing assets and liabilities; financial flows relating to these instruments; ROR on individual assets and liabilities; and links between the real and monetary sides of the economy.

In the same study by Dixon et al. (2015), using the financial CGE model, they were able to examine household saving behaviours under the assumption that these households are given the liberty to invest their own savings, instead of through intermediaries. Their study generated interesting results on how an increase in the super contribution rate could influence households in terms of their allocation of funds to different types of assets. These might include the purchase of securities issued by domestic financial sectors or by foreign entities, housing equity or government bonds. In Brunei's context, although the capital market is not well developed and there are limited investment products, data can still be obtained by capturing household savings and investment patterns through household surveys. Once the government-issued *sukuk* is available in the secondary market, it is very likely that domestic households will want to hold some as investments.

Another approach to this thesis might be to study what could be the driving factors to achieve a successful diversified economy. In this approach, one could pick a suitably broad-based hypothetical economy that is performing well economically without owning any hydrocarbon reserves. One suggestion would be to select Brunei's close neighbour, Singapore, which is also a small and open economy with high GDP per capita. In Figure 9-2, it can be seen that Singapore started with lower GDP per capita in the 1980s compared to Brunei. The GDP per capita, however, caught up by 1989 and since then it has surpassed Brunei's economic performance, both in nominal GDP and GDP per capita (IMF 2015).

Figure 9-2: GDP per capita in ASEAN-6



Source: IMF (2015c)

Based on several observations, Singapore would be a suitable candidate for reference as a hypothetical diversified economy, to be used in terms of the economic structure and industry base. As observed by Cleary and Wong (1994), there are several aspects of Brunei's development strategies that seek to emulate those of Singapore. Brunei is adopting a knowledge-based economy approach in its strategy to generate and sustain growth (LTDP 2007), which is similar to a strategy that Singapore is actively pursuing (Chia 2001). This is also evident in several key projects, such as the development of the iCentre, a key business incubator and entrepreneurial development centre in Brunei that is modelled after a similar centre in Singapore. There is close cooperation between Brunei and Singapore, both at the government level and the private sector level in terms of the sharing of best practices, know-how, capacity building, and technology transfer. There are strong economic interactions and the bilateral trade between the two countries expanded more than 80 per cent between 2005 and 2011.

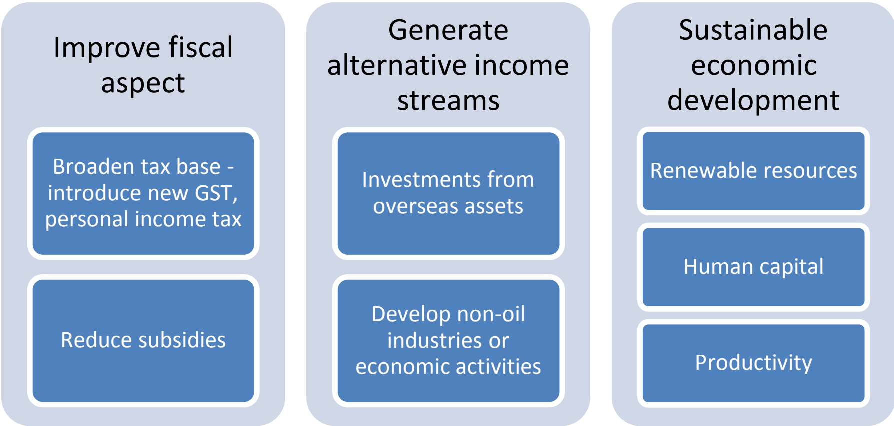
The investment from Singapore flowing into Brunei grew almost 200 per cent between 2005 and 2010 (Goh 2012). Both Brunei and Singapore are microstates sharing various historical links, including the parity of currencies[31], and their development processes are very much government-led (Crosby 2007).

To derive the underlying structural drivers, selected data from the Singapore IOT could be used as the main features of a hypothetical future economy for Brunei in the post-oil era, guided by the current policy directions. The same historical decomposition technique could be used to estimate changes in technology, consumer preferences, the position of foreign demand curves for Brunei products and other naturally exogenous trade variables that are made endogenous. With these estimated values, the causation and magnitude of these driving factors for output, employment and other endogenous macro variables could be attributed. By applying the CGE modelling techniques, the key driving factors that enable the transition of Brunei to a prosperous, post-hydrocarbon economy could be identified.

There are other examples of possible policies where simulations could be run for further research into Brunei's transition period (see Figure 9-3).

[31] Brunei and Singapore have maintained a unique historical bilateral agreement on their respective currencies called the Currency Interchangeability Agreement (CIA) since 1967. This has withstood the test of time given the changing global economic and financial landscape over the past 48 years.

Figure 9-3: Possible policies for simulation research



Once Brunei achieves the state of diversification, CGE modelling techniques could also be used to analyse how the degree of diversity in the exports could bring about economy-wide changes and also changes to GDP per capita as a proxy of economic development over time. A similar study has already been done by Naudé and Rossouw (2008) on South Africa.

In conclusion, the dynamic CGE model BRUGEM developed in this thesis could serve as a reference or base model for the Brunei economy in order to study many potential policy simulations. Further enhancement to the model is possible in order to conduct more research. BRUGEM could be a tool kit to help policymakers in formulating policies, in assessing the economic impacts of policy change and in other areas of interest.

Appendices

Appendix 2-1 Calculation of oil and gas break-even prices for 2014

There are two types of break-even prices, one for the government and one for oil companies. The fiscal break-even oil price is the price required to balance the government budget. For Brunei, it is a function of the government expenditure, its oil production and the market oil price. The oil price has been high on several occasions but, due to interruptions caused by the maintenance of facilities, Brunei was not able to capitalise on this situation with higher oil production levels. In those periods, a budget deficit was incurred as the revenue generated was insufficient to cover government expenditure. The year 2014 is used as an example to calculate the fiscal break-even price. Oil and gas made up 89 per cent of the government revenues, and 45 per cent and 55 per cent in terms of total hydrocarbon export values respectively in 2014. Based on the daily average production level of oil and gas for 2014, and the assumed 89 per cent of the annual government expenditure of B$7.276 billion (DOS 2015) that is financed by oil and gas revenue, the fiscal break-even price for oil is US$48.6 per barrel and for gas is US$5.6 per MMBtu. The calculation is summarised below.

Annual government expenditure is B$7.276 billion, and average oil and gas prices are US$104.44 per barrel and US$16.611 per MMBtu respectively at an average exchange rate of US$1.00 = B$1.30. Average oil production is 126.38 thousand barrels per day and 1,338,118 MMBtu per day (DOS 2015).

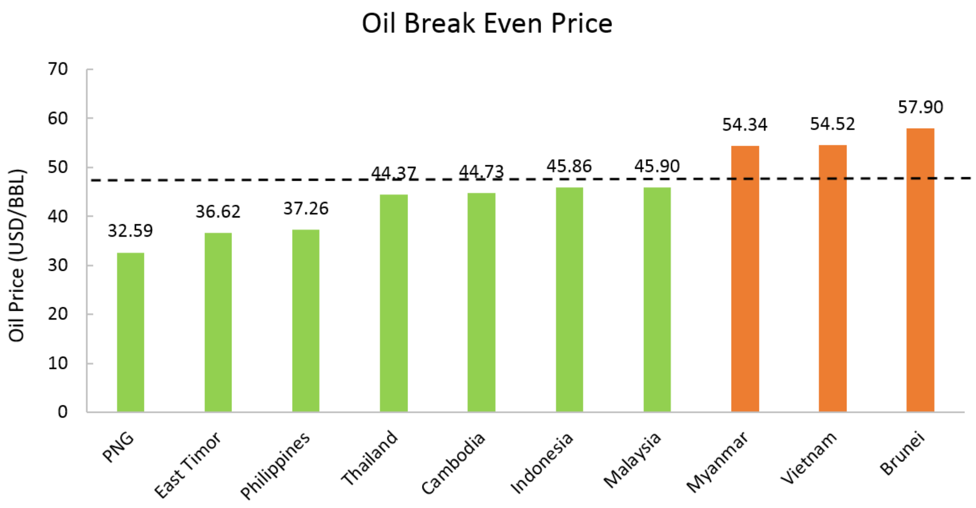
	B$/day
Government expenditure	*19,934,246*
89% to be financed by oil and gas	*17,741,479*
Daily revenue generated by oil production	*7,983,666 or 45% share*
Daily revenue generated by gas production	*9,757,814 or 55% share*

Based on the above share of oil and gas contribution to the total daily revenues generated by oil and gas, the break-even price can be calculated as follows:

*Oil break-even price = 7,983,666/(126.38*1000) = B$63.2 or US$48.6 per barrel*

Gas break-even price = 9,757,814/1,338,118 = B$7.3 or US$5.6 per MMBtu

An oil firm has a different break-even price to the fiscal break-even price. From the oil firm's perspective, whether to go ahead with investment in a project must be based on an assessment of the break-even price of crude oil that can be sold to cover its costs. Any market oil price that falls below that break-even price will cause the oil company to lose money for every barrel of oil produced. Besides the production costs, an oil firm needs to consider the government taxes and royalties, subject to the nature of the oil well and location. Xu (2015) estimated that the break-even price for Brunei is US$57.90 per barrel, making it the most expensive in the Southeast Asia region for a small-medium sized field and unprofitable in the current climate of low oil prices. As Xu (2015) points out, the existing oil firms are facing the dilemma of continuing to develop new projects while waiting for the oil price to rebound, or deferring an investment subject to the future risk of production and lease expiry. The government may need to offer more incentives, such as tax relief, to encourage more FDI in the oil sector itself.



Source: http://www.palantirsolutions.com/blog-research/blog/2015/february/4/breakeven-price-crude-oil-southeast-asia (viewed 16/8/15)

Appendix 3-1 Percentage change examples used for linearisation

Levels form	100*ordinary change	Percentage change
X	Xx	$x = 100\Delta X/X$
$3X$	$3Xx$	x
XY	$XY(x+y)$	$x+y$
X/Y	$(X/Y)(x-y)$	$x-y$
X^{α}	$X^{\alpha}(\alpha x)$	αx
$X+Y$	$Xx+Yy$	$(Xx+Yy)/(X+Y)$ $= S_x x + S_y y$ where $S_x = X/(X+Y)$, $S_y = 1-S_y$
In the examples below we assume *a vector of quantities X_i, total X.* *a vector of prices P_i, average P.* *a vector of values V_i, total V, such that $V_i = P_iX_i$, (thus $v_i = p_i+x_i$).* *that $V = PX$, (thus $v = p+x$).*		
Adding up quantities (rare)		
$X = \Sigma X_i$	$Xx = \Sigma X_i x_i$	$x = \Sigma S_i x_i$ where $S_i = X_i/X$
Adding up quantities with a common price P (frequent)		
$PX = P\Sigma X_i$	$PXx = \Sigma PX_i x_i$ or $Vx = \Sigma V_i x_i$ or $\Sigma V_i(x-x_i) = 0$	$x = \Sigma S_i x_i$ where $S_i = V_i/V$
Adding up values		
$V = \Sigma V_i$	$Vv = \Sigma V_i v_i$ or $V(p+x) = \Sigma V_i(p_i+x_i)$	$v = \Sigma S_i(p_i+x_i)$ where $S_i = V_i/V$
Decomposing value changes into indices of price and quantity change		
$V = \Sigma V_i$	$V(p+x) = \Sigma V_i(p_i+x_i)$	from $v = \Sigma S_i(p_i+x_i)$ price part: $p = \Sigma S_i p_i$ quantity part: $x = \Sigma S_i x_i$ so $v = p + x$
CES (no tech change)		
$X = CES(X_i)$		$x_i = x - \sigma(p_i-p)$ where $p = \Sigma S_i p_i$ implying $x = \Sigma S_i x_i$
CES (with tech change, a_i<0 for progress)		
$X = CES(X_i/A_i)$		$x_i-a_i= x - \sigma(p_i+a_i-p)$ where $p = \Sigma S_i(p_i+a_i)$ implying $x = \Sigma S_i(x_i-a_i)$
Ordinary change in a ratio		
$R = X/Y$	$Rr = 100\Delta R = (X/Y)(x-y)$ $100\Delta R = R(x-y)$	$100(\Delta R)/R = r = x - y$
$N = (X-M)/(X+M)$	$200(X+M)(X+M)\Delta N = 4MX(x-m)$	$200\Delta N = (1-N^2)(x-m)$

Source: Centre of Policy Studies (2015)

Appendix 3-2 Brief background on GEMPACK

GEMPACK is not a single program but a package of different programs designed to implement different modelling tasks at hand. These are listed in Table 1 below.

Table 1: List of some programmes in GEMPACK

Program	Description
TABmate	A text editor tailored to GEMPACK use
ViewHAR	To view and modify HAR data files
ViewSOL	To view simulation results
AnalyseGE	To analyse simulation results by presenting an integrated view of input data, model equations and results
WinGEM	A portal to all other GEMPACK programs, which guides the user through the stages of specifying a model, creating data files and running simulations. Commonly used for running comparative static simulations.
RunDynam	A user-friendly Windows interface that allows users to organise the ingredients, as well as perform and interpret multi-period simulations with recursive dynamic models. It allows users to construct a base case (which can be a forecast) and policy deviations from the base case. It is possible to run a comparative static model on RunDynam as well. Users can choose the input data files, closure and shocks on text files and specify a solution method. Results of both base case and policy deviation can be viewed on screen or exported to other programs.

Source: Harrison et al. (2013)

The main tasks in model implementation include the following (Centre of Policy Studies 2010):

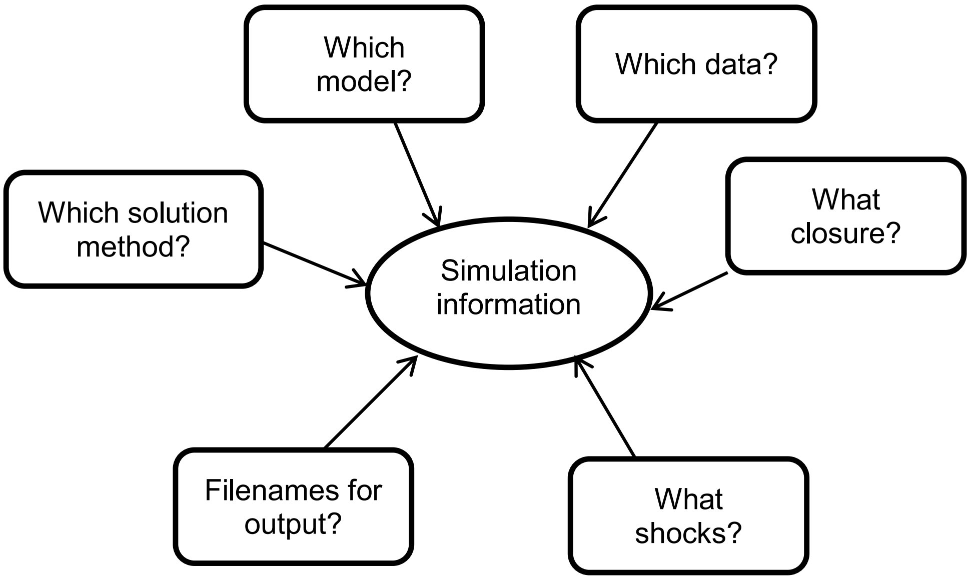
- Writing the equations of the model in ordinary algebra. For example, Equations (3.1) to (3.4) can be represented in TABLO language used by GEMPACK as shown in Table 2 using Box 3-1 (in Chapter 3) as an example. TABLO is used in the TABmate program to edit text files, to write out input and command files as well as instructions in STI files to condense the model;

Table 2: Conversion of model equations into algebra for TABLO coding

Model equations	Algebra for TABLO coding
$F[V_t]=0$	$2x_1+x_3=0$ $X_1x_1+2X_2^2x_2=0$
$A(\overline{V}_{t-1})v_t=0$	$\begin{bmatrix} 2 & 0 & 1 \\ X_1 & 2X_2^2 & 0 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}=0$
$A_Y(\overline{V}_{t-1})\,v_t^y+A_X(\overline{V}_{t-1})v_t^x=0$	$\begin{bmatrix} 2 & 0 \\ X_1 & 2X_2^2 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}+\begin{bmatrix} 1 \\ 0 \end{bmatrix}x_3=0$
$v_t^y=-A_Y(\overline{V}_{t-1})^{-1}*A_X(\overline{V}_{t-1})\,v_t^x$ $v_t^y=B(\overline{V}_{t-1})\,v_t^x$	$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}=-\begin{bmatrix} 2 & 0 \\ X_1 & 2X_2^2 \end{bmatrix}^{-1}\begin{bmatrix} 1 \\ 0 \end{bmatrix}x_3$ $\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}=\begin{bmatrix} -1/2 \\ X_1/4X_2^2 \end{bmatrix}x_3$
Note: Matrices A and B are the coefficients while the vector are the percentage changes in the variables. If any of the matrices is not invertible, an error will occur.	

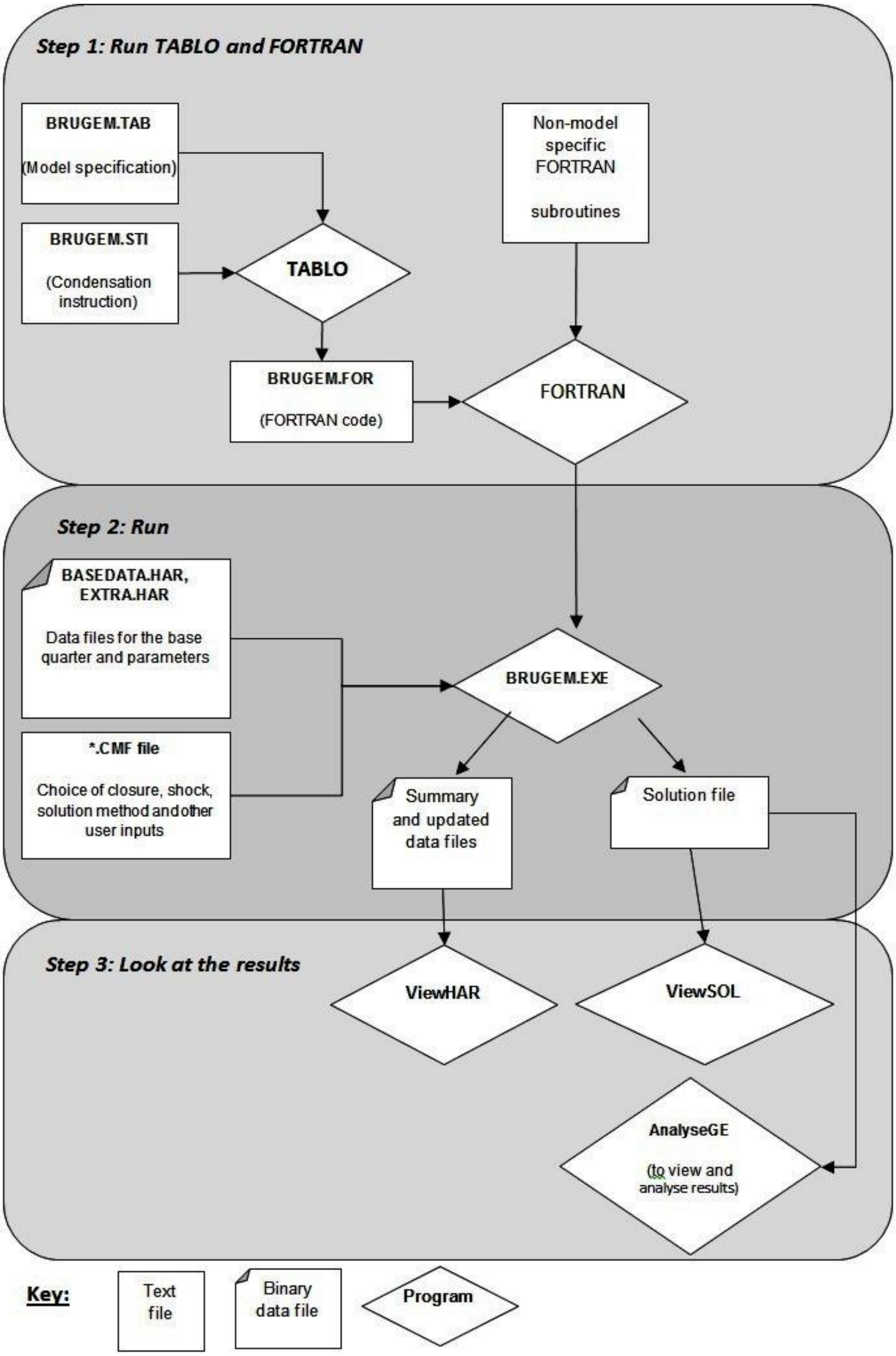
- Storing, modifying and using the data, which provide an initial solution to the model. These data must also be in a form that can be read by both humans and computer programs. Besides storing data, ViewHAR is the program that can be used for browsing, extracting and modifying the contents of the GEMPACK Header Array files;
- Specifying model closures and simulation scenarios in the TABmate program;
- Running the simulations (such as WinGEM or RunDynam program); and
- Examining and interpreting the results with the use of ViewSOL and AnalyseGE programs.

Figure 1: Information required to specify a simulation



Source: Harrison et al. (2013)

Figure 2: Stages in the GEMPACK process



Source: Harrison et al. (2013)

Although CGE models are widely used by various national and international organisations around the world for economic policy analysis, the barriers to enter this field of CGE analysis seem high and even prohibitive without sufficient technical knowledge. Most pioneers develop their own model theory, construct their own database, devise a solution strategy and hire programmers to implement that strategy in a model-specific program. Due to the extensive model algebra, data and programming involved to run the simulations in the background, these factors often lead to the perception that the CGE model is a “black box” to a non-expert audience (Böhringer et al. n.d.). Since numerical solutions of a very large and complex system of equations are required, significant computing power is needed to produce the output for analysis in an efficient and cost effective matter. Fortunately, with the standardisation of the basic model framework, data sources and format, computers, user-friendly interface software and training, CGE modelling is becoming more accessible, allowing sharing and results to be replicated (Horridge et al. 2013).

There are three main general-purpose modelling programs. GAMS (General Algebraic Modelling System) was developed by Alex Meeraus at the World Bank in the 1980s and in the private sector (GAMS Corp) in the 1990s. GEMPACK was developed by Ken Pearson at La Trobe University in the 1980s and has been further developed at the Centre of Policy Studies by Mark Horridge, Michael Jerie and Ken Pearson. The third model system, MPSGE (Mathematical Programming System for General Equilibrium Analysis), was developed by Tom Rutherford, also in the 1980s, with high-level languages for CES nests. Fundamentally, MPSGE is a subsystem of GAMS (Horridge et al. 2013). Essentially two key CGE software platforms emerged in the 1980s in two different geographical regions: GAMS in the USA and GEMPACK in Australia. By the middle of the 1990s, nearly all CGE models for policy analysis were solved using either GAMS, GEMPACK or MPSGE.

Horridge et al. (2013) argued that despite their differences and individual strengths and weaknesses, all of these three software suites generate the same numerical results. Unlike GAMS, which is a general purpose programming tool that solves systems in levels, GEMPACK is designed to specify most of the non-linear model equations in differential form and specifically to solve a CGE model in the levels or in percentage changes. As illustrated by Pearson (2002), the advantage of having percentage change formulation is in its simplicity. Less data requirements means that computing costs can be saved by eliminating the need to track levels of prices and quantities (since the initial values of these levels can be retrieved from a balanced IOT). Percentage change equations are relatively easy to understand and interpret since the coefficients are usually interpreted as elasticities, cost shares and sales shares. Equations in this form can also be easily adapted to perform BOTE calculations, which facilitate understanding and checking of results.

GEMPACK is particularly useful for novices in performing complex tasks in recursive dynamic models through automated organisation of the runs in sequence, assembly and reporting of results. As most modellers have experienced, a systematic sensitivity analysis is often required where different parameters and/or shocks need to be implemented and the model to be run several times to report the deviation of results across these runs. GEMPACK offers a convenient point-and-click in the users' interface to input these details, leaving the software to do the rest. Another key strength of GEMPACK is its ability to allow cost-effective decomposition analysis of the results by just adding a few lines of code.

Appendix 3-3 Brief notes on selected production functions, elasticity and constrained minimisation problems

1. Constant Elasticity of Substitution (CES) function

The CES function is a general class of production function that can be represented by: $Y = A\left[\sum_{i=1}^{n} \delta_i X_i^{-\rho}\right]^{-1/\rho}$

where Y is output, the X_i's are inputs, and A and the δ_i's are positive parameters. ρ is a parameter whose value is greater than -1 but not equal to zero. The value of A is defined so that $\sum_i \delta_i = 1$ (Dixon et al. 1980). The function has the property of constant-returns-to-scale. To see this, if all inputs are scaled by any positive constant, say α, we have:

$$A\left[\sum_i \delta_i (\alpha X_i)^{-\rho}\right]^{-1/\rho} = \alpha A\left[\sum_i \delta_i X_i^{-\rho}\right]^{-1/\rho}$$

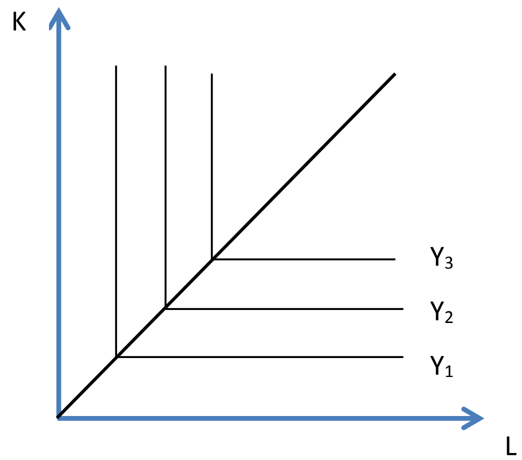
Thus for αX_i the output will be αY.

2. Leontief function

The Leontief function is a production function where the factors of production are used in fixed proportions. In other words, there is no substitutability between the factors or the inputs. In mathematical terms, a Leontief production function can be written as:

$$Y = min(aK,\ bL) \quad \textit{where } a,\ b > 0$$

The isoquants from a Leontief production function are shown below for different output levels, y_1, y_2 and y_3. Note that the Leontief function is a special case in a CES production function, where the substitution elasticity is set to zero (Horridge 2003).



A constrained optimisation problem

In this example, industries in BRUGEM are assumed to choose their inputs to minimise costs subject to a CES production function.

Minimise: $C_i = \sum_i^N P_i X_i$ of producing given output Z,

subject to: $$Z = \left(\sum_i \delta_i X_i^{-\rho} \right)^{-1/\rho}$$

by choosing inputs: $X_i \left(i = 1 \ to \ N \right)$,

where C_i : total production costs $\qquad$ P_i : input costs

Z : total output $\qquad$ X_i : inputs into production

δ_i positive parameter where $\sum_i \delta_i = 1$ $\qquad$ $\rho > -1$ parameter

The Lagrangian function to this minimisation problem is:

$$L = \sum_i^N P_i X_i - \Lambda \left[\left(\sum_i \delta_i X_i^{-\rho} \right)^{-1/\rho} \right]$$

The first order conditions are:

$$P_k = \Lambda \frac{\partial Z}{\partial X_k} = \Lambda \delta_k X_k^{-(1+\rho)} \left(\sum_i \delta_i X_i^{-\rho} \right)^{-(1+\rho)/\rho}$$

Hence $\frac{P_k}{P_i} = \frac{\delta_k}{\delta_i} \left(\frac{X_i}{X_k} \right)^{1+\rho}$ or $X_i^{-\rho} = \left(\frac{\delta_i P_k}{\delta_k P_i} \right)^{-\rho/(\rho+1)} * X_k^{-\rho}$

Substituting the above expression back into the CES production function, we have:

$$Z = \left(\sum_i \delta_i \left(\frac{\delta_i P_k}{\delta_k P_i} \right)^{-\rho/(\rho+1)} * X_k^{-\rho} \right)^{-1/\rho} = X_k \left(\sum_i \delta_i \left(\frac{\delta_k P_i}{\delta_i P_k} \right)^{\rho/(\rho+1)} \right)^{-1/\rho}$$

This gives the input demand functions:

$$X_k = Z \left(\sum_i \delta_i \left(\frac{\delta_k P_i}{\delta_i P_k} \right)^{\rho/(\rho+1)} \right)^{1/\rho}$$

Or $X_k = Z \delta_k^{1/(\rho+1)} \left(\frac{P_k}{P_{ave}} \right)^{-1/(\rho+1)}$ where $P_{ave} = \left(\sum_i \delta_i^{1/(\rho+1)} P_i^{\rho/(\rho+1)} \right)^{(\rho+1)/\rho}$

In percentage change form, we get:

$$x_k = z - \sigma(p_k - p_{ave})$$

and $p_{ave} = \sum_i S_i p_i$

where $\sigma = \frac{1}{\rho + 1}$ and $S_i = \frac{\delta_i^{1/(\rho+1)} P_i^{\rho/(\rho+1)}}{\left(\sum_k \delta_k^{1/(\rho+1)} P_k^{\rho/(\rho+1)} \right)}$

Multiplying both sides of the input demand function by P_k:

$$P_k X_k = Z \delta_k^{1/(\rho+1)} P_k^{\rho/(\rho+1)} P_{ave}^{1/(\rho+1)}$$

Hence $$\frac{P_k X_k}{\sum_i P_i X_i} = \frac{\delta_k^{1/(\rho+1)} P_k^{\rho/(\rho+1)}}{\left(\sum_i \delta_i^{1/(\rho+1)} P_i^{\rho/(\rho+1)}\right)} = S_k$$

and S_i is the cost shares.

3. Armington elasticity

Named after Armington (cited in Dixon et al. 1982), an Armington elasticity represents the elasticity of substitution between domestically produced and imported goods. The Armington assumption is that imports are imperfect substitutes for domestic goods with the same name. This specification, used in ORANI-G and MONASH-style models, produces results in which imports will respond in a realistic manner to changes in the relative prices of imported and domestic goods. Without this specification, any significant changes in the relative prices of domestic and imported goods can lead to total elimination of either from the domestic market (Dixon et al. 1982). This is known as the import-domestic ‘flip-flop’ problem. Readers who are interested in exploring more about Armington elasticity, and ther elasticities related to international trade, should refer to Hillberry and Hummels (2013).

Appendix 4-1 Original list of industries and commodities in IOT 2005

No.		Description	Code
1	INDUSTRIES	Crop and animal production, hunting and related service activities	AgriAnmlPrd
2		Forestry and logging	ForestLog
3		Fishing and aquaculture	FishAquacul
4		Mining of coal and lignite	CoalMining
5		Extraction of crude petroleum	CrudePetrol
6		Extraction of natural gas	NaturalGas
7		Mining of metal ores	MetalOres
8		Other mining and quarrying	OtherMining
9		Mining support services activities	MiningSptSrv
10		Manufacture of food products, beverages and tobacco products	FoodBvgTobac
11		Manufacture of textiles, wearing apparel, leather and related products	TextilesAppL
12		Manufacture of wood and of products of wood and cork, except furniture	WoodPrd
13		Manufacture of paper and paper products	PaperPrd
14		Printing and reproduction of recorded media	PrintRecPrd
15		Manufacture of coke and refined petroleum products	CokePetroPrd
16		Manufacture of chemicals, chemical products, pharmaceuticals, rubber and plastic products	ChemPhrmRbrP
17		Manufacture of other non-metallic mineral products	OthNonMetal
18		Manufacture of basic metals	BasicMetals
19		Manufacture of fabricated metal products, except machinery and equipment	FabMetalPrd
20		Manufacture of computers, electronic and optical products	CompElectOpt
21		Manufacture of electrical equipment	ElectriclEqp
22		Manufacture of machinery and equipment n.e.c.	MachineryEqp
23		Manufacture of motor vehicles, trailers and semi-trailers	MotorVehTrlr
24		Manufacture of other transport equipment	OthTrsprtEqp
25		Manufacture of furniture	Furniture
26		Other manufacturing	OthManuf
27		Repair and installation of machinery and equipment	RprInstlSrv
28		Electricity, gas, steam and air conditioning supply.	ElecGasAircn
29		Water collection, treatment and supply	WaterTrmtSup
30		Sewerage, waste collection, treatment and disposal activities; materials recovery; remediation activities etc.	SwgWstSrv
31		Construction of buildings	BldgConstruc
32		Civil engineering	CvlEngConstr
33		Specialised construction activities	SpecConstrc
34		Wholesale and retail trade and repair of motor vehicles and motorcycles	WhReTrdRepMV
35		Wholesale trade, except of motor vehicles and motorcycles	WhTrdSrv
36		Retail trade, except of motor vehicles and motorcycles	ReTrdSrv
37		Land transport and transport via pipelines	LndTrnsPpSrv
38		Water transport	WaterTrnsSrv
39		Air transport	AirTrnsSrv
40		Warehousing and support activities for transportation	WrhsgSrvTrns
41		Postal and courier activities	PostlCourier
42		Accommodation	AccomSrv
43		Food and beverage service activities	FoodBvgSrv
44		Publishing activities	PublishgSrv
45		Motion picture, video and television programme production, sound recording and music publishing activities	PicSndPrdSrv
46		Broadcasting and programming activities	PrgmBrdctSrv
47		Telecommunication	TelecomSrv
48		Computer programming, consultancy and related activities	ComPrgmCnslt
49		Information service activities	InfoSrv
50		Financial service activities, except insurance and pension funding	FinSrv
51		Insurance, reinsurance and pension funding, except compulsory social security	InsrnPnsFSrv
52		Other financial activities	OthFinSrv
53		Real estate activities	RealEstSrv
54		Legal and accounting activities	LegalActgSrv
55		Activities of head offices; management consultancy activities	MgtCnsltSrv
56		Architectural and engineering activities; technical testing and analysis	ArcEngTchSrv
57		Scientific research and development; advertising and market research	RnDRschSrv
58		Other professional, scientific and technical activities	OthPrfTchSrv
59		Veterinary activities	VetSrv
60		Rental and leasing activities	RentalLsgSrv
61		Employment activities	EmploymtSrv
62		Travel agency, tour operator and other reservation services	TrvlAgtSrv
63		Security and investigation activities	SecuritySrv
64		Services to buildings and landscape activities; office administrative, office support and other business support activities	AdminBizSrv
65		Public administration and defence; compulsory social security	PubAdmDfnSoc
66		Education	Education
67		Human health activities	HealthSrv
68		Residential care activities; social work activities without accomodation	ResCareSWSrv
69		Creative, arts and entertainment activities; libraries, arcives, museums and other cultural activities	ArtEntCltrl
70		Sports activities and amusement and recreation activities	SportRcrtSrv
71		Activities of membership organisations	MemberOrgSrv
72		Repair of computers and personal and household goods	RepairSrvHH
73		Other personal service activities	OthPrsnlSrv
74		Activities of households as employers of domestic personnel	DomSrvHH

No.		Description	Code
1		Products of agriculture, hunting and related services	AgriAnmlPrd
2		Products of forestry, logging and related services	ForestLog
3		Fish and other fishing products; aquaculture products; support services to fishing	FishAquacul
4		Coal and lignite, metal ores, other mining and quarrying	Coal
5		Crude petroleum	CrudePetrol
6		Natural gas, liquefied or in gaseous state	NaturalGas
7		Mining support services	MetalOres
8		Food products, beverages and tobacco products	OtherMining
9		Textiles, wearing apparel, leather and related products	MiningSptSrv
10		Wood and products of wood and cork, except furniture; articles of straw and plaiting materials, paper	FoodBvgTobac
11		Printing and recording services	TextilesAppL
12		Coke and refined petroleum products	WoodPrd
13		Chemicals, chemical products, basic pharmaceutical products and pharmacetcal preparations, rubber and plastic poroducts	PaperPrd
14		Other non-metallic products	PrintRecSrv
15		Basic metals, fabricated metal products	CokePetroPrd
16		Computer, electronic and optical products, electrical equipment	ChemPhrmRbrP
17		Machinery and equipment n.e.c.	OthNonMetal
18		Motor vehicles, trailers and semi-trailers	BasicMetals
19		Other transport equipment	FabMetalPrd
20		Furniture	CompElectOpt
21		Other manufactured goods	ElectriclEqp
22		Repair and installation services of machinery and equipment	MachineryEqp
23		Electricity, gas, steam and air conditioning	MotorVehTrlr
24		Natural water, water treatment and supply services	OthTrsprtEqp
25		Sewerage services; sewage sludge; waste collection, treatment and disposal services; materials recovery services	Furniture
26		Buildings and building construction works, construction c.e., specialised construction	OthManuf
27		Wholesale and retail trade and repair services of motor vehicles and motorcycles	RprInstlSrv
28		Wholesale trade service and retail services, except of motor vehicles and motorcycles	ElecGasAircn
29		Land transport services and transport services via pipelines	WaterTrmtSup
30		Water transport services	SwgWstSrv
31		Air transport services	BldgConstruc
32		Warehousing and support services for transportation	CvlEngConstr
33	COMMODITIES	Postal and courier services	SpecConstrc
34		Accommodation services	WhReTrdRepMV
35		Food and beverage serving services	WhTrdSrv
36		Publishing services , pictures,bproadcasting	ReTrdSrv
37		Telecommunications services , computer programming, information services	LndTrnsPpSrv
38		Financial services, except insurance and pension funding	WaterTrnsSrv
39		Insurance, reinsurance and pension funding services, except compulsory social security, aux. services	AirTrnsSrv
40		Real estate services	WrhsgSrvTrns
41		Legal and accounting services, services of head offices	PostlCourier
42		Architectural and engineering services; technical testing and analysis services	AccomSrv
43		Scientific research and development services; advertising and market research services , other services, veterinary services	FoodBvgSrv
44		Rental and leasing services, employment services, security, service buildings	PublishgSrv
45		Travel agency, tour operator and other reservation services and related services	PicSndPrdSrv
46		Public administration and defence services; compulsory social security services	PrgmBrdctSrv
47		Education services	TelecomSrv
48		Human health services, residenzial care	ComPrgmCnslt
49		Creative, arts and entertainment services; library, archive, museum and other cultural services, etc.	InfoSrv
50		Services of households as employers of domestic personnel	FinSrv
51		Insurance, reinsurance and pension funding, except compulsory social security	InsrnPnsFSrv
52		Other financial activities	SrvFinInsrn
53		Real estate activities	RealEstSrv
54		Legal and accounting activities	LegalActgSrv
55		Activities of head offices; management consultancy activities	MgtCnsltSrv
56		Architectural and engineering activities; technical testing and analysis	ArcEngTchSrv
57		Scientific research and development; advertising and market research	RnDRschSrv
58		Other professional, scientific and technical activities	OthPrfTchSrv
59		Veterinary activities	VetSrv
60		Rental and leasing activities	RentalLsgSrv
61		Employment activities	EmploymtSrv
62		Travel agency, tour operator and other reservation services	TrvlAgtSrv
63		Security and investigation activities	SecuritySrv
64		Services to buildings and landscape activities; office administrative, office support and other business support activities	AdminBizSrv
65		Public administration and defence; compulsory social security	PubAdmDfnSoc
66		Education	Education
67		Human health activities	HealthSrv
68		Residential care activities; social work activities without accomodation	ResCareSWSrv
69		Creative, arts and entertainment activities; libraries, arcives, museums and other cultural activities	ArtEntCltrl
70		Sports activities and amusement and recreation activities	SportRcrtSrv
71		Activities of membership organisations	MemberOrgSrv
72		Repair of computers and personal and household goods	RepairSrvHH
73		Other personal service activities	OthPrsnlSrv
74		Activities of households as employers of domestic personnel	DomSrvHH

Appendix 4-2 List of sectors in IOT 2010

	Industry/commodity
1	Rice
2	Vegetables
3	Fruits
4	Other crops
5	Livestock
6	Forestry and logging
7	Fisheries
8	Oil and gas mining
9	Other mining including support services to mining
10	Manufacture of food, beverage and tobacco products
11	Manufacture of wearing apparel & textiles
12	Manufacture of printing and reproduction of recorded media
13	Manufacture of coke and refined petroleum products
14	Manufacture of non-metallic mineral products
15	Other manufacturing
16	Electricity, gas and steam
17	Water supply, sewerage
18	Construction
19	Sale of motor vehicles
20	Maintenance & repair of MV
21	Trade
22	Land transport
23	Water transport
24	Air transport
25	Warehousing and support activities for transporation
26	Postal and courier
27	Hotels
28	Restaurants
29	Publishing, motion pictures, video, TV and radio
30	Telecommunication
31	Computer programming, consultancy and information service activities
32	Banking
33	Insurance and other financial auxiliary services
34	Real estate
35	Owner occupied dwellings
36	Legal activities
37	Accounting, book keeping and auditing activities; tax consultancy
38	Architectural and engineering activities; technical testing and analysis
39	Other professional, scientific and technical services
40	Travel agencies
41	Other administrative and support services
42	Public administration and defence; compulsory social security
43	Education
44	Health
45	Domestic services
46	Other services

Appendix 4-3 New list of industries and commodities for IOT 2005

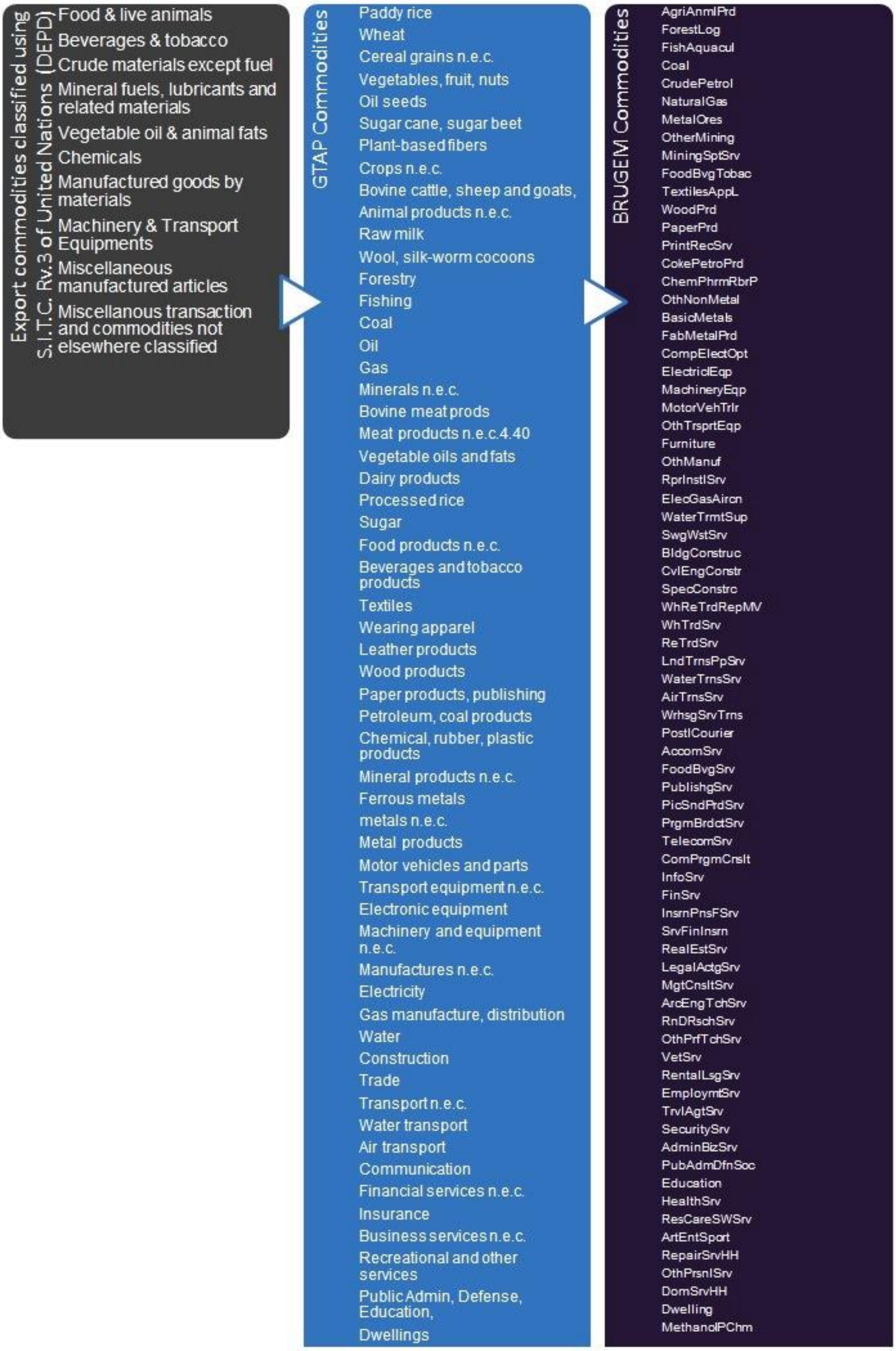
No.		Description	Code
1		Crop and animal production, hunting and related service activities	AgriAnmlPrd
2		Forestry and logging	ForestLog
3		Fishing and aquaculture	FishAquacul
4		Mining of coal and lignite	CoalMining
5		Extraction of crude petroleum	CrudePetrol
6		Extraction of natural gas	NaturalGas
7		Mining of metal ores	MetalOres
8		Other mining and quarrying	OtherMining
9		Mining support services activities	MiningSptSrv
10		Manufacture of food products, beverages and tobacco products	FoodBvgTobac
11		Manufacture of textiles, wearing apparel, leather and related products	TextilesAppL
12		Manufacture of wood and of products of wood and cork, except furniture	WoodPrd
13		Manufacture of paper and paper products	PaperPrd
14		Printing and reproduction of recorded media	PrintRecPrd
15		Manufacture of coke and refined petroleum products	CokePetroPrd
16		Manufacture of chemicals, chemical products, pharmaceuticals, rubber and plastic products	ChemPhrmRbrP
17		Manufacture of other non-metallic mineral products	OthNonMetal
18		Manufacture of basic metals	BasicMetals
19		Manufacture of fabricated metal products, except machinery and equipment	FabMetalPrd
20		Manufacture of computers, electronic and optical products	CompElectOpt
21		Manufacture of electrical equipment	ElectriclEqp
22		Manufacture of machinery and equipment n.e.c.	MachineryEqp
23		Manufacture of motor vehicles, trailers and semi-trailers	MotorVehTrlr
24		Manufacture of other transport equipment	OthTrsprtEqp
25		Manufacture of furniture	Furniture
26		Other manufacturing	OthManuf
27		Repair and installation of machinery and equipment	RprInstlSrv
28		Electricity, gas, steam and air conditioning supply.	ElecGasAircn
29		Water collection, treatment and supply	WaterTrmtSup
30		Sewerage, waste collection, treatment and disposal activities; materials recovery; remediation activities etc.	SwgWstSrv
31		Construction of buildings	BldgConstruc
32		Civil engineering	CvlEngConstr
33		Specialised construction activities	SpecConstrc
34	INDUSTRIES	Wholesale and retail trade and repair of motor vehicles and motorcycles	WhReTrdRepMV
35		Wholesale trade, except of motor vehicles and motorcycles	WhTrdSrv
36		Retail trade, except of motor vehicles and motorcycles	ReTrdSrv
37		Land transport and transport via pipelines	LndTrnsPpSrv
38		Water transport	WaterTrnsSrv
39		Air transport	AirTrnsSrv
40		Warehousing and support activities for transportation	WrhsgSrvTrns
41		Postal and courier activities	PostlCourier
42		Accommodation	AccomSrv
43		Food and beverage service activities	FoodBvgSrv
44		Publishing activities	PublishgSrv
45		Motion picture, video and television programme production, sound recording and music publishing activities	PicSndPrdSrv
46		Broadcasting and programming activities	PrgmBrdctSrv
47		Telecommunication	TelecomSrv
48		Computer programming, consultancy and related activities	ComPrgmCnslt
49		Information service activities	InfoSrv
50		Financial service activities, except insurance and pension funding	FinSrv
51		Insurance, reinsurance and pension funding, except compulsory social security	InsrnPnsFSrv
52		Other financial activities	OthFinSrv
53		Real estate activities	RealEstSrv
54		Legal and accounting activities	LegalActgSrv
55		Activities of head offices; management consultancy activities	MgtCnsltSrv
56		Architectural and engineering activities; technical testing and analysis	ArcEngTchSrv
57		Scientific research and development; advertising and market research	RnDRschSrv
58		Other professional, scientific and technical activities	OthPrfTchSrv
59		Veterinary activities	VetSrv
60		Rental and leasing activities	RentalLsgSrv
61		Employment activities	EmploymtSrv
62		Travel agency, tour operator and other reservation services	TrvlAgtSrv
63		Security and investigation activities	SecuritySrv
64		Services to buildings and landscape activities; office administrative, office support and other business support activities	AdminBizSrv
65		Public administration and defence; compulsory social security	PubAdmDfnSoc
66		Education	Education
67		Human health activities	HealthSrv
68		Residential care activities; social work activities without accomodation	ResCareSWSrv
69		Creative, arts and entertainment activities; libraries, arcives, museums and other cultural activities; Sports activities and amusement and recreation activities; Activities of membership organisations	ArtEntSport
70		Repair of computers and personal and household goods	RepairSrvHH
71		Other personal service activities	OthPrsnlSrv
72		Activities of households as employers of domestic personnel	DomSrvHH
73		Dwellings	Dwelling
74		Methanol and petrochemicals	MethanolPChm

No.		Description	Code
1	COMMODITIES	Products of agriculture, hunting and related services	AgriAnmlPrd
2		Products of forestry, logging and related services	ForestLog
3		Fish and other fishing products; aquaculture products; support services to fishing	FishAquacul
4		Coal and lignite, metal ores, other mining and quarrying	Coal
5		Crude petroleum	CrudePetrol
6		Natural gas, liquefied or in gaseous state	NaturalGas
7		Mining support services	MetalOres
8		Food products, beverages and tobacco products	OtherMining
9		Textiles, wearing apparel, leather and related products	MiningSptSrv
10		Wood and products of wood and cork, except furniture; articles of straw and plaiting materials, paper	FoodBvgTobac
11		Printing and recording services	TextilesAppL
12		Coke and refined petroleum products	WoodPrd
13		Chemicals, chemical products, basic pharmaceutical products and pharmacetcal preparations, rubber and plastic poroducts	PaperPrd
14		Other non-metallic products	PrintRecSrv
15		Basic metals, fabricated metal products	CokePetroPrd
16		Computer, electronic and optical products, electrical equipment	ChemPhrmRbrP
17		Machinery and equipment n.e.c.	OthNonMetal
18		Motor vehicles, trailers and semi-trailers	BasicMetals
19		Other transport equipment	FabMetalPrd
20		Furniture	CompElectOpt
21		Other manufactured goods	ElectriclEqp
22		Repair and installation services of machinery and equipment	MachineryEqp
23		Electricity, gas, steam and air conditioning	MotorVehTrlr
24		Natural water, water treatment and supply services	OthTrsprtEqp
25		Sewerage services; sewage sludge; waste collection, treatment and disposal services; materials recovery services	Furniture
26		Buildings and building construction works, construction c.e., specialised construction	OthManuf
27		Wholesale and retail trade and repair services of motor vehicles and motorcycles	RprInstlSrv
28		Wholesale trade service and retail services, except of motor vehicles and motorcycles	ElecGasAircn
29		Land transport services and transport services via pipelines	WaterTrmtSup
30		Water transport services	SwgWstSrv
31		Air transport services	BldgConstruc
32		Warehousing and support services for transportation	CvlEngConstr
33		Postal and courier services	SpecConstrc
34		Accommodation services	WhReTrdRepMV
35		Food and beverage serving services	WhTrdSrv
36		Publishing services , pictures,bproadcasting	ReTrdSrv
37		Telecommunications services , computer programming, information services	LndTrnsPpSrv
38		Financial services, except insurance and pension funding	WaterTrnsSrv
39		Insurance, reinsurance and pension funding services, except compulsory social security, aux. services	AirTrnsSrv
40		Real estate services	WrhsgSrvTrns
41		Legal and accounting services, services of head offices	PostlCourier
42		Architectural and engineering services; technical testing and analysis services	AccomSrv
43		Scientific research and development services; advertising and market research services , other services, veterinary services	FoodBvgSrv
44		Rental and leasing services, employment services, security, service buildings	PublishgSrv
45		Travel agency, tour operator and other reservation services and related services	PicSndPrdSrv
46		Public administration and defence services; compulsory social security services	PrgmBrdctSrv
47		Education services	TelecomSrv
48		Human health services, residenzial care	ComPrgmCnslt
49		Creative, arts and entertainment services; library, archive, museum and other cultural services, etc.	InfoSrv
50		Services of households as employers of domestic personnel	FinSrv
51		Insurance, reinsurance and pension funding, except compulsory social security	InsrnPnsFSrv
52		Other financial activities	SrvFinInsrn
53		Real estate activities	RealEstSrv
54		Legal and accounting activities	LegalActgSrv
55		Activities of head offices; management consultancy activities	MgtCnsltSrv
56		Architectural and engineering activities; technical testing and analysis	ArcEngTchSrv
57		Scientific research and development; advertising and market research	RnDRschSrv
58		Other professional, scientific and technical activities	OthPrfTchSrv
59		Veterinary activities	VetSrv
60		Rental and leasing activities	RentalLsgSrv
61		Employment activities	EmploymtSrv
62		Travel agency, tour operator and other reservation services	TrvlAgtSrv
63		Security and investigation activities	SecuritySrv
64		Services to buildings and landscape activities; office administrative, office support and other business support activities	AdminBizSrv
65		Public administration and defence; compulsory social security	PubAdmDfnSoc
66		Education	Education
67		Human health activities	HealthSrv
68		Residential care activities; social work activities without accomodation	ResCareSWSrv
69		Creative, arts and entertainment activities; libraries, arcives, museums and other cultural activities; Sports activities and amusement and recreation activities; Activities of membership organisations	ArtEntSport
70		Repair of computers and personal and household goods	RepairSrvHH
71		Other personal service activities	OthPrsnlSrv
72		Activities of households as employers of domestic personnel	DomSrvHH
73		Dwellings	Dwelling
74		Methanol and petrochemicals	MethanolPChm

Appendix 4-4 List of sets, coefficients and parameters in the core BRUGEM database

TABLO name	Dimension	Name
COM	74 commodities	Set COM commodities
IND	74 industries	Set IND industries
SRC	2 sources	Set SRC sources
OCC	1 occupation	Set OCC occupation
MAR	7 margins	Set MAR margin commodities
NONMAR	67 non-margins	Set NONMAR non-margin commodities
TRADEMAR	3 trade margins	Set TRADEMAR trade margins
TRANSMAR	4 transport margins	Set TRANSMAR transport margins
V1LND	IND	Land
V1LAB	IND*OCC	Labour
V1CAP	IND	Capital
V1PTX	IND	Production tax
V1OCT	IND	Other cost tickets paid by industry
MAKE	COM*IND	Multiproduct matrix
V0TAR	COM	Tariff revenue
V1BAS	COM*SRC*IND	Intermediate basic flows
V2BAS	COM*SRC*IND	Investment basic flows
V3BAS	COM*SRC	Household basic flows
V4BAS	COM	Export basic flows
V5BAS	COM*SRC	Government basic flows
V6BAS	COM*SRC	Inventories basic flows
V1MAR	COM*SRC*IND*MAR	Intermediate margins
V2MAR	COM*SRC*IND*MAR	Investment margins
V3MAR	COM*SRC*MAR	Household margins
V4MAR	COM*MAR	Exports margins
V5MAR	COM*SRC*MAR	Government margins
V6MAR	COM*SRC*MAR	Inventories margins
V1TAX	COM*SRC*IND	Intermediate tax
V2TAX	COM*SRC*IND	Investment tax
V3TAX	COM*SRC	Household tax
V4TAX	COM	Export tax
V5TAX	COM*SRC	Government tax
V6TAX	COM	Inventories tax
SIGMA1LAB	IND	Labour sigma
SIGMA1PRIM	IND	Primary factor sigma
SIGMA1OUT	IND	Output sigma
SIGMA1	COM	Intermediate Armington
SIGMA2	COM	Investment Armington
SIGMA3	COM	Household Armington
FRISCH	1	Frisch parameter
EPS	COM	Household expenditure elasticities
EXP_ELAST	COM	Individual export elasticities
EXP_ELAST_NT	1	Collective export demand elasticity
IsIndivExp	COM	Flag, >0.5 for individual export commodities, else collective export

Appendix 4-5 Mapping of commodities from GTAP to BRUGEM



Appendix 4-6 Export demand elasticities for BRUGEM

BRUGEM commodities	Foreign elasticity of export demand (EXP_ELAST)
1 AgriAnmlPrd	-7.070
2 ForestLog	-4.130
3 FishAquacul	-7.070
4 Coal	-4.270
5 CrudePetrol	-7.112
6 NaturalGas	-10.870
7 MetalOres	-4.270
8 OtherMining	-4.270
9 MiningSptSrv	-4.270
10 FoodBvgTobac	-2.205
11 TextilesAppL	-5.245
12 WoodPrd	-4.760
13 PaperPrd	-4.130
14 PrintRecPrd	-4.130
15 CokePetroPrd	-2.940
16 ChemPhrmRbrP	-4.620
17 OthNonMetal	-4.620
18 BasicMetals	-5.005
19 FabMetalPrd	-4.655
20 CompElectOpt	-6.160
21 ElectriclEqp	-5.670
22 MachineryEqp	-5.670
23 MotorVehTrlr	-3.920
24 OthTrsprtEqp	-6.016
25 Furniture	-5.248
26 OthManuf	-5.248
27 RprInstlSrv	-3.920
28 ElecGasAircn	-3.920
29 WaterTrmtSup	-3.920
30 SwgWstSrv	-3.920
31 BldgConstruc	-3.920
32 CvlEngConstr	-3.920
33 SpecConstrc	-3.920
34 WhReTrdRepMV	-3.920
35 WhTrdSrv	-3.920
36 ReTrdSrv	-3.920
37 LndTrnsPpSrv	-3.920
38 WaterTrnsSrv	-3.920
39 AirTrnsSrv	-3.920
40 WrhsgSrvTrns	-3.920

41 PostlCourier	-3.920
42 AccomSrv	-3.920
43 FoodBvgSrv	-3.920
44 PublishgSrv	-3.920
45 PicSndPrdSrv	-3.920
46 PrgmBrdctSrv	-3.920
47 TelecomSrv	-3.920
48 ComPrgmCnslt	-3.920
49 InfoSrv	-3.920
50 FinSrv	-3.920
51 InsrnPnsFSrv	-3.920
52 SrvFinInsrn	-3.920
53 RealEstSrv	-3.920
54 LegalActgSrv	-3.920
55 MgtCnsltSrv	-3.920
56 ArcEngTchSrv	-3.920
57 RnDRschSrv	-3.920
58 OthPrfTchSrv	-3.920
59 VetSrv	-3.920
60 RentalLsgSrv	-3.920
61 EmploymtSrv	-3.920
62 TrvlAgtSrv	-3.920
63 SecuritySrv	-3.920
64 AdminBizSrv	-3.920
65 PubAdmDfnSoc	-3.920
66 Education	-3.920
67 HealthSrv	-3.920
68 ResCareSWSrv	-3.920
69 ArtEntSport	-3.920
70 RepairSrvHH	-3.920
71 OthPrsnlSrv	-3.920
72 DomSrvHH	-3.920
73 Dwelling	-3.920
74 MethanolPChm	-4.289

Appendix 6-1 Methodology of decomposition using GEMPACK

Suppose an endogenous variable Z can be expressed as a function F of n exogenous variables $X_{1,}X_{2,}....X_n$ via Equation (6.13):

$$Z = F(X_{1,}X_{2,}...X_n) \quad (6.13)$$

Suppose that the vector of exogenous variables $\tilde{X} = (X_{1,}X_2...X_n)$ moves along some path starting at pre-shock values $\tilde{X}^0 = (X_1^0, X_2^0...X_n^0)$ in 2005 to their final value in 2011 where:

$$\tilde{X}^1 = (X_1^1, X_2^1...X_n^1) = (X_1^0 + \Delta X_1 + X_2^0 + \Delta X_2 + ... + X_n^0 \Delta X_n) \quad (6.14)$$

If we can divide all shocks into M equal instalments, the effect of applying each instalment could be approximated as Equation (6.15).

$$dZ = F_1 dX_1 + F_2 dX_2 + ... + F_n dX_n \quad (6.15)$$

where $F_i = {\partial F}/{\partial X_i}$ and $dX_i = {\Delta X_i}/{M}$

If M is sufficiently large leading to sufficiently small dX_i, the approximation in Equation (6.4) will be exact. The terms on the right-hand side of Equation (6.15) will distribute the total change in dZ between the n exogenous variables. Once all the M instalments are implemented, we can add up all the results for $F_i dX_i$ over each of the M steps. The contribution made by each shock ΔX_i to the total change ΔZ along the path can be calculated as:

$$C_{X_i toZ} = \sum_{s=1}^{M} F_{i,s} dX_{i,s} \tag{6.16}$$

where $C_{X_i toZ}$ is the contribution of ΔX_i to ΔZ and s is the number of steps

The sum of contributions from all exogenous shocks should equal the changes in Z:

$$\Delta Z = \sum_{i}^{n} C_{X_i toZ} \tag{6.17}$$

Appendix 6-2 BOTE equations in percentage form

As discussed in Section 6.2, a percentage form of the BOTE model is sometimes necessary to illustrate the simulation results. The version below was derived from the same BOTE equations shown in Figure 5-3, in levels with more details drawn from the underlying model. Since natural resources such as oil and gas reserves are important primary factor inputs, the definition of capital in Equation (2) of Figure 3 (below) encompasses all forms of capital, including the underlying natural resources that are used for production.

Figure 6-2 shows the BOTE equations that were used in the same part of the analysis of simulation results in Chapters 6 and 8. As seen in the last column of Figure 3 (below), each of these equations was linked to some of the equations in the underlying main BRUGEM. Equation (8-10) is a simplification of two of the BOTE Equations (1) and (7) shown in Figure 5-3 in level form.

In Figure 3 (below), the letter S represents a share where the subscript is the numerator and superscript is the denominator. For example, S_C^Y represents the share of consumption in GDP (denoted by Y) and S_D^C represents the domestic (D) share of goods or services in total consumption. Equation (1) shows that the percentage change in real GDP is a share-weighted sum of the percentage changes in each of the major expenditure components. In Equation (2), from the production side, changes in real GDP are explained as a share-weighted sum of the percentage changes in primary factor inputs less the percentage change of a technical change variable (a negative value of technical change indicates an improvement that raises GDP). Equation (3) is the zero pure profit condition, where the percentage change in the price of output is expressed as a share-weighted sum of the percentage change in the price of inputs, with an allowance for technological change. Equation (4) is derived by taking the difference between Equations (3.16) and (3.17) in Chapter 3, and shows that the labour to capital ratio is inversely related to the wage to cost of capital rental ratio. Equation (5) is based on the levels equation, which equates nominal consumption to a function of nominal after-tax income and the average propensity to consume.

Figure 3: BOTE equations and variables in percentage form for analysis

			Links to Chapter 3 equations
GDP expenditure	$y = S_C^Y c + S_I^Y i + S_G^Y g + S_X^Y x - S_M^Y m$	(1)	(3.134)
GDP supply	$y = S_L^Y l + S_K^Y k - a$	(2)	(3.132)
Zero pure profit condition	$p = S_L p_L + S_K p_K + a$	(3)	(3.19)
CES production function	$l - k = -\sigma(p_L - p_K)$	(4)	(3.16) - (3.18)
Nominal consumption function	$c + p_c = y - t + p + apc$	(5)	(3.140)
Consumer price index	$p_C = S_D^C p + S_M^C(p_M + \phi)$	(6)	(3.62)
Imports	$m = y - \alpha(p_M + \phi - p)$	(7)	(3.105), (3.118)
Exports	$x = -\varepsilon(p - \phi)$	(8)	(3.69), (3.70)
Rate of return	$p_K - p = \xi$	(9)	(3.156)
Investment as a function of rate of return and GDP	$i = y + \xi$	(10)	
Real wage	$rw = p_L - p_C$	(11)	

Key: σ>0 is primary factor substitution elasticity α>0 is Armington import substitution elasticity ε>0 is export demand elasticity Φ is the exchange rate (B$/foreign currency) l- labour k- capital	a-technical change t- income tax rate ξ - gross rate of return ϕ - nominal exchange rate (numeraire) p - domestic price level p_c - consumer price p_M - import price in foreign currency rw- consumer real wage	p_L - nominal wage p_K - nominal rental cost of capital apc -average propensity to consume c- real private consumption i- real investment g -real govt expenditure x-real exports m-real imports y – real GDP

Changes in the domestic price level, as measured by the consumer price index (CPI), are explained by Equation (6) as a share-weighted combination of domestic and import prices in local currency. The percentage change in import volume is explained in Equation (7) as a positive function of the change in real GDP (activity effect) and an inverse function of the import price, relative to the domestic price, multiplied by the

Armington import elasticity (relative price effect). Equation (8) explains the percentage change in export volume as an inverse function of the change in export price, multiplied by the export demand elasticity. The ROR can be approximated to the rental cost of capital relative to the domestic price level. The percentage change form of this relationship is shown in Equation (9). Changes in investment are a function of changes in real GDP and ROR in Equation (10). The change in consumer real wage (rw) is defined in Equation (11) as the difference between the percentage changes of nominal price of labour and the consumer price index.

There are 11 equations with 19 variables. Therefore, 8 variables had to be set exogenously for the model to be solved.

Appendix 8-1 Analysis of Policy 1 simulation results of the fall in producer real wage

With productivity improvement, why does producer real wage fall when the government demand is fixed? This can be explained by splitting the industries into two broad categories: government (G) and non-government (NG) sectors.

Based on Figures 8-4 and 8-5, we can write out the following equations. Since capital stock is exogenous in the closure used, Equations (8.21) and (8.22) show that the percentage change in the sectoral output is a function of the percentage change in the sectoral share of labour multiply by the percentage change in the employment of labour in that sector and a technical change term. The government output is fixed as indicated by $\overline{y_G}$ in Equation (8.21) as illustrated in Figure 8-4 in Section 8.2.2. For non-government sector, the price of non-government output, $\overline{p_{NG}}$ is assumed fixed in Equation (8.24) as approximation to the nearly infinite elastic demand schedule in Figure 8-5. Equations (8.25) and (8.26) are the sector-specific CES production function of the general form of Equation (4) in Figure 3 of Appendix 6-2. The notation for S is the similar to that in Appendix 6-2. For example, S_L^G means the share of labour in government sector while S_G^L means the share of government employees in total employment of labour. For the prices, p_K^{NG} is the rental cost of capital in non-government sectors and so on.

$$\overline{y_G} = S_L^G l_G - a \qquad (8.21)$$

$$y_{NG} = S_L^{NG} l_{NG} - a \qquad (8.22)$$

$$p_G = S_L^G p_L + S_K^G p_K^G + a \qquad (8.23)$$

$$\overline{p_{NG}} = S_L^{NG} p_L + S_K^{NG} p_K^{NG} + a \qquad (8.24)$$

$$l_G - k_G = -\sigma(p_L - p_K^G) \qquad (8.25)$$
$$l_{NG} - k_{NG} = -\sigma(p_L - p_K^{NG}) \qquad (8.26)$$

With exogenous capital stocks, Equations (8.25) and (8.26) can be further simplified to:

$$p_K^G = p_L + {l_G}/{\sigma} \qquad (8.27)$$
$$p_K^{NG} = p_L + {l_{NG}}/{\sigma} \qquad (8.28)$$

The percentage change in aggregate labour is made up of the share-weighted sum of the percentage change in government and non-government sectoral labour. Since aggregate labour is fixed, we have:

$$S_G^L l_G + S_{NG}^L l_{NG} = \bar{l} \qquad (8.29)$$

The overall price level is given by Equation (8.30):

$$p = S_L^Y p_L + S_K^G S_G^Y p_K^G + S_K^{NG} S_{NG}^Y p_K^{NG} + a \qquad (8.30)$$

From Equation (8.30), (8.27) and (8.28), we can derive:

$$p = p_L + \frac{S_K^G S_G^Y}{\sigma} l_G + \frac{S_K^{NG} S_{NG}^Y}{\sigma} l_{NG} + a \qquad (8.31)$$

From Equation (8.21):

$$l_G = \frac{a}{S_L^G}$$
$$l_{NG} = \frac{-S_G^L}{S_{NG}^L} l_G = \frac{-S_G^L}{S_{NG}^L} \cdot \frac{a}{S_L^G}$$

where

$$S_G^L = {L_G}/{L}$$
$$S_{NG}^L = {L_{NG}}/{L}$$

Therefore,

$$p = p_L + \frac{S_K^G S_G^Y}{\sigma} \cdot \frac{a}{S_L^G} - \frac{S_K^{NG} S_{NG}^Y}{\sigma} \cdot \frac{S_G^Y}{S_{NG}^Y} \cdot \frac{a}{S_L^{NG}} + a$$

$$p = p_L + a\left[\left(\frac{K}{L}\right)_G . \frac{S_G^Y}{\sigma} - \left(\frac{K}{L}\right)_{NG} . \frac{S_G^Y}{\sigma} + 1\right]$$

$$p_L - p = -a\left[\frac{S_G^Y}{\sigma}\left\{\left(\frac{K}{L}\right)_G - \left(\frac{K}{L}\right)_{NG}\right\} + 1\right] \qquad (8.32)$$

Based on Equation (8.32), if $\left(\frac{K}{L}\right)_G < \left(\frac{K}{L}\right)_{NG}$ since government sector is labour intensive while non-government sectors which include oil and gas are capital intensive, the second term in square brackets will be a large negative number. Even with an improvement in productivity making the term $-a$ a positive number, multiply this with a large negative number will still lead to a decline in producer real wage.

Therefore in the policy 1 simulation of productivity improvement, producer real wage falls due to fixed government demand. This analysis also explains the counter-intuitive results on producer real wage in column 3 in Section 6.3.3.

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