MONGOLIA'S RESOURCES BOOM: A CGE ANALYSIS

A THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ECONOMICS

By

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Abstract

Mongolia's geographical location, its economic structure and its mineral wealth give it unique characteristics. Tapping its natural resources in a way that equally benefits the social and economic well-being of Mongolians is the greatest challenge. The resources boom in recent years directly impacted remarkable economic growth, and affected Mongolia's economic structure, social welfare, institutional quality and environment. The unprecedented improvement in the terms of trade and the large inflow of foreign direct investment (FDI) were driven by the industrialisation of Mongolia's neighbour and a main trading partner, China. Externally generated growth is, however, a double-edged sword. The boom brought with it economic fragility and loss of international competitiveness. It made the economy vulnerable to commodity price slumps and adverse changes in FDI.

The thesis constructs, tests and applies two economy-wide models for Mongolia: a comparative static CGE model, ORANIMON, and a dynamic CGE model, MONAGE. The models serve as laboratories for economic analysis in order to develop informed views on policy in Mongolia. The detailed nature of the models and the databases allow ORANIMON and MONAGE to capture salient features of the Mongolian economy. Short-, medium- and long-run simulations were undertaken for validating the modeling and evaluating the impact of the mining boom. Simulation results show that there were significant structural changes in the Mongolian economy over the period studied, 2005 to 2012. The shifts in foreign demand for Mongolian mineral export commodities contributed most of the economic growth. Maintaining flexible currency and wage adjustment, cultivating productivity through micro-economic reform and improving institutional quality are crucial for Mongolia to overcome the difficulties associated with the structural change.

Areas for future research within an economic modelling framework emerge: an analysis of the impact of resources boom on poverty and inequality; a policy-relevant research related to the livestock sector; a long-term baseline for the Mongolian economy and an empirical assessment for examining the dynamic responses of macroeconomic policies to large capital outflows.

Declaration

I, Esmedekh Lkhanaajav, declare that the PhD thesis entitled 'Mongolia's Resources Boom: A CGE Analysis' 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 Date

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List of Abbreviations

ADB	Asian Development Bank
AIDADS	An Implicitly Directly Additive Demand System
AUSD	Australian Dollar
BOP	Balance of Payments
BOTE	Back-of-the-Envelope
CA	Current Account
CDE	Constant Difference Elasticity
CES	Constant Elasticity of Substitution
CET	Constant Elasticity of Transformation
CGE	Computable General Equilibrium
CIF	Cost, Insurance and Freight
CMEA	Council of Mutual Economic Assistance
COPS	Centre of Policy Studies
CPI	Consumer Price Index
CRESH	Constant Ratio of Elasticities of Substitution, Homothetic
CRETH	Constant Ratios of Elasticities of Transformation, Homothetic
CRS	Constant-Returns-to-Scale
CV	Coefficient of Variation
DIA	Direct Investment Abroad
ERI	Economic Research Institute
ET	The Erdenet mine
FA	Financial Account
FDI	Foreign direct investment
FOB	Free on Board
FRED	Federal Reserve Bank of the Eighth District
FSL	Fiscal Stability Law
FTA	Free Trade Agreement
GAMS	Generalized Algebraic Modelling System
GDP	Gross Domestic Product

GEMPACK	General Equilibrium Modelling Package
GFC	Global Financial Crises
GFCF	Gross Fixed Capital Formation
GHG	Green House Gas
GNE	Gross National Expenditure
GNI	Gross National Income
GTAP	Global Trade Analysis Project
IIP	International Investment Position
ILO	International Labour Organisation
IMF	International Monetary Fund
IO	Input Output
IOT	Input Output Table
KA	Capital Account
LES	Linear Expenditure System
LME	London Metal Exchange
MMRF	Monash Multi Regional Forecasting model
MNT	Mongolian National Tugrug (Currency)
MONAGE	Mongolian Applied General Equilibrium model
MP	Marginal Product
MRTS	Marginal Rate of Technical Substitution
NAFTA	North American Free Trade Agreement
NFL	Net Foreign Liabilities
NSO	National Statistical Office
OCA	Other Changes in Financial Assets and Liabilities Accounts
OCT	Other Costs Ticket
OECD	Organisation for Economic Cooperation and Development
ORANI-G	ORANI Generic
ORANIMON	ORANI Mongolia model
ORES	ORANI Regional Equation System
OT	The Ouy Tolgoi mine

PC	Productivity Commission
RBA	Reserve Bank of Australia
REER	Real Effective Exchange Rate
RER	Real Exchange Rate
RMB	Renminbi, National Currency of the People's Republic of China
ROW	Rest of the World
SALTER	Sectoral Analysis of Liberalising Trade in the East Asian Region
SNA	System of National Accounts
SSA	Systematic Sensitivity Analysis
ST	Supply Table
SUTs	Supply and Use Tables
SWF	Sovereign Wealth Fund
TERM	The Enormous Regional Model
TOFT	Terms of the Trade
TRDS	Trade Sensitivity
TT	The Tavan Tolgoi coal mine
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNSNA	United Nations System of National Accounts
USAGE	United States Applied General Equilibrium model
USD	United States Dollar
UT	Use Table
VAT	Value-Added Tax
VU	Victoria University
WB	World Bank

Chapter 1. Introduction and Background

1.1 Introduction

1.1.1 Objective of the research

Mongolia is endowed with huge mineral resources, which represent significant potential for its future. It has experienced a large-scale resources boom in recent years. The average growth rate was 8.5% in the past decade. The highest economic growth of 17.5% was recorded in 2011. The mining sector constitutes 20% of gross domestic product (GDP) and mineral exports consist of more than 70% of total exports, on average. A significant portion of government income comes from natural resource exploitation.

Mineral resources present development opportunities, but they also cause challenges for Mongolia. The economy has undergone substantial structural changes due to the recent resources boom. However, such changes brings with them potential economic fragility, notably the vulnerability to commodity price slumps and a sudden reversal of foreign direct investment or out flight of foreign capital. In the last year, Mongolia has started to experience the sour taste of the 'dog days' that have followed the boom.

Over the past two decades, the structure of the Mongolian economy has changed, shifting away from agriculture and manufacturing towards services, but also with the mining industry growing in importance due to the mining boom. Economic activity has also shifted towards resource-rich areas. Changes in the structure of the economy have been driven by a range of factors. In recent years, the rate of structural change has increased, driven by the rise in resource export prices and the surge in mining investment.

Analysis of such changes in the Mongolian economy requires economic modelling tools capable of investigating the underlying factors of the changes, evaluating policy alternatives to counteract negative effects and producing forecasts of the likely path that the Mongolian economy will take in the future.

Computable General Equilibrium (CGE) modelling is an extensively used and accepted tool for estimating the impacts of changes in economic conditions such as the mining boom currently being experienced in Mongolia. CGE models belong to the economy-wide class of models, that is, those that provide industry disaggregation in a quantitative description of the whole economy (Dixon & Rimmer 2010a). CGE models are based on a comprehensive economy-wide database and can serve as a laboratory for policy analysis. The CGE framework helps capture interrelationships between economic sectors and accounts for the repercussion effects of policy (Dixon & Rimmer 2002). Even if only one sector is directly involved, there will be indirect effects on other sectors, so that economy-wide modelling is needed. For these reasons, CGE analysis has become a mainstream contributor to policy dialogues (Anderson, Martin & Van der Mensbrugghe 2012).

The thesis is concerned with the construction and applications of two computable general equilibrium (CGE) models in order to analyse the impacts of the recent mining boom in Mongolia's economic context and to make a contribution to the modelling capacity for policy analysis in Mongolia. ORANIMON, based on the ORANI-G model of the Australian economy (Horridge 2000), is the first Centre of Policy Studies (COPS) style comparative static CGE model of the Mongolian economy. ORANI-G is a generic version of the ORANI model of the Australian economy (Dixon et al. 1982). ORANI was developed in the late 1970s at the IMPACT project and has served as a foundation for CGE models of many countries. The second model, MONAGE, is the first single-country COPS style recursive dynamic CGE model of the Mongolian economy, and has evolved from ORANIMON. The main advances in MONAGE over ORANIMON are in dynamics and it is built on the Mini-USAGE model (Dixon & Rimmer 2005). The models are suitable frameworks for analysing structural change and social welfare in Mongolia and the impacts of different policies on the economy.

The other objective of the thesis is to use CGE modelling to seek ways for Mongolia to escape the resource trap. More specifically, the research is going to provide policymakers with a detailed CGE analysis of the impact of the resources boom and to offer potential policy alternatives towards establishing a sustainable economic structure. Smaller resource-rich countries, such as Mongolia, are more likely to import final goods and materials because of their more limited opportunities for capturing both external and internal economies of scale in manufacturing. Diffusing the dependence on minerals and developing non-mineral sectors are crucial for Mongolian economic growth. In addition, mineral economies are potentially more vulnerable to policy error than economies with more diversified economic linkages (Dixon, Kauzi & Rimmer 2010). Volatility in developing countries arises from external shocks, such as the fluctuations in the prices of export commodities, which are exemplified in the copper and coal prices in the case of Mongolia in recent years.

The distinction between Gross Domestic Product (GDP), which measures income generated in a country, and Gross National Income (GNI), which measures income belonging to the residents of a country, is crucial in research designed to analyse the impacts of the resources boom on living standards and socio-economic sustainability. This distinction is carefully incorporated into my research on Mongolia.

There are several reasons for employing CGE models in economic analysis. First, their marriage of detailed data and economic theory allows these models to be used to analyse economic shocks that have broad and dramatic impacts, such as the recent resources boom in the case of Mongolia. There are no historically equivalent shocks of this nature and extent within the relevant time series data in Mongolia, given the shocks to the size of the economy and its absorption capacity. Hence it is helpful to use CGE models for evaluating impacts and clarifying thinking relating to the likely consequences of unprecedented shocks in the Mongolian economic context.

Second, CGE models emphasize detailed modelling of economic structure. Rich treatment of the structure of both the supply and demand sides of the economy facilitates detailed analysis of the mining boom and aspects in international trade, and subsequent impacts on aggregate and industry levels of the economy. For instance, ORANIMON produces detailed effects for two alternative scenarios, enabling us to analyse the different aspects and implications of the mining boom.

Third, CGE models provide comprehensive economy-wide results of given shocks, including those that are macro, regional, occupational, fiscal, industry-specific, socio-economic, and more.

Fourth, CGE models are useful for analyzing a developing small economy such as Mongolia's, which recently transitioned from a centrally planned to a market-oriented economy. It is often a case that, for many developing countries, there are hardly any reliable data at all or time series data long enough to enable utilization of econometric methods.

Metaphorically speaking, CGE models are like economic 'operating theatres', where modelers or users can be considered economic 'surgeons'. Of course, economic 'surgeons' do not remove 'an infected part' of the economy. They do have to look at all parts and interconnections of the economy inside and out, and they can identify the issues and may offer policy alternatives. The models are not, however, remedies to Mongolia's economic problems or fortune tellers for the roller coaster economy. There are other aspects of the Mongolian economy, notably the lack in governance and institutional quality (particularly corruption), which the models do not capture directly. But ORANIMON and MONAGE can serve as laboratories for analysing important economic issues and simulating potential impacts of various shocks in order to help develop informed views on policy in Mongolia.

1.1.2 Defining structural change

What is structural change?

Structural change refers to changes in the overall size and structure or make-up of an economy in terms of the distribution of activity and resources among industries and regions. The make-up or structure of an economy is generally defined in terms of the distribution of output across industries or regions. Since production of goods and services require inputs, structural change also refers to the movement of primary inputs (land, labour and capital) and other production inputs between different industries or regions as a result of sustained or permanent changes in market conditions and/or of government policy (PC 2003b).

What are the sources for the change?

A variety of market-related influences (including technological changes and changes in consumer tastes and preferences) and government-related influences (such as micro economic reforms in the case of Australia) can create structural change.

According to Nobel laureate Prescott (2006), either one or more of the variables underlying an economic structure of an economy must be altered for structural change to take place. These fundamental structural variables are: (a) endowment; (b) technology; and (c) preferences.

He writes (p.208):

> Preferences, on the one hand, describe what people choose from a given choice set. Technology, on the other hand, specifies what outputs can be produced given the inputs. Preferences and technology are policy invariant. They are the data of the theory and not the equations as in the system-of-equations approach. With the general equilibrium approach, empirical

knowledge is organized around preferences and technology, in sharp contrast to the system-of-equations approach, which organizes knowledge about equations that specify the behavior of aggregations of households and firms.

The fourth variable which causes structural change is termed 'institutions'. This refers to the set of laws, rules and regulations, and governance frameworks that influence the behaviors of producers and consumers (PC 2003b).

1.2 Background to the Mongolian economy

Mongolia is transitioning a democratic political system and a market-oriented economy; it is located in Northeast Asia. Its population reached the long-awaited 3 million 'threshold' in 2015. The land surface area of the country is 1.56 million square kilometres, making it the least densely populated country in the world. The capital city is Ulaanbaatar. There are 21 provinces, which are divided into 329 districts. Around one third of the population still has a nomadic lifestyle, herding livestock and living in traditional yurts.

Figure 1.1 Mongolia's position

Source: www.maps.com

As can be seen from Figure 1.1, Mongolia is a landlocked country sandwiched between two major super powers: China from the south and Russia from the north. Because of its geographic position and harsh climatic conditions, with cold and long winters, shipping and transportation are costly and inefficient.

Mongolia is a country with vast mineral resources. There are over 6000 known mineral deposits of more than 80 different minerals. Mongolian mineral resource wealth is estimated at USD 1.0-3.0 trillion, with coal, copper and gold making up the main reserves (Fisher et al. 2011).

Mongolia hosts 10% of the world's known coal reserves. The Tavan Tolgoi coal mine (TT) is one of the world's largest untapped coking and thermal coal deposits, with 4.5 billion tons of established reserves (Gupta, Li & Yu 2015). Mongolia is one of the major coal exporters to China, briefly overtaking Australia in 2011 and 2012 (Batdelger 2014).

The Ouy Tolgoi mine (OT) is the largest recently utilized copper deposit in the world, with mineral reserves of 1,393 million tons of ore grading 0.93% copper and 0.37 grams per ton of gold. OT, operated by Rio Tinto, attracted more than USD 6 billion in foreign direct investment (FDI) for its first phase development and started commercial production in 2013.

The Erdenet mine (ET), a government-owned joint venture with Russia, and one of the ten largest mines in Asia, has been exporting copper ores since the 1970s. The dividend and tax payments of ET accounted for one-third of government revenue on average until recently.

There are several other large deposits that are classified as strategically important. In addition, there are a number of medium and small-scale deposits and mines in Mongolia.

1.2.1 Transition years

Mongolia transitioned from a centrally planned to a market-oriented economy. Today, a market mechanism plays a crucial role in resource allocation in Mongolia. The prices of goods and services are determined by supply and demand in their respective markets. During the communist period, the government, a central planner, set and fixed the prices of all goods and services and planned the production, consumption and other economic activities of all agents. The fixed price system ensured the stability and predictability of the planned economy, yet it also eventually led to the demise of the system (Chuluunbat 2012).

There was a major change in economic structure due to the transition. After 70 years of socialist development, the sudden collapse of communism in 1990 resulted in a massive economic contraction and devastation in the Mongolian economic structure and its industrial base between 1989 and 1993. The contraction was almost double that experienced by the United States during the Great Depression of the 1930s in terms of the plunge in domestic absorption (Boone 1994).

Mongolia used to receive quite large transfers, equivalent to 30% of its GDP, from the former Soviet Union. These transfers disappeared suddenly in 1990. The cessation of Soviet aid was further exacerbated by the simultaneous collapse of the Council of Mutual Economic Assistance (CMEA), which provided a market for Mongolia's exports and supplied most of its imports. Mongolia was forced to adjust to the world of hard currency. Hence Mongolia's terms of trade fell substantially due to the fall in the price of its main export commodity, the copper produced by ET, and the cessation of other agricultural exports to CMEA (Nixson & Walters 2006).

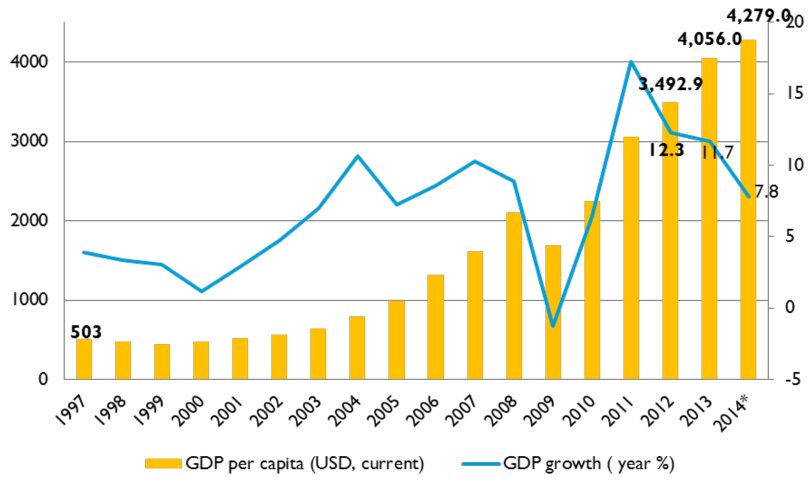
The transition from a centrally planned economic system to a market-based economic system was difficult and challenging. According to Mongolian transition economics literature, fundamental reforms such as privatization of state-owned companies, price liberalization and establishment of market-based institutions were completed by 2005 (Batnasan, Luvsandorj & Khashchuluun 2007).

During the years of transition, Mongolian government policies were geared toward stabilizing macroeconomic conditions with guidance from the World Bank (WB) and the International Monetary Fund (IMF). As of 2005, the economy had recorded a decade of continual growth that averaged around 4.5% per year. During these years, macroeconomic policies were generally prudent, with decreasing foreign debt, stable fiscal surpluses, increasing international reserves and moderate inflation levels (Batdelger 2009).

1.2.2 Mining boom years

Figure 1.2 shows the changes in GDP per capita and economic growth. Mongolia has been one of the fastest growing economies over the past decade. Real GDP growth averaged 8.5% over that period, and per capita GDP more than quadrupled. Mongolia moved from low-income status to lower middle-income in 2012 and to upper middle-income in 2015 (WB 2015).

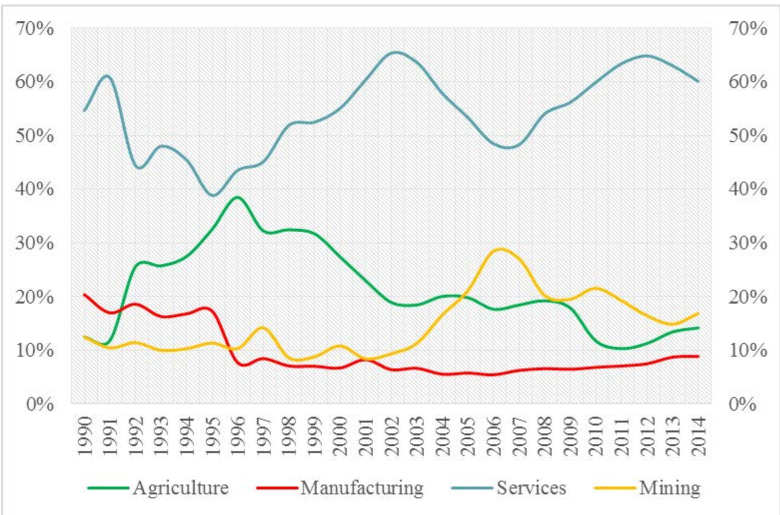
Figure 1.2 GDP per capita (USD, current price) and real GDP growth (%)



Source: Economic Research Institute (ERI)

Over the past two decades, as we can observe from Figure 1.3, the structure of the Mongolian economy has changed and shifted from sectors prominent in the socialist period towards services, also with growth in the importance of the mining industry. Geographically, economic activity has also shifted towards the resource-rich province of Umnugobi where the Tavan Tolgoi and Ouy Tolgoi mines are located.

Figure 1.3 Sectoral shares of GDP (%)



Source: National Statistical Office (NSO), ERI

Changes in the structure of the economy have been driven by a range of factors, including rising demand for services, rapid economic growth in China, economic policy and technical change.

Agriculture has a significant but declining importance in the Mongolian economy. The share of agriculture has been decreasing since its peak of 38.5% in 1996 to just about

15% in 2014. The sudden drops in the share of agriculture in Figure 1.3 around 2001-2002 and 2009-2010 indicate the impacts of ‘dzud’ disasters that occurred in those years. Dzuds occur when the harsh winter conditions (in particular, heavy snow cover) prevent livestock from accessing pasture or from receiving adequate hay and fodder. The Mongolian agriculture sector is more labour intensive than that of Australia. From Table 1.1, we can observe that agriculture accounted for 46%, on average, of total persons employed annually between 1991 and 2004. It is a second largest employer after the services sector and one-third of persons have been employed in agriculture, on average, in recent years.

Since 1990, the share of manufacturing in the overall economy has declined. Over the last two decades, the mining industry’s share of nominal output has fluctuated considerably. Table 1.1 that the average share of the mining industry doubled from its average in 1991-2004 to its average in 2005-2012.

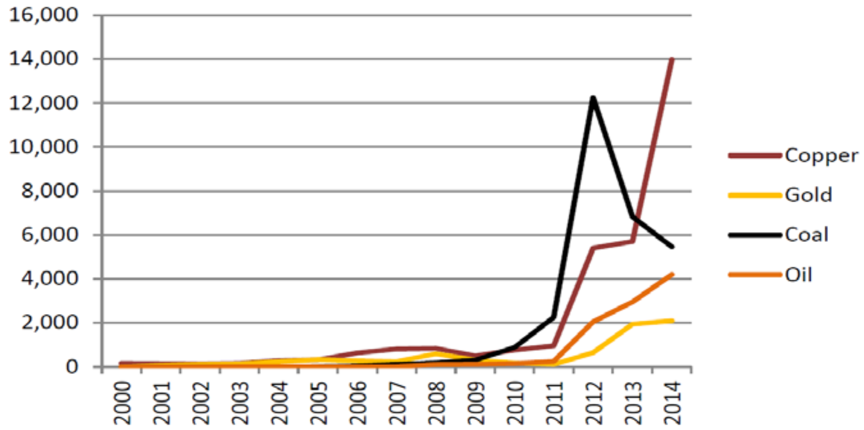
Table 1.1 Sectoral shares in Output and Employment

	Agriculture	**Mining**	**Manufacturing**	**Services**
Output				
1991-1997	28%	11%	15%	47%
1998-2004	25%	11%	7%	58%
2005-2012	16%	22%	6%	56%
Employment				
1991-1997	46%	2%	9%	43%
1998-2004	46%	3%	6%	45%
2005-2012	36%	4%	5%	54%

Service industries are generally more labour intensive (and less capital intensive) than manufacturing in Mongolia, with services employing around 54% of the workforce on average in recent years. Moreover, services took over agriculture to become the most labour intensive sector during the recent mining boom in the period of 2005-2012.

As it can be seen from Figures 1.4 and 1.5 that export income of the Mongolian mining sector increased sharply, owing to higher international prices and the partial utilization of OT and TT.

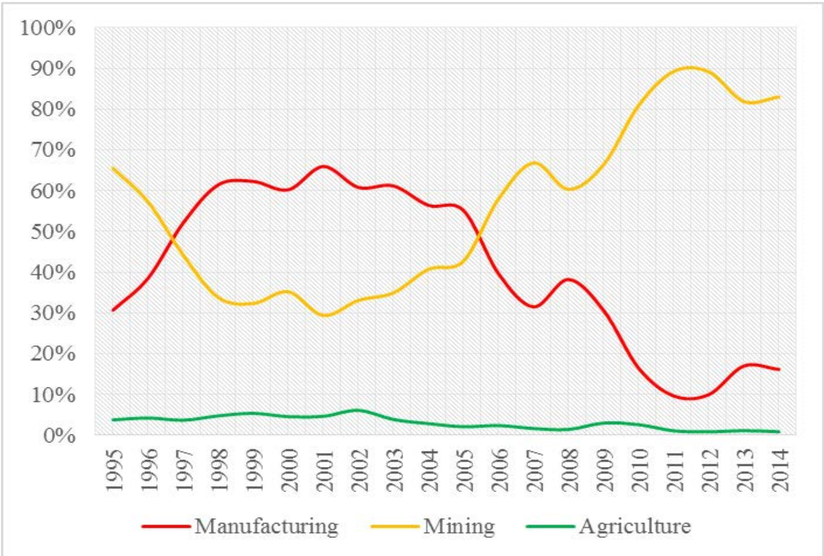
Figure 1.4 Value of Mineral Exports (USD Million)



Source: NSO, ERI

The mining share in total exports has risen substantially since the early 2000s. In particular, the share has increased markedly from 2005, reaching to almost 90% in 2011 and 2012. On the contrary, the manufacturing share in total exports has fallen dramatically since 2005 as shown in Figure 1.5.

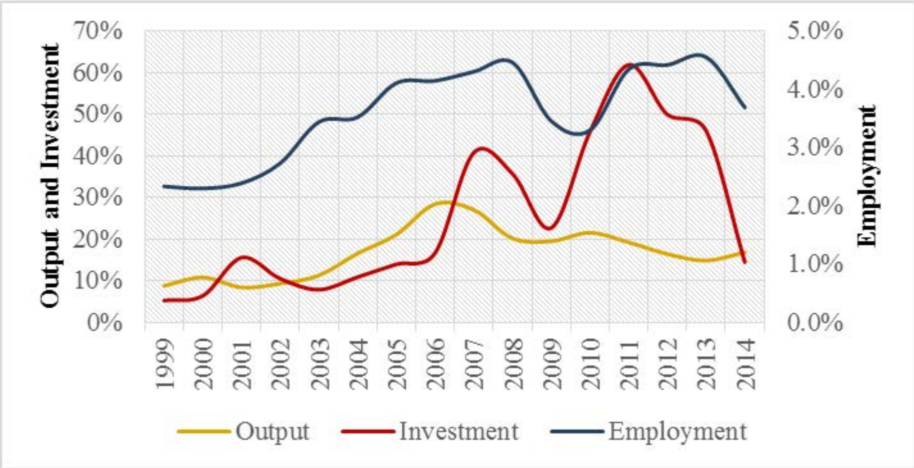
Figure 1.5 Export composition



Source: NSO, ERI

Figure 1.6 compares the movements in the shares of output, investment and employment in the mining sector during the recent mining boom. Investment in the mining sector has also risen from 5% of total investment in the early 2000s to 60% at its height in 2011. Since 2012, the investment share of the mining industry has fallen substantially due to the global economic environment and the government's harsh policies towards foreign investment (Batdelger 2015).

Figure 1.6 Mining activity



Source: NSO, ERI

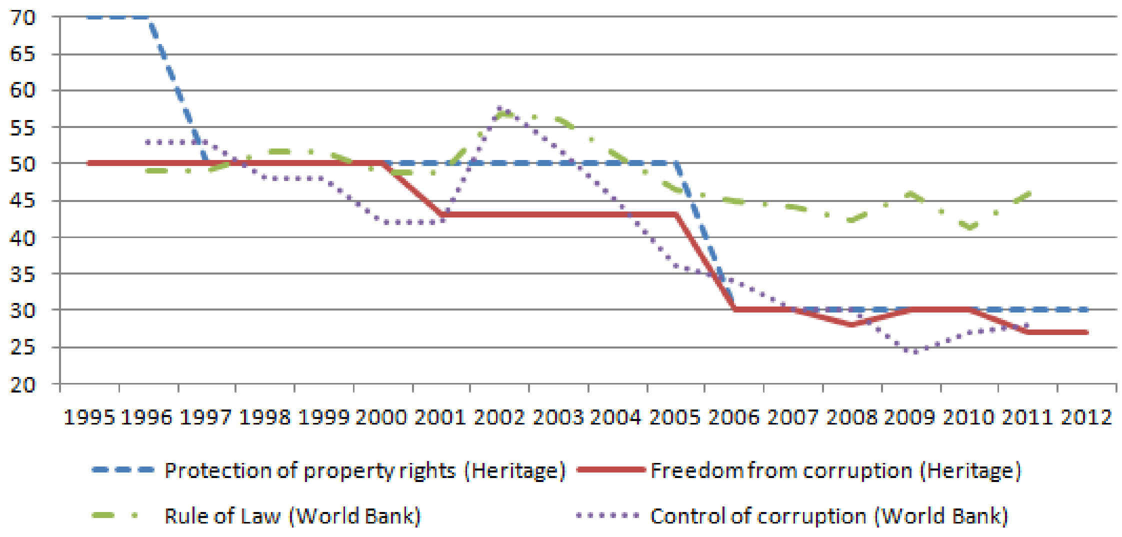
The mining boom directly impacted the remarkable economic growth in the past decade. It fundamentally affected Mongolia’s economic structure, social welfare and environment. At the peak of the mining boom, the resources industry became so pervasive that Mongolians gave the nickname ‘Minegolia’ to Mongolia (Langfitt 2012).

The Mongolian mining boom also brought a wave of unauthorized miners and introduced a new terminology, ‘ninja miners’, to the world. According to Wikipedia, ninja miners are people who dig unauthorized small mines or used mines mostly for gold in Mongolia. These miners are so named since they use basic tools such as pans, and carry them on their backs, thus resembling ‘teenage mutant ninjas’ (turtles) in the popular cartoon.

1.2.3 Institutional quality in Mongolia

Mongolia’s institutional quality has deteriorated during the recent mining boom. A steep rise in government revenues and an increasing role of the government in the economy makes it ‘an attractive breeding ground for rent-seeking by government officials’ (Batdelger 2014, p. 3). Figure 1.7 shows the dynamics of major institutional quality indices for Mongolia in the recent years. Both the World Bank’s control of corruption and the Heritage freedom from corruption indices have declined sharply since the early 2000s. The Heritage index for protection of property rights has dropped significantly.

Figure 1.7 Institutional quality indicators for Mongolia



Source: ERI

1.3 Background to Dutch Disease Literature

Mongolia is rich in natural resources. But this does not mean Mongolia can become a rich country. The experiences of resource-rich nations have been dissimilar. Some countries like Australia and Botswana have harnessed their resource wealth to boost their economic performance, whilst others like Nigeria and Sub-Saharan African countries have found themselves worse off. In general, countries with a huge natural resource endowment have underperformed compared with their counterparts with resource deficiency in recent decades, according to substantial empiric evidence (Auty 1994; Sachs & Warner 2001). The poor performance of resource-rich countries is often referred to as a 'resource curse' or a 'staple trap' (Auty 1994). When a country experiences a resource boom, it normally undergoes a real appreciation of its currency exchange rate. A real appreciation brings about a loss of competitiveness in manufacturing and trade-exposed sectors (Corden 1981; Gregory 1976; Snape 1977) which may lead to progressive de-industrialization – a phenomenon known as 'Dutch disease' (Economist 1977).

Australia has produced a number of great minds in economics. Australian economists have contributed to the development of theories and analysis in economic growth, international trade, economic modelling, agricultural economics, labour economics, tourism economics and more. In particular, their contributions to international trade theory and economic modelling (i.e., CGE modelling) are ground breaking and have had a lasting impact, internationally.

There is a large body of literature devoted to analysing the Dutch disease and the policy implications of natural resources development, known as the Dutch disease economics literature (Bandara 1991a). This has predominantly been developed by Australian economists and is closely related to the Australian international trade theory. The origin of the Australian international trade theory can be traced way back to the 1930s. The theory was formulated by Wilson (1931) and was developed further by Salter (1959), Swan (1960), Corden (1960) and Gregory (1976). In the Australian international trade model, there are three goods: exports, imports and non-internationally traded home goods. Combining exports and imports to traded goods using their fixed price relativity, the model can be reduced to a two goods and two prices model.

In his pioneering study of the Dutch disease, 'Some Implications of the Growth of the Mineral Sectors', Gregory (1976) showed, using an inter-sectoral model, that the growth of the mineral sector would lead to a real appreciation, which, in turn, could have a negative impact on the import-competing and other non-mineral export industries.

Gregory's analysis was pursued by Snape (1977). The discovery of North Sea oil reserves shed light on the same idea in Britain. Then the term 'Dutch disease' appeared in 1977 (Economist 1977). Discussing various implications with a three-sector 'Dutch disease' model that referred to Gregory (1976) and Snape (1977), Corden presented a paper at a conference in 1978, which was then published in 1981 (Corden 1981). Forsyth and Kay (1980) examined the impact of the growth of North Sea oil production on the British economy. Corden and Neary (1982) further developed a three-sector model and defined the effects associated with mineral development. We classify these 1970s to early 1980s papers as the classic Dutch disease literature. Due to the recent mining boom, the interest in Dutch disease has been rekindled. The authors of the classic literature have produced reflections and new ideas that particularly relate to the nature of the recent mining boom. We classify the recent literature as the new Dutch disease literature.

1.3.1 Classic Dutch disease literature

1.3.1.1 Gregory thesis

Gregory had two purposes in mind when responding to the 1970s economic environment in Australia. According to Corden (2006), the nominal exchange rate appreciated three times in less than a year, from December 1972 to September 1973, and forced a devaluation in September 1973.

Within a year, from December 1972 to December 1973, the effective exchange rate[1] appreciated by 20%, and between December 1973 and December 1974 it depreciated by 15% (Gregory & Martin 1976).

In July 1973, the Whitlam government reduced all tariff rates levied on imported goods by one quarter (25%). This affected the highly protected manufacturing industries including motor vehicles and most of the relatively labour intensive industries greatly (Anderson 1987). The uniform tariff cut was influenced by macroeconomic conditions at that time: inflation and a balance-of-payments surplus. The purpose of the uniform cut was, by increasing the supply of imports, to reduce inflation (Anderson 2014; Corden 1995).

Gregory's first purpose was to increase understanding of the potential effects of these two policy instruments: a large across-the-board tariff cut and changes in the nominal exchange rate. Australian mineral exports, coal in particular, had increased sharply since 1964/1965. His second purpose was to increase understanding of the relationship between the development of the new mineral export sector during the 1960s and 1970s and the large structural breaks, mainly evident in large falls in the male full-time employment/population ratio, in the Australian economy (Gregory 2012).

Gregory measured the effects of changes in tariffs on different sectors of the Australian economy indirectly by observing the adjustments of each sector to the rapid growth of mineral exports, using a comparative static analysis. He calculated that the mineral discoveries had a much greater impact on import-competing sectors than the hotly debated across-the-board 25% general reduction in tariffs in Australia. The adverse effect on the import-competing sector was similar to that of a tariff reduction, while the adverse effect on the non-mineral export sector was similar to that of a tariff increase (Corden 2006).

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[1] The effective exchange rate is a weighted average of the Australian exchange rate with each of its major trading partners where the weights are the proportions of all Australian trade (imports plus exports) with each country.

His methodology was ingenious and yet simple. Gregory described the methodology in Coleman (2009):

> If you want to know the effect of *B* on *A* and you cannot see any variation of *B*; then look for *C* that varies and affects *A* in much the same way that *B* would do if it varied? Then, if you put the variations in *C* into variations in *B* equivalents, you are home. (p.23)

When exploring the potential effect of a 25% tariff cut (that is, *B*) on an import-competing sector (that is, *A*), he took a real exchange rate change (that is, *C*) as a link. In other words, he decided to link real exchange rate changes generated from the rapid increases in mineral exports to the tariff change in order to evaluate its impact on the economy.

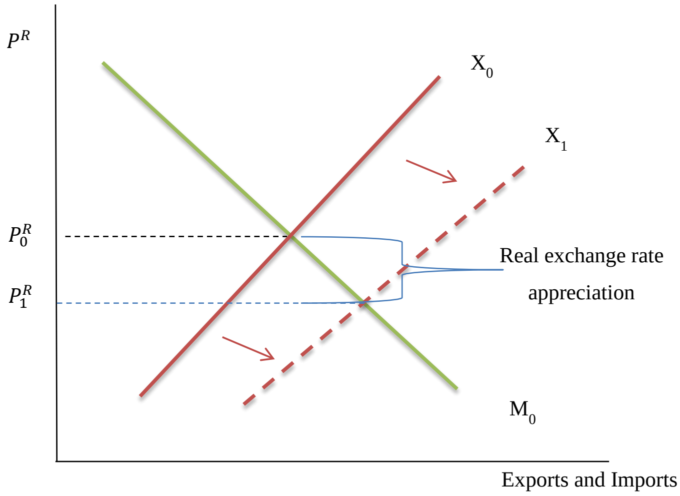
We show Gregory's model in Figure 1.8. The relative price of traded to non-traded goods is shown on the vertical axis and the quantities of exports and imports are measured on the horizontal axis. Gregory assumes that international terms of trade are constant and import goods are perfect substitutes for domestically produced import-competing goods. Hence relative prices of import goods, import-competing goods, export goods, and domestically consumed exportable goods are all fixed. Through these assumptions, he could place the quantities of both exports and imports on the horizontal axis with units where a unit of exports can be exchanged for a unit of imports. The curves X_0 and M_0 indicate the supply of export goods and the demand for import goods at any given price ratio of traded and non-traded goods.

If the relative price of traded and non-traded goods increases, the profitability of producing tradable goods (export goods and import substitutes) will increase. As a consequence, the quantity of exports will consequently rise and the quantity of imports will decline. Conversely, where there is a fall in the relative price, the profitability of producing tradable goods will decrease. As a consequence, the quantity of exports will decline and the quantity of imports will grow.

In the case of a supply-side mineral boom, the export curve shifts to the right, reducing the equilibrium relative price from P_0^R to P_1^R and increasing the equilibrium quantities of both exports and imports. The reduction in relative price may come from domestic inflation or exchange rate appreciation or both.

In his framework, he shows that mineral discoveries increase the quantity of imports and consequently reduce the size of the import-competing sector. In addition, he demonstrates that new mineral exports exert pressure on the quantity of traditional or old export goods and hence reduce the size of this sector.

Figure 1.8 Gregory's analysis



The paper was named 'Gregory Thesis' by *The Australian* newspaper and Chris Hurford, who was a member of federal parliament from Adelaide, South Australia. The Gregory thesis, also referred to as the mineral paper, made a profound impact in the arena of economic policy debate in Australia, provided the dominant theoretical framework for analysing resource reallocation and exchange rate implications of the Australian mineral boom in 1970s, and led to the subsequent development of the Dutch disease literature. Corden (2006) emphasized that '… the tariff comparisons on which Gregory focused were not the aspects that attracted attention. Rather, it was the simple argument that the mineral boom must have an adverse effect on import-competing manufacturing industry' (p.25).

1.3.1.2 Snape's analysis

Snape (1977) used a general equilibrium approach to refine and extend Gregory's study. He pointed out some difficulties associated with the partial equilibrium nature of Gregory's model. The export and import curves in Figure 1.8 do not shift as aggregate income and aggregate demand change. There are some questions about the time period over which adjustment may occur. In addition, there is no consideration regarding the effects of a mineral boom on the costs of other industries. In other words, Gregory's model does not capture the income and cost impacts of mineral boom. Snape starts off with a simple model, in which there are two categories of goods: minerals and other. He assumes both categories of goods are tradable goods. He also assumes constant international terms of trade. Using a production frontier graph, he shows that the productivity of labour and capital will increase due to the mineral discoveries. Then he shows that production of other goods will fall as a whole, but some goods in the category may rise, even if their relative prices are fixed. He provides an example of such a scenario:

> To illustrate, suppose that mineral production prior to the discovery had been fairly labour intensive but the newly discovered deposits led to a substitution of capital for labour and lower the demand for labour. Other industries could hire labour more cheaply than before and may increase their production. This possibility is overlooked by a partial equilibrium analysis (1977, p. 151).

Snape moved on to introduce non-tradable goods. Instead of using a three-dimensional representation, however, he combined exportable and importable goods into tradable goods and then added non-tradable goods as a second category. He added demand into the production frontier analysis, adopting a community preference map, and found that there was a possibility that the production of non-tradable goods could increase or decrease due to two effects. On the one hand, the increased price and marginal cost of non-tradable goods discourages demand for them. On the other, increased national income encourages demand for non-tradable goods.

Next he added explicit factors of production into his model. He assumed that there were three categories of goods (exportable, importable and non-tradable) and at least three types of factors, of which labour is mobile across the three sectors. Non-tradable goods are assumed to be produced by labour. He found that there is a magnified effect of mineral discoveries on the payments of factors specific to minerals and a squeezing effect on the payment of factors to other tradable goods.

1.3.1.3 Corden's contributions

Max Corden has made an extensive contribution to the study of Dutch disease internationally through his series of analyses of structural change in a small open economy (Corden 1981, 1984; Corden & Neary 1982). Corden and Neary (1982) provided a three-sector economic framework, the 'core model' of Dutch disease economics, to analyse the impact of growth in the ‘booming sector’ (a resource sector) to the lagging sector (tradable manufacturing) and to the non-tradable sector (non-tradable manufacturing and services). Tradable goods are exposed to international competition, and hence their prices are determined in the world market, whereas non-tradable goods are not exposed to international competition and thus their prices are dependent upon the domestic supply of and demands for them.

As a result of a resources boom, there are two types of effects, according to the core model: the resource movement effect and the spending effect.

A boom is generated by a price rise, or a new resource discovery raises the marginal products of mobile factors in the booming sector, which, in turn, increases the factor prices. This draws resources from other sectors, causing structural changes. This is the resource movement effect.

A boom increases domestic income, resulting in extra spending for both tradable and non-tradable goods. As the prices of tradable goods are determined in the world market for a small country, extra spending does not induce increases in the prices of tradable goods. Extra spending, however, causes prices of non-tradable goods, which are determined in the domestic market, to increase, resulting in a real exchange rate appreciation (that is, a rise in the relative price of non-tradable goods to tradable goods). As a result, the production of non-tradable goods becomes attractive, discouraging the production of tradable goods. This effect is called the spending effect. Both effects can have a negative impact on the tradable manufacturing sectors, leading to a de-industrialization effect.

According to Corden and Neary (1982), there are three possible reasons for the Dutch disease effects: (a) an improvement in the technology of the booming sector; (b) an increase in foreign capital flows; and (c) an increase in the price of the export commodity.

1.3.2 New Dutch disease literature

Gregory (2011) analyses the mining boom of 2000s in comparison with the 1970s boom, focusing on the important economic differences of the two booms: the recent one was generated by export price increases and the older one was generated by export volume increases. Further, Gregory (2012) measures the increase in Australian living standards relative to the United States resulting from the terms of trade changes –

through their direct trading gain effect and indirect real GDP effect as about 25 per cent and concluded that this increase probably placed Australian living standards well above those of the United States. Gregory and Sheehan (2013) view the recent mining boom as moving through three stages- the increase in the terms of trade, an induced mining investment response and a significant increase in mining exports, and explore the implications and policy issues arising as the mining boom passes through these three stages.

Corden (2012) defines a three-speed economy for Australia to explain the recent mining boom. He argues that the mining boom leads to a real appreciation that pressures lagging sectors such as manufacturing, tourism, education and agriculture, and he offers options to reduce Dutch disease: piecemeal protectionism, moderate exchange rate effects by running a fiscal surplus, combined with lowering the interest rate, and establishing a sovereign wealth fund.

Using the balance of payments model, Freebairn (2015) analyses the time path of pressures for exchange rate adjustment to different stages of a mining boom under different industry and economic circumstances. The time path effects of a mining boom is considered for four discrete time periods: initial demand driven boom (the terms of trade boom), investment period, production period and the end of boom. He finds that the relationship between the terms of trade and the exchange rate is not simply monotonic as it may be different in different phases or it may reverse from one phase to another. Finally, Freebairn concludes that a computable general equilibrium model which captures the different stages of a mining boom is desired in the next stage of the analysis.

Theoretically, the abundance of natural resources could improve the host countries economic performance due to 'big push' effects of higher investment in infrastructure and human capital development (Sachs & Warner 2001). In fact, some countries, such as Australia where the existence of a strong mining sector has led to the rapid expansion of the export of mining technology and services and the development of human capital associated with those new technologies, have avoided resource curse. Some research work such as Alexeev and Conrad (2009) find that natural wealth has positive effects on living standard, when controlling for a number of variables, particularly dummies for East Asia and Latin America in their cross-country analysis. Therefore, whether mineral resources are a blessing or a curse still remains a controversial question.

1.4 Background to Historical and Decomposition simulation studies

COPS style CGE models contain a large number of economic relationships linking observable features of the economy, such as macroeconomic aggregates, commodity prices and outputs, household consumption composition and commodities with the structural features of the economy, such as production technologies and household tastes. In the historical simulation, many of the variables which represent observable features of the economy are determined exogenously. This enables models to calculate the outcomes for typically unobservable variables describing the features of the economy's structure. These variables include industry production technologies, household tastes and the positions in export demand and import supply curves. The original historical and decomposition analysis was by Dixon and McDonald (1993). They explained the structural changes in the Australian economy for the period 1986-87 to 1990-91. Dixon and Rimmer (2002) defined the analytical method for historical, decomposition, policy and forecasting simulations with an illustrative application of the Australian motor vehicle industry from 1987 to 2016. Dixon, Mennon and Rimmer (2000) explored the impacts of changes in technology and preferences on the rapid growth of trade for the period 1986/87-1992/93. Wittwer and Anderson (1999) used a regional CGE model to assess the Australia's grape and wine industries through historical, decomposition, policy and forecasting analyses for the period 1986 to 2003. Dixon and Rimmer (2003) quantified several aspects of technical change in US industries for the period 1992 to 1998 with the USAGE model. With the MONASH model, Giesecke (2004) carried out historical and decomposition simulations for the period 1996/97-2001/02. Tran (2007) carried out historical and decomposition simulations with the COPS style dynamic CGE model of the Vietnamese economy, MVN. Giesecke and Tran (2009) further refined the historical and decomposition analysis of the Vietnamese economy. Mai, Adams and Dixon (2009) carried out historical and forecasting simulations in the case of China with the MONASH CHINA Multi-Country model. They estimated China's technological convergence with developed countries empirically. Dixon and Rimmer (2014), with USAGE, decomposed movements in U.S macro and industry variables from 1992 to 1998 into the contributions of North American Free Trade Agreement (NAFTA) factors and other factors.

1.5 Structure of the thesis

The thesis consists of four parts and eight chapters. The first part, Introduction and Background, includes this chapter and Chapter 2. This chapter provides a brief general background to the Mongolian economy. In addition, it presents a brief literature review on the Dutch disease literature and on the COPS style approach for analysing structural change: historical and decomposition simulations. Chapter 2, dedicated to the COPS-style modelling, defines that modelling, describes its history and offers a brief literature review on CGE modelling in general.

The methodology part contains the theoretical frameworks and database construction of two CGE models developed in three chapters. Chapter 3 presents the theoretical framework of ORANIMON, focusing on examining the underlying mechanisms inherited from ORANI. Chapter 4 describes the theoretical additions of MONAGE, focusing on dynamics, closures and additional technical innovations related to technology and tastes, welfare measures and the facilitation for different types of simulations. Chapter 5 provides descriptions of data, methods for building the database, estimations of parameters and the results from related validity analysis. In building a CGE model the crucial step is to set up a database that is formulated in a given year. This database creation requires painstaking interpretation of statistics and frequent interactions with statistical agencies (Dixon & Rimmer 2002). Fortunately, the National Statistical Office of Mongolia (NSO) provided various unpublished data and involved the author in its discussions and projects related to the compilation and dissemination of input output tables (IOTs), enabling the creation of twin databases for 2005 and 2012.

The application part of the thesis is concerned with the analysis of the mining boom during 2005-2012. The part comprises two chapters. The ORANIMON applications are for studying the impacts of early commodity price increases, started around 2005, and the associated sudden growth of investment in the Mongolian economy. The analysis and findings are presented in Chapter 6. The MONAGE simulations are concerned with the analysis of the structural changes in the Mongolian economy between 2005 and 2012. Chapter 7 discusses historical simulation, which provides detailed estimation of changes in structural variables such as technologies, preferences and the movement in export demand supply curves. In addition, the chapter presents the decomposition simulation, which analyses the contributions of the structural changes to the macro- and industry-level economic performance of the economy during the period. These simulations are concerned with the implications of the mining boom for macroeconomic performance, employment, the balance of trade, the overall price level and the level of output in each industry. In addition, we can identify the winners and losers as a result of the mining boom. Further, these simulations enable us to investigate the Dutch disease effects in the Mongolian economic context.

The final part, Chapter 8, summarizes major findings, highlights the contributions and limitations of the study, and proposes avenues for further research.

Chapter 2. COPS Style CGE Modelling and Analysis

2.1 Preamble

Economics is the study of how economic agents – producers, investors, households, foreigners and governments – make choices under conditions of scarcity, and of the results and efficiency of those choices. In any economic system, scarce resources have to be allocated among competing uses. These resources are allocated by the combined choices and interactions of economic agents in an economy. Inevitably, the choices of economic agents come down to the relative importance of competing uses, thereby creating trade-offs. Economic theories postulate the optimisation behaviours of economic agents under given resource and technology constraints, with signalling from market prices. Households maximise their utility subject to their budget constraints, and producers maximise their profits subject to their production technology constraints. Solutions to these optimisation problems yield the demands and supplies of commodities and services respectively. Prices, determined by market equilibria, play a crucial role in resource allocation. Hence, the optimising behaviours of economic agents are the means of introducing market or price mechanism in the model (Dixon & Rimmer 2002).

Interactions of agents and repercussions of episodes in an economy are capable of being captured in an economy-wide general equilibrium framework. The theory of general equilibrium analysis was pioneered by Walras (1877) and Edgeworth (1881). Leon Walras provided the first general equilibrium description of a complex economic system with the interactions of independent economic agents. Francis Edgeworth introduced the well-known tool of general equilibrium analysis of exchange that is named after him – the Edgeworth box. Major theoretical contributions related to the existence, uniqueness, stability and optimality of general equilibria were made also by Kenneth Arrow, Gerard Debreu, Hiroshi Atsumi, Hirofumi Uzawa and Michio Morishima from 1950 to the 1970s.

CGE modelling is an empirical approach of general equilibrium analysis. Since 1960, CGE modelling has gradually replaced other economy-wide approaches such as input-output modelling and economy-wide econometric modelling. It also became a dominant economy-wide framework for policy analysis in 1990s, with a vast amount of literature concerning various aspects and applications of CGE modelling (Dixon 2006; Dixon &

Jorgenson 2013). Dixon et al. (1992) described CGE modelling as an integration of a general equilibrium theoretical structure, data about the economy of interest, and solution methods to solve the models numerically. Dervis and Robinson (1982) identified CGE models as those that 'postulate neo-classical production functions and price-responsive demand functions, linked around an input-output matrix in a Walrasian general equilibrium model that endogenously determines quantities and prices'. Shoven and Whalley (1992) defined CGE modelling as a conversion of the Walrasian general equilibrium structure into realistic models of actual economies by specifying production and demand parameters, and incorporating data reflective of real economies. Dixon and Parmenter (1996) described the distinguishing characteristics of CGE models as follows:

(i) CGE models are general since they include explicit specifications of the behaviour of several economic agents/actors;

(ii) CGE models employ market equilibrium assumptions as they describe how demand and supply decisions made by different economic agents determine the prices of at least some commodities and factors that in turn ensure market equilibria; and

(iii) CGE models are computable and produce numerical results.

CGE modelling can therefore be characterised by its applied nature and quantitative approach in general equilibrium analysis. Applied general equilibrium (AGE) modelling is an alternative term used to describe CGE modelling.

CGE models belong to the economy-wide class of models. Hence, they provide industry disaggregation and the behaviours of economic agents in a quantitative description of the whole economy. According to Dixon and Rimmer (2010), the original empirical economy-wide model was Leontief's input-output system (Leontief 1936). Leontief's input-output system portrays 'both an entire economy and its fine structure by plotting the production of each industry against its consumption from every other' (Leontief 1951, p. 15). He provided a tabular representation of the economy – the input-output tables. These tables show a detailed disaggregation of the supply and use of inputs and outputs in the economy.

Leontief's input-output system in matrix form can be shown as:

$$X = AX + Y \tag{2.1}$$

where X is a vector of outputs; Y is a vector of final demands; and A is the input-output coefficient matrix. In input-output modelling, the production of each commodity (the vector X) satisfies the intermediate (the matrix AX) and final (the vector Y) demands with given technology specified by the input-output coefficient matrix (A). Each input-output or technical coefficient (a_{ji}) in matrix A defines the value of intermediate inputs that are required by industry i from industry j to produce a unit of output in industry i ($a_{ji} = Z_{ji}/X_i$ where Z_{ji} is the intermediate input sales from industry j to industry i). Input-output analysis, as Leontief described (1951, p. 21), is ‘a method of analysis that takes advantage of the flow of goods and services among the elements of the economy to bring a much detailed statistical picture of the system into the range of manipulation by economic theory’. Input-output modelling is still popular in applied economic research.

The next stage of economy-wide modelling was the programming model pioneered by Sandee (1960). In his demonstration of the planning model for India, Sandee used a linear programming method to maximise a welfare (material consumption) function, subject to Leontief’s technology specification. Notable contributions to the programming models were made by Manne (1963) and Evans (1972). H. D. Evans’ internationally acclaimed study of protection in Australia was an important methodological contribution to the analysis of protection and to the applied general equilibrium framework (Dixon & Butlin 1977).

Input-output and programming models could not provide underlying market mechanism of interactions in the economy and lacked clear descriptions of the behaviour of individual agents (Dixon & Rimmer 2010a). In these models, the economy is visualised as a single agent (Dixon & Jorgenson 2013).

Lief Johansen (1960) advanced economy-wide modelling through the explicit identification of behaviour by economic agents in his model of Norway’s economy. The publication of Johansen’s book, ‘A Multi-sectoral Study of Economic Growth’, marked the birth of CGE modelling (Dixon & Jorgenson 2013). In Johansen’s 22-sector model, households maximise utility subject to their income constraints; industries choose primary and intermediate inputs to minimise their costs of producing any given level of output, subject to their production frontiers and the need to satisfy demands for their outputs; and investors allocate the economy's capital stock between industries to maximise their returns. The overall outcome for the economy is determined by the actions of individual agents driven by the price adjustment mechanism (invisible hand) that equalises demand and supply in various markets.

Dixon (2010a) reminds us that there was no single starting point for CGE modelling even though Johansen was 'the first one to plant a seed in what has now become the CGE forest' (p. 5).

Herbert Scarf's work (1967; Scarf & Hansen 1973) brought greater attention and enthusiasm to CGE modelling. His students, John Whalley and John Shoven, further contributed to the development of Scarf's approach, which is also known as a combinatorial approach. Scarf's method, however, has been largely abandoned in favour of much simpler methods used by other approaches (Dixon 2006).

Dale Jorgenson and his associates solved their CGE model by iterative methods independently. They continue to make path-breaking contribution to CGE modelling through theoretical and econometric innovations (Dixon & Jorgenson 2013; Dixon & Rimmer 2010a). Irma Adelman, Sherman Robinson and their associates at the World Bank developed another widely used CGE approach. The models developed using their framework belong to the tradition of World Bank CGE modelling (Bandara 1991a). The Generalized Algebraic Modelling System (GAMS) software (Brooke, Kendrick & Meeraus 1996) is used in their Social Accounting Matrix based models.

Peter Dixon and his associates developed the Centre of Policy Studies (COPS) approach, adopting and extending Johansen strategies for computing, and for organising and understanding results. In this sense, COPS style modelling is directly descended from Johansen. The influence of Johansen, combined with the institutional arrangements under which COPS style models have been developed, has given this form of modelling some distinctive technical characteristics (Dixon, Koopman & Rimmer 2013). COPS style models are solved with the General Equilibrium Modelling Package (GEMPACK) software (Harrison & Pearson 1996). The progress of CGE modelling software and the differences among the main systems such as GEMPACK and the GAMS are detailed in Horridge et al. (2012). COPS style modelling is also known as 'Australian style' CGE modelling (Hertel 2013).

Finally, Global Trade Analysis Project (GTAP), an exceptional venture and a collaborative network of organisations and individuals, has emerged as a united force in CGE modelling, bringing an explosion of interests in global environmental, trade, energy, land-use and many other economic issues. Thomas Hertel and associates of the GTAP network have shaped the development of CGE modelling into a new era since its inception in 1991. GTAP is now recognised as a global brand of CGE modelling. Alan Powell, one of the founders of COPS style modelling, concludes 'in the discipline of economics there has never been a research oriented community as large or as enthusiastic as the associates of GTAP (Powell 2007). GTAP modellers employ both GEMPACK and the GAMS.

This chapter will continue with a brief history and a discussion of the distinctive features of COPS style models. In addition, it will introduce solution methods, notations, tools and functions that are used in this thesis.

2.2 A Brief History: From ORANI to new generation COPS models

This section briefly describes the history of COPS style of CGE modelling; from ORANI to new generation COPS models. ORANI and other COPS style models can be readily identified as belonging to the Johansen class of multi-sectoral models (Dixon, Koopman & Rimmer 2013; Dixon et al. 1982). Retaining the advantages of Johansen's approach and combining them with the institutional arrangements under which COPS style models have been developed, COPS style modelling has become a well-recognised school of economic modelling, thought and analysis with distinctive technical characteristics and a transferable know-how.

2.2.1 ORANI

COPS style models evolved from ORANI (Dixon et al. 1982). ORANI is a comparative static model of the Australian economy. It was developed in the late 1970s in the framework of the IMPACT project and has served as a foundation for CGE models of many countries. Its first applications (Dixon et al. 1977; Dixon, Powell & Harrower 1977) brought a wide exposure in the Australian economic policy debate (Powell & Snape 1992).

When summarising the most important developments in economic policy during 1967-1975, Corden (1995) highlighted a long-run perspective of economic policy analysis. He wrote:

> Thanks to Mr. Whitlam and the initiative of Mr. Rattigan, the Tariff Board was replaced by the Industries Assistance Commission (IAC), with Mr. Rattigan the chairman of the new IAC. Its mandate was much wider than that of the Tariff Board, and it was conceived on a much more ambitious scale. This was the beginning of an important and remarkable organisation, one which acquired a world reputation and which, through its careful empirical work and strong and consistent "economic rationalist" analysis, undoubtedly influenced informed thinking and policy-making in the broad area of industry assistance subsequently. There is really a remarkable contrast between the Tariff Board reports of the early sixties (and some of the reports reviewed in my 1967 lecture) which were empty of serious economic analysis, and the highly professional reports of the IAC, backed up with effective rate and subsidy equivalent measures and the use of general equilibrium modelling resulting from the IMPACT project (Anderson 2014, pp. 370-2).

In his most celebrated paper, 'Gregory thesis', Gregory (1976) foresaw the importance of the IMPACT project and its models, and wrote:

> To fully account for general equilibrium effects [of the rapid growth of mineral exports] would require a much more complex and computerised model such as the IMPACT model being developed by a number of Australian government departments (p. 75).

The abovementioned institutional arrangements have played an essential role for the development of COPS school of modelling. The Australian government-initiated IAC had set up the IMPACT project under the direction of Powell, aimed at improving available policy information systems for governments as well as for private and academic analysts. More specifically, the IMPACT project was to build policy-oriented economy-wide models and to organise training associated with these models (Dee 1994; Powell & Snape 1992).

The Productivity Commission (PC) acknowledged the origin of the IMPACT project as a source of its strong analytical tradition in its 30th anniversary book titled 'From industry assistance to productivity: 30 years of the Commission' as:

> While the number of detailed tariff inquiries fell, their breadth and complexity increased, as did the depth of the analytical approaches employed. GA (Marshall) Rattigan, the first Chairman of the IAC, together with one of his senior advisors at the Commission, Bill Carmichael (later

> to become Chairman himself), realised the importance of developing quantitative models capable of analysing the economy-wide consequences of policy and policy changes for economic activity and employment, as well as for regions, sectors and individual industries. Effective rate calculations, although revealing, were not enough. Consequently, the IAC helped construct increasingly sophisticated quantitative economic models of the Australian economy (PC 2003a, pp. 4-5).

The integrity and vison of outstanding public servants (notably, A. Rattigan, W. Carmicheal and B. Kelly), the insights and influences of Australian leading economists (notably, M. Corden, B. Gregory and R. Snape) and the policy problem of much debated tariff were the preconditions of the IMPACT project and its brainchild ORANI becoming influential in Australian policy analysis immediately.

CGE modelling became influential, as Powell and Snape (1992) expressed, not just because the tool had caught the imagination of some of Australia's best economists (Dixon and colleagues) but because it was the right tool for the policy problem at hand. They highlighted the following conditions under which ORANI was developed; independence, full documentation, and involvement of the policy clientele. Powell, in his foreword to 'Global Trade Analysis: Modelling and Applications' (Hertel 1997) , pointed out that the replicability of an experiment is necessary for economics to earn its status as a science and emphasised that 'this can amount to a tall order' in the case of CGE work (p. xiii). In fact, ORANI showcases this 'tall order'.

Dixon is the founder and leader of COPS style modelling. After graduating with Honours in Economics from Monash in 1967, he pursued his PhD at Harvard under Leontief's supervision. His PhD was awarded in 1972 by Harvard (Parmenter 2004). Titled 'The Theory of Joint Maximisation', this thesis was subsequently published in the North Holland Contributions to Economic Analysis series (Dixon 1975). His thesis made a number of contributions to economic analysis, particularly to the literature on the computations of numerical solution to general equilibrium models (Mackinnon 1976). Dixon introduced the joint maximisation approach for the computation of equilibria and developed effective algorithms, providing an alternative to Scarf's combinatorial approach. The essence of the theory of joint maximisation is 'the notion that general equilibrium solutions may be found by solving suitably chosen programming problems' (Dixon 1975). Dixon acknowledged that Evans' 1968 PhD thesis inspired him to study for his PhD and named Evans as one of three people who influenced him greatly. He was brought to the IMPACT project by Powell, one of the founders for this school of modelling and also one of three people who influenced Dixon greatly, to build an economy-wide model. Dixon integrated Armington's imperfect substitution specification (Armington 1969) with Leontief's input-output model to build ORANI. Originally, ORANI introduced a number of innovations such as: flexible closures; multi-product industries and multi-industry products; the CRESH and CRETH substitution possibilities; specifications of technical change and indirect taxes associated with every input-output flow; explicit modelling of transport, wholesale and retail margins; and a regional dimension (Dixon & Rimmer 2010a).

ORANI was initially built to analyse the impacts of high tariff, identifying the losers from protection and quantifying their losses. ORANI showed how high tariffs caused high costs in Australia and confirmed that cutting tariffs from the high levels in the 1970s would produce overall benefits for Australia. ORANI simulations showed that cutting tariffs would increase average wage rates – and hence, living standard – while not harming aggregate employment. It would also stimulate export activity that would bring prosperity to regions like Western Australia and Queensland (Dixon et al. 1977). Dixon (1978) reiterated his theory and described how the theory of joint maximisation forms a basis for ORANI's computational technique by comparing his approach with that of Scarf.

ORANI was designed to provide results that would be persuasive to practical policy makers rather than to academics, hence it encompassed considerable detail. The first version of ORANI had 113 industries and a facility for generating results for Australia's eight states and territories. In addition to its industry and regional details, ORANI was equipped with detail in other areas such as detailed specifications of margins that were normally ignored in academic research (Dixon 2006).

Since 1977, ORANI has been used in numerous analyses and simulations on the effects of mineral discoveries, major infrastructure projects, new technologies, mining booms and busts, and the impacts of various government policies changes in policy instruments such as import tariffs, other tax rates, public spending, interest rates, microeconomic and labour market reform, as well as other environmental and legal regulations on the Australian economy.

Reviews of several hundred published ORANI applications of early years in Australian context can be found in Powell and Snape (1992) and Dee (1994).

ORANI, furthermore, has become the most diversely exported know-how or technology of Australia, and has served as the foundation and starting template of models for many other countries, including South Korea (Vincent 1982), New Zealand (Nana & Philpott 1983), Papua New Guinea (Vincent 1991), the Philippines (Coxhead & Warr 1995; Coxhead, Warr & Crawford 1991), South Africa (Horridge et al. 1995), Indonesia (Wittwer 1999), China (Adams et al. 2000b) and many others. ORANI-Generic (Horridge 2000, 2014; Horridge, Parmenter & Pearson 1998) is a modern version of ORANI designed for teaching purposes as well as to serve as a foundation from which to construct new models.

Adaptations of ORANI-G have been created for many countries, including Brazil, Denmark, Japan, Ireland, Italy, Malaysia, Mongolia, Pakistan, Qatar, Saudi Arabia, Sri Lanka, Taiwan, Thailand, Venezuela and Vietnam. ORANI has still been used extensively for applied research in Australia and worldwide. As of today, there are well over fifteen hundred published ORANI applications and ORANI based analyses[2].

Dixon and Rimmer (2002) summarised and attributed the success of ORANI to five factors. The first factor is a full documentation of methods, data and results (Dixon et al. 1982; Horridge 2000, 2014; Horridge, Parmenter & Pearson 1993). The second factor is the dissemination and transfer of know-how through training courses and active connection with stakeholders such as clients, academics, other users and potential users. The third one is the availability of the GEMPACK package which allows modellers and other users to deal with very large systems with relative ease and control. The fourth factor is the versatility of ORANI associated with the flexible closure that enables it to analyse a wide variety of issues. The last factor is the usage of back-of-the-envelope (BOTE) calculations to identify principal mechanisms and data and check the plausibility of the results as well as help others to digest and understand the results from a particular application.

[2] Author's estimation

2.2.2 COPS style dynamic models

The evolution of ORANI brought about the COPS style dynamic model of the Australian economy, MONASH, in early 1990s. MONASH is fully documented by Dixon and Rimmer (2002). It has served as a platform for dynamic models of other countries, including the USAGE model of the U.S. and the CHINAGEM model of China (Mai, Dixon & Rimmer 2010). COPS style dynamic models advanced ORANI with regard to dynamics and closures in addition to the further technical development. Equipped with dynamic features, COPS style CGE models are used to generate forecasts of the prospects of overall economies, different industries, labour occupations and regions on the top of 'what if' policy analysis.

In dynamic CGE analysis, base-case (reference-case) forecasts are important, which is not the case for comparative static CGE analysis. MONASH incorporates four types of inter-temporal linkages: physical capital accumulation and rate-of-return-sensitive investment; foreign debt accumulation and the balance of payments; public debt accumulation and the public sector deficit; and dynamic adjustment of wage rates in response to gaps between the demand for and supply of labour.

Further, it allowed both static and forward-looking (rational) expectations in the mechanism for determining investment. COPS style models are capable of producing estimates of changes in technologies and consumer tastes, decomposing the impacts of those structural changes, forecasting for industries, commodities/trade, regions, occupations and households, and the impacts of proposed policy change and other shocks to the economic environment (Dixon & Rimmer 2002).

Perhaps the world's most detailed CGE model in the sectoral and commodity dimension is the COPS style model, USAGE. It has 500 industries and commodities, 51 top-down regions and 700 employment categories. USAGE has been used extensively in numerous studies analysing the effects of trade barriers and their removal, assessing free trade agreements (FTAs), quantifying the impact of immigration and border control, evaluating the impacts of terrorism, catastrophic events and flu epidemics, and estimating the effects of environmental policy changes in the North American context. Mini-USAGE (Dixon & Rimmer 2005), a smaller version of USAGE designed for teaching, has made a significant difference to novice modellers.

2.2.3 COPS style regional models

There are three types of COPS style regional models: ‘top-down’, ‘bottom-up’ and ‘stand-alone’ models. ‘Top-down’ models have regional disaggregation attachment that is used to decompose the results of national models. Originally, ORANI had a regional ‘top down’ extension called ORANI Equation Systems (ORES). ORES was based on the LMPST method (Leontief et al. 1965) for disaggregating results from a national input-output model named after initials of its authors. The main idea of the method was to divide industries into national and local groups. ORES is widely acknowledged as the first regional CGE model in the world (Madden 1990). Original ORANI analyses identified those regions that were winners and those regions that were losers from a policy change, and estimated the relative sizes of wins or losses in terms of the percentage of gross output (Dixon et al. 1982).

‘Bottom-up’ models involve the explicit modelling of economic activities which are determined by the interactions of economic agents in regions. The theory of ‘bottom-up’ models at the regional level is the same as that at the national level (Wittwer & Horridge 2010). National level results are obtained through the aggregation of regional results. FEDERAL, a COPS style regional model developed by Madden (1990), is an example of early COPS style ‘bottom-up’ model. Further contributions to FEDERAL were made by Giesecke (2000), and Wittwer and Anderson (1999). FEDERAL and its variants were, however, restricted to two regions: Tasmania and the rest of Australia or South Australia and the rest of Australia, due to their ‘residual’ input output table (Elliott & Woodward 2007) generation method. An eight-region in-house regional COPS style model, MMRF (Naqvi & Peter 1996; Peter et al. 1996), was developed in the early 1990s. Adams et al. (2000a) converted MMRF to a recursive dynamic model. This extended version MMRF-Green incorporated extensive Green House Gas (GHG) accounting and climate change policy features. Since the 1990s, COPS style regional models have played a leading role in CGE analysis in Australia. Giesecke and Madden (2013) emphasised that ‘MMRF has become the workhorse model of Australian CGE modelling with hundreds of applications’ (p. 400). Furthermore, MMRF has been used extensively as a chief policy analysis model in important organisations like the PC. In a tradition of ORANI, MMRF serves as a platform for multiregional CGE model of other countries. Notable drawbacks for ‘bottom-up’ models like MMRF are the data requirement and dimensionality problems as these become larger and larger.

‘Stand-alone’ models are those developed for a single region analysis. Giesecke (2011) constructed COPS style ‘stand-alone’ CGE model for a single U.S. region. Using regional IOTs and ORANI-G as a platform, he devised a method for building a single region model and then applied it to the construction of Los Angeles County’s CGE model.

2.2.4 Global Trade Analysis Project (GTAP)

The GTAP model (Hertel 1997) is the most significant application and extension of ORANI technology in an international arena (Dixon & Rimmer 2002). GTAP aspires to support a standardised database and CGE modelling platform for international economic analysis (Hertel 2013).

GTAP was innovated with a multifaceted approach so that it can be characterised by four different dimensions. Firstly, GTAP is an institutional innovation. The GTAP consortium was established in 1993, bringing crucial players such as World Bank together in its early stages. Secondly, it is a network. Since its inception in 1991, GTAP has become the largest cooperative network of organisations and researchers in Economics (Dixon & Jorgenson 2013). Thirdly, it is a database. GTAP provides a fully documented, publicly available global database which contains complete bilateral trade information, transport and protection linkages. GTAP 9 Data Base, the latest release, features 147 countries/regions and 57 sectors/commodities. As of today, the GTAP database is ‘by far the most widely used trade and protection database in the world’ (Anderson, Martin & Van der Mensbrugghe 2012, p. 879). The GTAP database is also used in the applications of different multi-country/global models such as World Bank’s LINKAGE global economic model (Anderson, Giesecke & Valenzuela 2010; Anderson, Martin & Van der Mensbrugghe 2012). Fourthly, GTAP is a global economic model. The standard GTAP model is a comparative, static, and global CGE model based on ORANI (Dixon et al. 1982) and SALTER[3] (Jomini et al. 1994). It is based on microeconomic foundations with a symmetric specification of economic agents (producers and households) in individual economies and of their trade linkages. The

[3] The acronym SALTER stands for Sectoral Analysis of Liberalising Trade in the East Asian Region. SALTER, named in honour of W. Salter, was itself ORANI style world trade model developed in IAC (current PC) for conducting an analysis of the economic effects of alternative trade liberalisation scenarios. GTAP founders T. Hertel and M. Tsigas contributed to the development of SALTER.

global transportation and international mobility of savings are also recognised in the model.

GTAP aims to facilitate multi-country economy-wide analyses on trade, climate change, economic growth and a wide range of other issues affecting the world as a whole. However, its vision is not to build a definitive model, as not only do most of its 27 consortium members have their own in-house models (i.e., the World Bank's LINKAGE, ENVISAGE and MAMS, OECD's METRO and GREEN, and ABARE's GTEM and its predecessor MEGABARE etc.), but its member organisations and individuals continue develop and use various customised models. Hence the standard modelling framework has been developed and designed to run with no additional data or parameters beyond those provided in the GTAP database (Hertel 2013). Since the standard GTAP model is a platform for development, there have been a number of extensions and variations. For instance, the GTAP-E (Burniaux & Truong 2002), one of the extended versions of the standard GTAP model, incorporates GHG emissions and provides for a mechanism to trade these emissions globally.

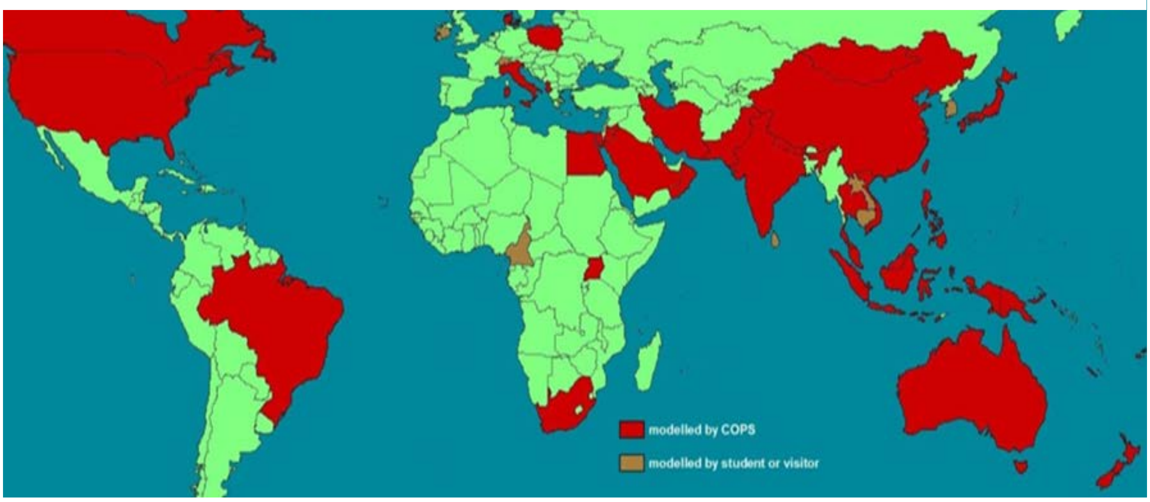
2.2.5 New generation COPS models

Victoria University (VU) -National (Dixon, Giesecke & Rimmer 2015) is a new generation COPS style CGE model. It is a dynamic multi-sectoral CGE model with a financial sector extension that can capture elements of financial repercussions. One of criticisms of CGE models is the absence of the role of money (Bandara 1991b). VU-National addresses this issue and has explicit treatments of financial intermediaries and their interactions/transactions with economic agents, financial instruments describing assets and liabilities, financial flows related to these instruments, rates of return on individual assets and liabilities, and links between the real and monetary sides of the economy. One of the earliest COPS style models of financial markets was created by Adams (1989). It is expected that financial CGE components will become a standard feature of COPS style models in near future.

The Enormous Regional Model (TERM) is another new generation COPS style 'detailed' regional CGE model with 'bottom-up' specification treating each region as a separate economy (Horridge, Madden & Wittwer 2005). In order to overcome the drawbacks faced by 'bottom –up' regional models, Horridge et al. (2005) adopted an approach first used in GTAP modelling to create TERM. TERM approach assumes identical technology in each region and splits national when this is not the case. TERM uses highly disaggregated regional IOT data obtained through the 'Horridge method', which generates sourcing shares. The key achievement of TERM is its ability to handle a greater number of regions or sectors. The latest version of TERM identifies 190 sectors in 205 statistical sub-divisions of Australia. In addition, it is solved relatively quickly due to its innovative approach enabled by identical proportions or common sourcing assumptions in inter-regional imports. With this assumption, inter-regional sourcing and associated margins data can be stored separately in two smaller satellite matrices in TERM. Its predecessors such as MMRF have a single huge matrix which restricts computational speed (Wittwer & Horridge 2010).

Let us have a look at following simplified example. If we consider USE and TRADE matrices in TERM, the USE matrix shows each commodity, user (intermediate and four final), source (domestic and imported) and regional origin but not the regional destination while the TRADE matrix shows each commodity, source (domestic and imported), regional origin and regional destination, but not the user. Reducing the actual sizes for simplicity, let us assume that the number of commodities/industries is 40 and the number of regional origins/destinations is 20. In this case, the dimensions of USE and TRADE matrices in TERM are $40 \times 2 \times (40 + 4) \times 20 = 70{,}400$ and $40 \times 2 \times 20 \times 20 = 32{,}000$ respectively. In a single matrix case (as in MMRF), the dimension for each matrix is $40 \times 20 \times 20 \times (40+4) \times 20 = 14{,}080{,}000$. This is 20 and 44 times larger than the dimensions of USE and TRADE matrices in TERM respectively. The sizable reduction of dimensions of matrices in TERM is due to a common sourcing assumption and dimensional restrictions of prices adopted from the GTAP model.

Figure 2.1 COPS style models in the world (not including GTAP)



Source: www.copsmodels.com

TERM has been used in various analyses, including natural disasters (Horridge, Madden & Wittwer 2005), agricultural management (Wittwer 2012), mining booms (Horridge & Wittwer 2006) and infrastructure development (Horridge & Wittwer 2008). The model provides opportunities to analyse the effects of small-region specific policy changes such as tourism impacts. TERM has also been served as a platform for the development of multi-regional models for several countries including China (Horridge & Wittwer 2008) and Indonesia (Horridge & Wittwer 2006). Figure 2.1 shows the countries for which COPS style models (not including GTAP) have been developed and used in policy analysis.

2.3 A General form of COPS style CGE model

Let us define a general COPS style model by:

$$F(X) = 0 \tag{2.2}$$

where F is an m-vector of differentiable functions of n variables X.

For CGE models, $n>m$ is generally the case. Each equation explains a variable but since $n>m$, values for some variables must be set by the modeller (or model user). The variables determined by the equations of the model are called endogenous variables and the variables determined by the model user are called exogenous variables. The 'closure' of a model is a selection of variables into endogenous and exogenous categories. One of the advantages of COPS style modelling is the freedom to employ a variety of different closures. Dixon (2006) highlighted the importance of flexible closure and wrote that 'an early insight at the IMPACT project was that the division of variables into the endogenous and exogenous categories should be flexible so that it can be varied from application to application' in retrospect (p. 9). Simple closure changes enable a CGE model to run with different underlying theories. Hence, we can imply that the closures reflect the economic theories under consideration. Closures allow us to do simulations in different environments: in the short or long run; with flexible or sticky wages; with neoclassical or new Keynesian pricing; with fixed or variable tax rates; and with a balanced or cyclical budget (Dixon & Rimmer 2002). Thus the closures must reflect the details of the economic question under investigation. In dynamic successors of ORANI, there are four basic closures: the historical closure, the decomposition closure, the forecast closure and the policy closure.

In addition to the closure, another important tool to solve a CGE model is a *numeraire*. Broadly speaking, a *numaraire* is the essential standard of measurement that enables the comparison of values relative to a common unit or denominator. Traditional COPS style CGE models follow a neoclassical property in which economic agents respond to changes in relative prices. There should be at least one exogenous variable measured in domestic currency. The relative prices of all commodities and inputs are specified and measured by a *numeraire*. Hence, all prices change relative to the *numeraire*. The choice of a *numeraire* is up to modellers and model users depending on the economic environment. During the years of fixed exchange regime, a nominal exchange rate was commonly used as a *numeraire*. With new and neo Keynesian wage rigidity, a nominal wage has often been used as a *numeraire*.

2.4 Solution methods

Many of the equations in COPS style models are essentially non-linear. Following Johansen, the models are solved by representing them as a series of linear equations relating percentage changes in model variables. There are two main approaches for solving CGE models: non-linear programming and derivative methods. Today, almost all CGE models are solved by the derivative method (Adams et al. 1994). The main advantage of the derivative method is that it provides the matrix of an initial solution and generates deviations in endogenous variables from their initial values created by deviations in exogenous variables from their initial values. The derivative method works by replacing the non-linear levels representation of the model with a linear first-order differential representation. The replacement can be either explicit or implicit. The explicit approach involves equations presented to the computer in linear first order differential form and the implicit approach involves equations presented in nonlinear form and converted to differential form in the computer via numerical means.

The derivative method used in COPS style models is the Johansen/Euler method developed by Dixon et al. (1982) and implemented through GEMPACK with explicit representation of the linear first-order differential form named in recognition of the Johansen and Euler. By contrast, the World Bank tradition models are solved in implicit representation implemented through the GAMS. As emphasised in Dixon and Rimmer

(2002), there are two advantages of explicit representation over the implicit representation: transparency of underlying economics of a model and the detectability of computational problems. In addition, the percentage change of a variable is a relative change whereas a change in the variable itself represents an absolute change. Thus, the percentage change is generally more interesting and more useful for comparative purposes.

This section explains solution methods and their applications to COPS style models.

2.4.1 Johansen solution procedure

As in equation (2.2), a COPS style model can be defined as an equilibrium vector, X, of length n variables satisfying a system of equations. F is a vector of functions of length m, where n > m. The Johansen approach is to derive from (2.2) a system of linear equations in which the variables are changes, percentage changes or changes in the logarithms of the components of X. Since the system (2.2) contains more variables than equations, we need to assign exogenously given values to *n-m* variables and solve for the remaining *m* endogenous variables.

The Johansen solution procedure can be defined using the following steps.

- First, the system of equations for the model is represented in its original levels form as $F(X) = 0$;

  where F is an m-vector of differentiable functions of n *level* variables X.
- Second, the total differential is taken of each equation in the model;
- Third, the expressions for the total differential of each equation are expressed in percentage change form.

  In our case, we obtain:

  $A(X)x = 0$

  where $A(X)$ is and $n \times m$ matrix whose components are functions of X. x is the vector of percentage changes in X.
- Fourth, the percentage change equations are evaluated at an initial solution to the levels form.

  $A(X)$ is evaluated at $X = X^I$.
- Fifth, a closure of the model is defined. Then, the model is solved for the percentage change movements in the endogenous variables away from their initial values given changes in the exogenous variables.

$A_\alpha(X^I)x_\alpha + A_\beta(X^I)x_\beta = 0;$

where x_α is the m×1 sub-vector of endogenous components of x;

Then the model is solved, assuming that the relevant inverse matrix exists:

$x_\alpha = -{A_\alpha}^{-1}(X^I)A_\beta(X^I)x_\beta$

More compactly we can write it as:

$x_\alpha = B(X^I)x_\beta;$

where $B(X^I) = -{A_\alpha}^{-1}(X^I)A_\beta(X^I)$.

$A(X^I)$ matrix defined in Johansen solution procedure is called the Tableau matrix. The Tableau matrix shows the sensitivity (elasticity in our example since we defined x as a percentage change) of every endogenous variable with respect to every exogenous variable. In his seminal work, Johansen used the Tableau matrix to decompose movements in industry outputs, prices and primary factor inputs into parts attributable to observed changes in six sets of exogenous variables: aggregate employment; aggregate capital; population; Hicks-neutral primary factor technical change in each industry; exogenous demand for each commodity; and the price of non-competing imports. Hence, the Tableau matrix enables us to understand the CGE model and its results, to assess it against reality or to do the checking of computed results (Dixon & Rimmer 2010a).

Due to linearization, the deviation from true value or linearization error may occur. The larger the shock, the greater the proportional linearization error is in general. Johansen recognized the linearization error in his computations and acknowledged that the solutions from his model were approximate.

2.4.2 Johansen/Euler solution procedure

Dixon et al. (1982) set out an extension to the Johansen method which eliminates linearization errors while retaining the simplifying advantages of linearized algebra. They employed Euler's method and added multiple steps. The Johansen method described above can be interpreted as a one-step Euler solution.

Johansen/Euler solution procedure breaks up the shock into a number of equal parts or steps. The linearized model is solved in each step for smaller shocks. After each step, the value of every endogenous variable affected by the shock is updated. In general, the more steps the shock is broken into, the more accurate the results are. However, for the level of convergence toward the true solution that the Euler method provides, it is computationally expensive.

2.4.3 Gragg's method

Gragg's method is very similar to Johansen/Euler method with some slight difference. When the shocks are broken into *N* parts, Euler's method does *N* separate calculations while Gragg's method does *N + 1*. It is more accurate than Euler's method for calculating the direction in which to move at each step. The default method in GEMPACK used for solving the GTAP model, for instance, is Gragg's method with Richardson's extrapolation.

2.4.4 Richardson's extrapolation

Richardson's extrapolation infers the results for an Euler or Gragg simulation of an infinite number of steps by using information on the rate at which the gap between simulations of different step sizes changes as the number of steps increases.

If we denote the results for endogenous variables from Euler/Gragg simulation of **N** steps as R(N), the following approximation often holds for COPS style model simulations:

$$(1) \quad R(2) - R(1) \approx 2(R(4) - R(2))$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$(\infty) \quad R(\infty) \approx 2.R(2) - R(1))$$

When Euler method is supplemented with Richardson's extrapolation, the number of steps (N) can be very small. As we can see from (∞), the number of steps can be 2 in normal applications of the model. Pearson (1991) showed multi-step Euler method complemented with Richardson's extrapolation can solve COPS style CGE models with any desired degree of precision.

2.5 Standard notations and conventions

This section introduces the notations and conventions used in COPS style modelling. One of the distinctive technical characteristics of COPS style models is the naming system invented with ORANI for ease of reference. There are four types of notations in COPS style models. The first type is a 'letter' notation. Lowercase symbols are used to represent percentage changes in the variables denoted by the corresponding uppercase symbols. For instance, a, p, w and x represent the percentage changes in A, P, V and X where they are technology parameter, price, value, and quantity respectively. The second one is a 'number' notation. One of the digits 0 to 6 indicates and identifies the user. The third type is 'a combination of letters' for further information. For example, TOT denotes total over all inputs for some user, MAR represents margins and LAB indicates labour.

To illustrate the second and third types of standard notation, let us have a look at the identity below where total supply of output in an economy is equal to the total use:

$$Z+IMP=A(Z+IMP)+I+C+EXP+G+\Delta INV \tag{2.3}$$

where Z is a domestic output; IMP is imports; $A(Z+IMP)$ is an intermediate use by producers/industries where A is a technology; I is an investment (use by investors); C is an consumption by households; EXP is exports; G is government use; and ΔINV is a change in inventories.

From (2.3), we can see that imports and domestic supply can be either used as intermediate inputs -$A(Z+IMP)$ by various industries, or consumed by investors (I), households (C), foreigners (EXP), governments (G) or set aside for future use INV. Household consumption (and government use if the government is wiser) determines society's economic welfare while intermediate inputs and investment contribute to a further increase of an output.

We denote and identify industries by 1, investors by 2, households by 3, exports by 4, governments by 5 and inventory by 6.

Then for demonstration purposes, we can define (2.3) in terms of values using second and third types of notation as:

$$V0TOT+V0CIF=V1TOT+V2TOT+V3TOT+V4TOT+V5TOT+V6TOT \tag{2.4}$$

where V0TOT is the value of domestic output; V0CIF is a value of imports used by ALL users; V1TOT is a value of intermediate use by producers/industries; V2TOT is a value of investment use by investors; V3TOT is the value of consumption by households; V4TOT is a value of exports; V5TOT is a value of government use; and V6TOT is the value of a change in inventories.

The following subscript set and index definitions are used in COPS models with slight difference on some occasions: *i* for industries; *c* for commodities; *m* for margin commodities; *s* for commodity sources; and *o* for occupation types. The complete list of notations used in COPS style models is shown in Table 2.1 below.

Table 2.1 The standard naming system in COPS style models

1. 'Letter' notation indicating the type of variable		
Notation in		Associated variable or coefficient
Levels	Percentage change	
A	a	Technology
P	p	Price, local currency
PF	pf	Price, foreign currency
X	x	Input quantity
V	w	Value, local currency
T	t	Tax
F	f	Shifter
2. 'Number' notation indicating user		
Notation		User
1		Current production (industries)
2		Investment (investors)
3		Consumption (households)
4		Export (foreigners)
5		Government(s)
6		Inventories
0		All users, or user distinction irrelevant
3. 'Combination of letters' notation for further information		
Notation		Information
BAS or bas		Basic
CAP or cap		Capital
CIF or cif		Imports at border prices
DOM or dom		Domestic

FAC or fac	All factors
IMP or imp	Imports (duty paid) or imported
LAB or lab	Labour
LND or lnd	Land
LUX or lux	Linear expenditure system (supernumerary part)
MAR or mar	Margin
OCT or oct	Other cost tickets
PRIM or prim	All primary factors
PUR or pur	At purchaser's prices
SUB or sub	Linear expenditure system (subsistence part)
TAR or tar	Tariffs
TAX or taxes	Taxes
TOT or tot	Total or average over all inputs for some user
4. Sets, indices and other notations	
Notation	Information
COM or C	Set of commodities
IND or I	Set of industries
OCC or O	Set of occupations
SRC or S	Set of sources (domestic and imported)
c	Index for commodities
i	Index for industries
o	Index for occupational types
s	Index for sources
_c	Summed over COM
_i	Summed over IND
_s	Summed over SRC
_o	Summed over OCC
_oi (_io)	Summed over OCC and IND or IND and OCC

Source: Modified from Horridge (2014, pp. 11-2)

2.6 Data requirement

Input-output tables are the main data input to COPS style CGE models. In the models, input-output tables provide an initial solution. A COPS model's computations start from an initial solution defined by input-output tables of certain year and generate deviations away from that solution due to the shocks under consideration. In addition, input-output tables provide the data for evaluation of numerous coefficients in the models (Dixon & Rimmer 2002). In addition to IOTs, a wide range of data from national accounts, government budgets, balance of payment, national surveys and censuses, and other statistical data are used. More data are often required for dynamic CGE models in their forecasting analysis and for micro-simulation CGE models in their distributional impact analysis. New generation COPS style financial CGE models require additional information about loanable fund markets and financial intermediaries. As computing power and software capability increase, CGE models contain greater details and thus require more and more information.

2.7 GEMPACK

GEMPACK (Harrison & Pearson 1996), developed in the COPS as an in-house software, is a suite of economic modelling software particularly designed for solving very large systems of non-linear equations and interrogating data and results in CGE models. GEMPACK automates the process of translating the model specification into a solution program (Horridge 2014). The implementation of CGE models can be written in levels and equations, percentage change equations or a mixture of them via algebra-like language used to describe and document the implementation. Then the GEMPACK program TABLO translates these texts into model-specific programs which solve the models. GEMPACK is equipped to handle a wide range of economic behaviour and contains an advanced method solving inter-temporal models with adaptive and rational expectations. It is used in over 500 organisations in 100 countries, including two organisations from Mongolia: the National University of Mongolia and the Central Bank of Mongolia.

A key motivation in designing and adopting GEMPACK was to allow economists to construct and run models without the hassle of complicated algorithms. The advances in GEMPACK, including user friendly Windows programs, have substantially increased modellers' and users' productivity. Some of GEMPACK's integrated development environments can identify and zip up all the original or source files needed to produce a simulation (Horridge et al. 2012). These developments have facilitated and expedited the transfer of CGE technology across the world. GEMPACK's speed to solve large CGE models is substantially faster than its counterparts. GEMPACK can solve the equations using one of four related solution methods: Johansen, Euler, Gragg's or the midpoint methods discussed in section 2.4.

2.8 Back-of-The-Envelope (BOTE) Analysis

A back-of-the-envelope (BOTE) model is a small model which can be managed with pencil and paper, designed to explain a particular application of a full-scale model. BOTE modelling is as old as CGE modelling. In his seminal work, Johansen (1960) used a one-sector BOTE model to guide his discussion of the huge number of results generated by his CGE model of Norway's economy. There has been a robust, well-established tradition among COPS style CGE modellers to use BOTE models and calculations for assessing model results. The usage of BOTE models and calculations is one of the distinctive characteristics of COPS style modelling.

In the original ORANI publication (Dixon et al. 1977, pp. 194-9), BOTE models were described as having the following roles:

> First, there is a purely practical point. With a model as large as ORANI, the onus is on the model builders to provide convincing evidence that the computations have been performed correctly, i.e., that the results do in fact follow from the theoretical structure and database. Second [BOTE calculations are] the only way: to "understand" the model; to isolate those assumptions which 'cause' particular results; and to access the plausibility of particular results by seeing which real-world phenomena have been considered and which have been ignored. Third, … by modifying and extending [BOTE] calculations … the reader will be able to obtain reasonably accurate idea of how some of the projections would respond to various changes in the underlying assumptions and data.

Via well-designed BOTE calculations, the model builder can isolate the economic mechanisms and data items that are important for a given set of results (Dixon & Rimmer 2002). In general, BOTE models and BOTE calculations are for explaining particular results from the full scale model and validating the plausibility of model results. Dixon and Rimmer (2002, pp. 108-9) identify the following five reasons for their emphasis on BOTE models and calculations. First, BOTE models and calculations serve as a necessary check for data handling and other coding errors. Second, they are capable of revealing result-affecting theoretical limitations. Third, BOTE models and calculations allow modellers and users to identify the principal mechanism and data items underlying particular results. Fourth, they are an effective form of sensitivity analysis. Fifth, BOTE models and calculations generate new theoretical insights and propositions. The nature of the BOTE models can be varied from application to application. For an ORANI simulation of an increase in oil prices, the corresponding BOTE model included the price of oil and the share of oil in the economy's production costs (Dixon et al., 1984). For an ORANI simulation of the effects of a tariff increase, the corresponding BOTE model included a tariff rate (Dixon et al., 1977, pp. 214-222). A large number of different types of BOTE equations and equation systems in levels and percentage change have been developed and used in COPS style models.

2.9 Linearization of the functions in COPS style models

This section discusses the conversion of the nonlinear representation of different functions used in COPS style models to an explicit linear first-order differential representation. We start with a brief for the differentiation rules pertaining to deriving percentage-change equations, and then provide the derivations of percentage-change equations for some functional forms commonly used in COPS style models.

2.9.1 Rules for deriving percentage-change equations

In deriving percentage-change equations, we apply following rules. Let us take a level of a variable, U.
Multiplication rule: If U is a product function of levels of variables R and W ($U = RW$), the percentage-change form is $u = r + w$ where u, r and w are the percentage changes in the variables represented by the corresponding uppercase symbols.

Table 2.2 The rules for deriving percentage change equations

	Representation in	
	Levels	**Percentage changes**
Multiplication rule	$U = RW$	$u = r + w$
Power rule	$U = R^{\alpha}$	$u = \alpha r$
Quotient rule	$U = R/W$	$u = r - w$
Addition/Subtraction rules	$U = R \pm W$	$Uu = Rr \pm Ww$ $u = S_R r \pm S_W w$

Source: Modified from Dixon, Koopman and Rimmer (2013)

Power rule: If U is a power function of a level of variable R ($U = R^{\alpha}$), the percentage-change form is $u = \alpha r$ where r is the percentage change in R and α is a parameter.

Quotient rule: If U is a quotient function of levels of variables R and W ($U = R/W$), the percentage-change form is $u = r - w$ where u, r and w are the percentage changes in the variables represented by the corresponding uppercase symbols.

Addition/Subtraction rules: If U is a summation/subtraction of levels of variables R and W ($U = R \pm W$), the percentage change forms are $Uu = Rr \pm Ww$ or $u = S_R r \pm S_W w$ where u, r and w are the percentage changes in the variables represented by the corresponding uppercase symbols and S_R and S_W are shares evaluated at the current solution. In the first step of a Johansen/Euler method, the current solution is the initial solution. Table 2.2 summarises the rules for deriving percentage change equations.

2.9.2 Commonly used functions in levels and percentage change forms

Economic theory of economic agents' behaviours, traced back in the work of Marshall (1890), is based on the maximisation of profit, subject to a production function, and the maximisation of utility, subject to a budget constraint. The objective of the theory, generally speaking, is to characterise the supply and demand functions, using only the restrictions on producer and consumer behaviours that arise from optimisation. The principal analytical tool employed for this purpose is the implicit function theorem.

The traditional or neoclassical approach to modelling economic agents' behaviour begins with the assumption that the underlying function is additive and homogenous. The additive (or aggregation) condition implies that costs on individual inputs must 'add up' to total costs for producers and expenditures in individual goods/services must 'add up' to total expenditure for consumers. The homogeneity condition implies that there is no money illusion; that is, decisions on purchases of inputs, goods and services are made on the basis of relative price and income. The key idea is that when the underlying function is linearly homogeneous, production or utility can be represented like any other good in the economy. Under these assumptions, demand and supply functions/equations can be derived explicitly from the necessary conditions for equilibria in interconnected markets.

(a) Cobb-Douglas function

The traditional approach for production was originated by Cobb and Douglas (1928). The Cobb-Douglas function is one of the most discussed functions in Economics. It owes part of its name to Paul Douglas who used US manufacturing data for the period 1899-1922 to infer the properties of the series. His colleague Charles Cobb, a mathematician, suggested the functional form. Although the function was initially based on manufacturing data with two inputs (capital stock and labour), it can be extended to include multiple inputs. It is also used to model consumption.

Let Z be the producer's activity level, and K and L the primary inputs of capital and labour used by the producer. Then, the Cobb-Douglas production function is:

$$Z = AK^{\propto}L^{\beta} \tag{2.5}$$

where the parameter A ($A > 0$) is a Hicks neutral technology parameter/shifter; and the parameters α and β are the function exponents.

The function exponents determine the degree of homogeneity. If each primary factor is increased by a factor λ total output will increase by $\lambda^{\alpha+\beta}$. In the original Cobb-Douglas function, $\alpha + \beta = 1$, hence, the function is of homogenous degree of 1 (constant returns to scale).

The characteristics of the Cobb-Douglas production function are:

- Factor income shares are constant (the key property of the Cobb-Douglas production function is the behaviour of factor income shares);
- Unitary elasticity of substitution (imperfect substitutability);
- Essentiality condition (a strictly positive amount is needed to produce a positive amount of output);
- Homothetic; that is, demand for input/good increases at same rate when activity level/income increases;

The limitations of Cobb and Douglas approach are shown in Arrow, Chenery, Minhas and Solow (1961) who pointed out that the Cobb-Douglas production function imposes *a priori* restrictions on patterns of substitution among inputs. In particular, elasticities of substitution among all inputs must be equal to unity.

The elasticity of substitution measures the degree of substitutability between any pair of inputs (i.e., capital and labour) in the production process. Formally, it measures the percentage change in factor proportions due to a change in the marginal rate of technical substitution. The elasticity of substitution can be expressed as:

$$\sigma = \frac{relative\ change\ in\ K/L}{relative\ change\ in\ {}^{P_L}/_{P_K}} \text{ and/or } \sigma = \frac{relative\ change\ in\ K/L}{relative\ change\ in\ MRTS_{LK}} \qquad \textbf{(2.6)}$$

where K is capital and L is labour; P_K are P_L are the prices of capital and labour respectively; σ is the elasticity of substitution between capital K and labour L; and the MRTS is a marginal rate of technical substitution.

The MRTS shows the rate at which one input may be substituted by another while maintaining the same level of output (*Z*).

Modern COPS style models, e.g. GTAP, use a Cobb-Douglas function in their theoretical specifications. The demand structure in the GTAP model is complex and there are four stages to the allocation of income over demand for commodities from various regions. In GTAP, representative households in regions allocate total regional income across private consumption, government consumption and saving by maximising a Cobb-Douglas per capita aggregate utility function at the upper or first level of the regional demand system. We look at an example of private expenditure for simplicity. Per capita utility from private consumption is, in turn, aggregated from private consumption of individual composite commodities through a non-homothetic constant difference elasticity (CDE) function (Hanoch 1975) at the second level of the regional demand. Then each individual composite commodity, further down at the third stage, is itself a constant elasticity of substitution (CES) aggregation of domestic and imported commodities. At the bottom level, the imported commodities themselves are a CES aggregation of commodities from many different regional sources.

Let us define the top level utility function in the GTAP model as a logarithmic Cobb Douglas function (Hertel & Tsigas 1997; Walmsley 1999):

$$\mathrm{U} = \beta_1 \ln\left(\frac{\mathrm{PRIVEXP}}{\mathrm{POP} * \mathrm{PPRIV}}\right) + \beta_2 \ln\left(\frac{\mathrm{GOVEXP}}{\mathrm{POP} * \mathrm{PGOV}}\right) + \beta_3 \ln\left(\frac{\mathrm{SAVE}}{\mathrm{POP} * \mathrm{PSAVE}}\right) \qquad \textbf{(2.7)}$$

where PRIVEXP is private household expenditures; GOVEXP is government expenditures; SAVE is savings; POP is population; PPRIV, PGOV and PSAVE are prices of corresponding variables. β_1, β_2 and β_3 are positive parameters where the sum of them is equal to 1.

The regional subscript (r) has been removed for simplicity. The global price of saving (PSAVE) is a *numeraire* price in the GTAP model.

The utility function in (3.3) is maximised subject to:

$$\mathrm{INCOME} = \mathrm{PRIVEXP} + \mathrm{GOVEXP} + \mathrm{SAVE} \tag{2.8}$$

The first order conditions for this optimisation in terms of percentage changes applying the rules in Table 2.2 give:

$$\mathrm{U} = \frac{\mathrm{PRIVEXP}}{\mathrm{INCOME}} \times \mathrm{up} + \frac{\mathrm{GOVEXP}}{\mathrm{INCOME}} \times [\mathrm{ug} - \mathrm{pop}] + \frac{\mathrm{SAVE}}{\mathrm{INCOME}} \times [\mathrm{qsave} - \mathrm{pop}] \tag{2.9}$$

where upper and lower case represent levels and percentage changes respectively for each variable.

The maximisation for utility subject to income gives demand equations for private consumption, government consumption and saving. When underlying function is a Cobb-Douglas, the demand for each should represent a constant share of income. However, it is not the case in the GTAP model. McDougal (2003) developed a new theory of multistage optimisation introducing a mechanism to link the cost of private utility and the level of private expenditure in the presence of non-homothetic sub-aggregates (CDE in this case). Hence, the optimal expenditure shares derived from the regional household's Cobb-Douglas utility function is not constant in the GTAP model. Hertel (2013) explained this representation of private consumption behaviour at the upper level by noting that 'as countries become richer, utility from private consumption becomes more costly and the regional household tends to spend more of its income on public goods and saving' (p. 829).

(b) Leontief function

Leontief function is a production function which implies that the factors of production are fixed or of technologically pre-determined proportions as there is no substitutability between factors due to changes in their relative prices. The characteristics of Leontief function are:

- Zero elasticity of substitution due to fixed proportions in demand for good or use of inputs;
- No price mechanisms;
- Homothetic; that is, demand for input/good increases at same rate when activity level/income increases.

In Leontief's input-output system, the input-output coefficients are largely fixed by technology (Leontief 1951).

The Leontief production function (Leontief, 1937) can be represented as:

$$Z = \min(\frac{X_1}{A_1}, \dots, \frac{X_i}{A_i}) \qquad \textbf{(2.10)}$$

where Z is the industry activity level; X_i $(i = \overline{1 \dots n})$ are the inputs used by industry; and A_i $(i = \overline{1 \dots n})$ are the input-output coefficients showing the minimum effective input of *i* required to support a unit of activity. $X_i/A_i(i = \overline{1 \dots n})$ are the effective units of the inputs. Effective input means the demand of inputs into which the effects of technical change have been taken account. In Leontief production technology, the minimum of the effective units of *n* inputs is chosen in finding the cost minimum. Applying the rules defined earlier in Table 2.2, we can write the percentage-change form of (2.10) as:

$$z = x_i - a_i \text{ or } x_i = z + a_i \qquad \textbf{(2.11)}$$

where lowercase symbols to represent percentage changes in the variables defined previously denoted by the corresponding uppercase symbols.

Equation (2.11) states that demand for effective input *i* will follow industry activity levels proportionally if there is no change in technology (a_i = 0). In this case, the share of each of the *n* inputs in total inputs will remain unchanged. We can see that reduction in the input-output coefficient (a_i) represents an improvement in the technology in the usage of input *i*, thus reducing the demand for input *i* proportionally. We will use the notation $Leontief[...]$ for Leontief specifications in the thesis afterwards. For instance, (2.10) can be shown as $Leontief\left[\frac{X_i}{A_i}\right]$.

(c) The Constant Elasticity of Substitution (CES) function

The CES function, introduced by Kenneth Arrow, Hollis Chenery, Bagisa Minhas, and Robert Solow (1961), achieves flexibility by treating elasticity of substitution as an unknown parameter. The authors prove that a production function with n inputs has constant elasticity of substitution between every pair of inputs if the production function is:

$$Z = \left[\sum_{i=1}^{n} \delta_i \left(\frac{X_i}{A_i}\right)^{-\rho}\right]^{-1/\rho} \quad \textbf{(2.12)}$$

where Z is the industry activity level; $X_i(i = \overline{1 \ldots n})$ are the inputs used by the industry; and A_i $(i = \overline{1 \ldots n})$ are the input-output coefficients showing the minimum effective input of *i* required to support a unit of activity. $X_i/A_i(i = \overline{1 \ldots n})$ are the effective units of inputs. $A_i > 0$, $\delta_i \geq 0$ for all i, $\sum_{i=1}^{n} \lambda_i = 1$ and $\rho \geq -1$ are parameters.

The function is homogeneous and has a constant elasticity of substitution ($\sigma = 1/(1 - \rho)$ between any two variables showing imperfect substitutability. ρ is usually given by econometric estimates of σ. With the Z, X_i, ρ and the price of input X_i are known, the δ_i can be deduced.

The CES function achieves flexibility by treating an elasticity of substitution as an unknown parameter. Furthermore, CES enables us to account for relative price effects. However, the CES function retains additivity and homogeneity, and thus restricts the pattern of substitution. Uzawa (1962) and McFadden (1963) show that the elasticities of all inputs (i.e., occupation-specific labour) must be the same. For instance, the elasticity of substitution between labour inputs from occupations Managers and Professionals is the same as that between labour inputs from occupations Professionals and Technicians and associate professionals under the CES specification. The justification for this assumption is that there is not enough information about occupational substitution to support the use of any other assumption. There are other developments in variable elasticity production functions, yet the CES production specification still remains the most popular one for applied economists. The Cobb-Douglas function is a special case of CES where σ is equal to 1 whereas the Leontief function is equivalent to a CES with σ set to 0.

If income shares are forecasted using a neoclassical production function (i.e., CES), the elasticity of substitution parameter σ is of prime importance. When σ is greater than 1, an increasing share of national income goes to capital as the capital-labour ratio increases. If σ is less than 1, capital's share declines as this ratio increases. When σ is equal to 1, income shares are unaffected by changes in the capital-labour ratio.

The percentage change form of (2.12) applying the rules we defined in Table 3.1 is:

$$\mathrm{z} = \sum_{i}^{n}(x_i - a_i)\,,\ i = 1, ..., n \qquad \textbf{(2.13)}$$

where

$$S_i = \frac{\delta_i X_i^{-\rho}}{\sum_{k=1}^{n} \delta_k X_k^{-\rho}},\ i, k = 1, ..., n\,. \qquad \textbf{(2.14)}$$

Commonly used assumption in CGE models is that producers in the economy are competitive and efficient. Hence, they are price-takers so that they treat all input and output prices as exogenously given and determined by the equilibria in their respective markets. We assume that a producer (industry) faces given input prices, $P_1, ..., P_n$ and they choose each input *i* to minimise total costs $\sum_{i=1}^{n} P_i X_i$ for any given activity level, *Z*. We assume earlier that $\rho > -1$ to avoid corner solutions.

Let us define the *effective* demand and *effective* price of input *i* as $X_i^e = X_i / A_i$ and $P_i^e = P_i / A_i$. The effective input in our context means the demand of inputs into which the effects of technical change have been taken account. Likewise, the effective price of input means the price/cost of inputs into which the effects of technical change have been taken account. The percentage changes in effective input and effective price are $x_i^e = x_i - a_i$ and $p_i^e = p_i + a_i$ respectively.

The total cost to minimise can be defined in levels as:

$$\sum_{i=1}^{n} P_i^e X_i^e \qquad \textbf{(2.15)}$$

Solving (2.15) subject to (2.12) and converting to the percentage change form by applying the rules in Table 3.1 yields:

$$x_i^e = z - \sigma(p_i^e - p^e) \qquad \textbf{(2.16)}$$

where lowercase symbols represent percentage changes in the variables denoted by the corresponding uppercase symbols; σ is a positive substitution parameter defined by $1/(1-\rho_i)$; and p^e is the weighted average of the percentage changes in all effective input prices defined by $p^e = \sum_{k=1}^{n} S_k p_k^e$. Here, S_k is the share of input *k* in total costs.

Replacing x_i^e and p_i^e in (2.16) with $x_i - a_i$ and $p_i - a_i$ and substituting p^e gives:

$$x_i - a_i = z - \sigma\left[p_i + a_i - \sum_{k=1}^{n} S_k(p_k + a_k)\right] \qquad \textbf{(2.17)}$$

The summation term on the right-hand side of (2.17) is now the Divisia price index of effective inputs.

The percentage change forms (2.16) and (2.17) are more easily understood and interpreted than the corresponding levels representation. Equations state that the demand for any input *i* is a function of an expansion effect and a substitution effect. If there is no change in relative prices and technology, demand for input *i* will move exactly with the firm's activity level, *z* (i.e. the expansion effect). The underlying reason, we should note, is the constant nature of returns to scale in the production function (2.12). Assuming that technology is fixed ($a_i = 0$), we can see that if the price of input *i* rises relative to the price of composite inputs, demand for input *i* will increase by a smaller percentage than the change in activity level (that is the substitution effect). The magnitude of the substitution effect is determined by the size of σ.

From the left-hand side of (2.17), we can see that reduction in the input-output coefficient (a_i) represents an improvement in the technology in the usage of input *i*, thus reducing the demand for input *i*. Another advantage that (2.17) offers is that significant saving in analytical and computational processes as it only requires cost shares. When using percentage change forms, initial quantities and prices are not required. There are other developments in variable elasticity production functions yet the CES production specification still remains the most popular one for applied economists. We use $CES[\ldots]$ notation for the functions of CES specifications for simplicity. For instance, (2.12) can be shown as- $CES\left[\frac{X_i}{A_i}\right]$. To avoid repetition, we leave out technological change terms in the linearization of the functions that we examine next, since the underlying idea and interpretation with technological change are prevailed and the technological change terms appear in a predictable pattern.

(d) Constant Elasticity of Transformation (CET) function

Powell and Gruen (1968) developed CES analog on the production possibilities frontier and demonstrated how it permits estimation of a linear approximation to supply response along the frontier. The CET transformation function is an empirical device for measuring supply response in the very short run since its scope was restricted to movements along the production possibilities surface. The elasticity of transformation measures the responsiveness of the output mix ratio to changes in the marginal rate of transformation.

The CET can be represented as:

$$Z = A\left[\sum_{c=1}^{m} \gamma_c Y_c^{-\rho}\right]^{-1/\rho} \tag{2.18}$$

where Z is as previously defined, A $(A > 0)$ is a technology parameter, $\gamma_c (0 < \gamma_c < 1)$ is a share parameter, Y_c $(c = \overline{1 \ldots m})$ are the m outputs that the industry produces, and ρ $(\rho \leq -1)$ is a substitution parameter.

The CET transformation function is algebraically identical to CES function, apart from a difference of sign determining its concavity, ρ: with the CES function $\rho \geq -1$, with the CET function $\rho \leq -1$.

We assume separability so that Z is exogenous to the choice of the Y_cs. It means that the composition of the firm's outputs (or activity level) is assumed to be determined independently of the industry's decision regarding a mix of outputs. As before, we assume the environment the producer operates is competitive so that the output prices it faces are determined exogenously in their respective markets. We also assume similarly that the producer is efficient so that it maximises its profit. In addition, we assume $\rho < -1$ to avoid corner solutions.

Total revenue to maximise can then be defined in levels as:

$$\sum_{c=1}^{m} P_c Y_c \qquad \textbf{(2.19)}$$

By following a procedure similar to that used for CES specification, we can find the CET output supply function in percentage change form as:

$$y_c = z - \varphi_c[p_c - p] \qquad \textbf{(2.20)}$$

where lowercase symbols represent percentage changes in the variables denoted by the corresponding uppercase symbols; φ_c is a positive substitution parameter defined by $(\varphi_c = 1/(1-\gamma_c)$; and p is a weighted average of the percentage changes in all input prices defined by $\sum_{k=1}^{m} R_k p_k$.

$$R_c = \frac{P_c Y_c}{\sum_{k=1}^{m} P_k Y_k}, \qquad (c = \overline{1 \dots m}) \qquad \textbf{(2.21)}$$

where R_cs are revenue shares of output *c*, and the summation term on the right hand side of (2.21) is the Divisia index of output prices.

Equation (2.20) states that the supply for any output *c* is a function of an expansion effect and a transformation effect. If there is no change in relative prices, supply demand for output *c* will increase at the same rate as the activity level, *z* (that is the expansion effect). This represents the constant nature of returns to scale in production possibility frontier function. If the price of output *c* rises relative to the price of composite outputs represented by the Divisia index in (2.20), supply of output *c* will increase relative to the activity level, *z* (that is the transformation effect). Similar to the CES case, the magnitude of latter effect is determined by the size of the substitution elasticity, φ. We use $CET[\ldots]$ notation for the functions of CET specifications for simplicity. For instance, (2.18) can be shown as- $CET[Y_c]$.

(e) The Constant Ratio of Elasticities of Substitution, Homothetic (CRESH) function

One of the commonly used functions in COPS style models is a more flexible function of the Constant Ratio of Elasticities of Substitution, Homothetic (CRESH) by Hanoch (1971). The CRESH specification was introduced in CGE modelling through ORANI. The CRESH specification offers a potential advantage over the CES specification if there is an empirical basis for assigning different values to substitution elasticities between different pairs of inputs. The general form of CRESH can be defined as:

$$\sum_{i=1}^{n} \left(\frac{X_i}{Z}\right)^{h_i} \frac{Q_i}{h_i} = \alpha \tag{2.22}$$

where Z and X_i are as previously defined; Q_i $(Q_i > 0, \sum_i^n Q_i = 1)$, $h_i(0 < h_i < 1;\ h_i \neq 0)$ and α are parameters.

If each Q_i/h_i has the same sign, then α must have their common sign. It is quite difficult to obtain an intuitive understanding of the input demand functions using levels representation in (2.22). Q_is and α can be determined on the basis of input-output data given values for the h_is. Yet, this is technically difficult (Dixon & Rimmer 2010a). Minimising (2.15) subject to (2.22) with the same assumptions used for the CES specification and deriving the percentage change form of the solution yields readily interpretable and easily calibrated representation of the input demand functions as:

$$x_i = z - \sigma_i(p_i - px), \quad i = 1, \ldots, n \tag{2.23}$$

where lowercase symbols represent percentage changes in the variables denoted by the corresponding uppercase symbols; σ_i is a positive substitution parameter defined by $1/(1 - h_i)$; and px is the weighted average of the percentage changes in all input prices defined by $p = \sum_{k=1}^{n} S_k^{\#} p_k$.

The weights $S_k^{\#}$ are modified cost shares of the form:

$$S_k^{\#} = \frac{S_k \sigma_k}{\sum_{i=1}^{n} S_i \sigma_i} \quad \textbf{(2.24)}$$

There are two notable differences for the CRESH from the CES. First, the weights used in calculating the average effective price in the CRESH are the modified costs shares rather than ordinary cost shares used for the CES. Second, as we emphasised earlier, CRESH input demand functions allow the substitution elasticity to vary across inputs. However, the usefulness of the CRESH function is restricted. It can only be useful, in the instance of primary factor demand, for land-using industries such as agriculture when there more than three primary factors. For all other industries, where only labour/capital substitution elasticity needs to be specified, the CRESH specification has no practical benefit over the CES function (Dixon & Rimmer 2002, p. 168). CRESH collapses into CES if all substitution parameters are equal, $\sigma_k = \sigma_i$ for all $i \neq k$. The interpretation of (2.23) is straightforward and similar to (2.17). We use $CRESH[\ldots]$ notation for the functions of CES specifications for simplicity. For instance, (2.22) can be shown as- $CRESH[X_i]$.

(f) Constant Ratios of Elasticities of Transformation, Homothetic (CRETH) function

The CRETH function (Vincent, Dixon & Powell 1980), one of ORANI's original contributions, can be represented as:

$$\sum_{c=1}^{m} \left(\frac{Y_c}{Z}\right)^{h_c} \frac{Q_c}{h_c} = \beta \quad \textbf{(2.25)}$$

where Z and Y_c are as previously defined; Q_c ($Q_c > 0, \sum_c^m Q_c = 1$), h_c ($h_c > 1$) and β are parameters.

Suggested by Dixon (1976), the CRETH function is identical to the CRESH production function except for the restrictions on h_is; the CRESH form requires $0 < h_i < 1$ whereas the CRETH form requires $h_c > 1$. As before, with representing the firm's activity level equation implies that the composition of outputs are nonspecific to inputs; therefore, inputs only provide a general capacity to produce.

Applying the method used in calculating (2.19) to (2.21), we can derive the following output supply functions from (2.25) in percentage change form as:

$$y_c = z - \theta_c[p_c - p] \quad \textbf{(2.26)}$$

where lowercase symbols to represent percentage changes in the variables denoted by the corresponding uppercase symbols; θ_c is a positive substitution parameter defined by $(\theta_i = 1/(1 - h_i)$; and p is a weighted average of the percentage changes in all output prices defined by Divisia price index $p = \sum_{k=1}^{m} R_k^{\#} p_k, k = \overline{1 \ldots m}$.

The weights $R_k^{\#}$ are modified revenue shares of the form:

$$R_k^{\#} = \frac{R_k \theta_k}{\sum_{c=1}^{m} S_i \theta_i} \quad \textbf{(2.27)}$$

The R_ks in (2.27) are revenue shares of output, k.

The percentage change form of the CRETH output supply functions (2.26) are similar to the percentage change of the CET output supply functions with two differences. First, the weights used in calculating the average price in the CRETH are the modified revenue shares rather than ordinary revenue shares used for the CET. Second, similar to CRESH, CRETH output supply functions allow the substitution elasticity to vary across outputs. CRETH collapses into CET if all substitution parameters are equal, $\theta_k = \theta_c$ for all $c \neq k$ since it is a generalisation of CET. The interpretation of (2.26) is straightforward and same as (2.20). We use $CRETH[\ldots]$ notation for the functions of CRETH specifications for simplicity. For instance, (2.25) can be shown as- $CRETH[Y_c]$.

(g) Linear expenditure system (LES)

Linear expenditure system (Stone 1954) or LES, the earliest and most extensively used in CGE models, is derived from the utility function suggested by Klein and Rubin (1947) of the form:

$$U = \prod_{c=1}^{m} (X_c - \vartheta_c)^{\beta_c} \qquad \textbf{(2.28)}$$

where U is utility, ϑ_c and β_c are behavioural coefficients and the β_c must sum to unity and subscript *c* refers to commodities.

We assume that a consumer (household) chooses each commodity *c* to maximise utility U described by (2.28) subject to the total budget- $M = \sum_{c=1}^{m} P_c X_c$, given commodity/services prices- $P_1, \dots, P_m$.

The maximisation problem results in expenditure equations of the form:

$$P_c X_c = P_c \vartheta_c + \beta_c (M - \sum_{k}^{m} P_k \vartheta_k) \qquad (2.29)$$

The name of LES derives from its property that expenditure on each commodity is a linear function of prices and total expenditure. We can re-write (2.29) and define the demand equations as:

$$X_c = \vartheta_c + \beta_c \frac{M - \sum_k^m P_k \vartheta_k}{P_c} \qquad (2.30)$$

The form of the demand equations in (2.30) are interpreted as follows.

(i) ϑ_c are quantities for the 'subsistence' requirements of each commodity or service regardless of price.

(ii) $M - \sum_k^m P_c \vartheta_c$, the left-over of budget after subsistent expenditures deducted, is 'luxury' or 'supernumerary' expenditure.

(iii) β_c are the shares of remnant budget to each commodity or service or marginal budget shares.

In COPS style modelling, (2.30) is broken down to three percentage change equations as we shall define in Chapter 3.

Rimmer and Powell (1992) note that a serious drawback of the LES is a constancy of marginal budget shares. To overcome this limitation, they developed an implicitly directly additive demand system (AIDADS) demand system. Their work can be traced back to Powell's System of Additive Preferences (Powell 1966) and Hanoch (1975). In the system of additive preferences, the allocation of budget is modified to reflect the substitution effects arising from the price changes. However, the issue of constant marginal budget shares is inherent in it as with the LES. In AIDADS, however, the marginal budget shares are not constant and ‘subsistent’ quantities are introduced. LES moves towards Cobb-Douglas unless subsistence expenditure grows over time. AIDADS eventually converges to Cobb-Douglas with expenditure growth (Powell et al. 2002).

2.10 Summary

In this chapter, the history of COPS style modelling was briefly described, defining it as a well-recognised school of economic modelling, thought and analysis with distinctive technical characteristics and a transferable know-how. Focusing on the distinctive technical characteristics, the methods, tools, functions, and notations conventions that are standard in COPS style modelling were presented. These standard conventions are used in the thesis, which is concerned with building, testing and implementing COPS style models for the Mongolian economy.

Part II. Methodology

Overview

Part II presents the theoretical frameworks and database construction of two CGE models developed for analysing the impacts of a recent mining boom in Mongolian economic context. ORANIMON is the first COPS style comparative static CGE model of the Mongolian economy. Not only is it first CGE model but it also is a powerful tool to study and address our research questions, we employ ORANIMON in the thesis. In addition, its theoretical framework serves as a base to its dynamic successor, MONAGE. Second model, MONAGE, is the first single country COPS style dynamic CGE model of the Mongolian economy. Both ORANIMON and MONAGE have been calibrated using 2005 and 2012 input-output databases.

Chapter 3 presents the theoretical framework of ORANIMON focusing on examining underlying mechanisms inherited from ORANI. We describe the ORANIMON equation system on the basis of optimizing behaviors of economic agents.

Chapter 4 describes the theoretical additions of MONAGE focusing on dynamics, closures and additional technical innovations related to technology and tastes, welfare measures and the facilitation for different types of simulations.

Chapter 5 provides descriptions of data, methods for building database, estimations of parameters and the results from related validity analysis.

The TABLO codes of the models and the databases are downloadable at http://www.copsmodels.com/archivep.htm, (TPEL0156).

Chapter 3. ORANIMON: A Comparative Static CGE Model of the Mongolian Economy

3.1 Preamble

ORANIMON is the first single country COPS style comparative static CGE model of the Mongolian economy. ORANIMON is based on ORANI-G model of the Australian economy (Horridge 2000). ORANI-G, designed for expository purposes and for adaptation to other countries, is a generic version of ORANI model (Dixon et al. 1977; Dixon et al. 1982).

ORANIMON embodies characteristics of the Mongolian economy via calibrations to 2005 and 2012 Mongolian input-output data. ORANIMON identifies 55 industries and 55 commodities in its 2005 database and 55 industries and 68 commodities in its 2012 database. Three primary factors are identified (labour, capital and land). The labour is further distinguished by 9 occupational types as in International Standard Classification of Occupations 2008 (ISCO-08), one digit major groups (ILO 2007). The model has a representative aggregate household.

Optimizing behavior governs decision-making by industries and households. Each industry minimizes its costs subject to given input prices and a constant-returns-to-scale (CRS) output function. Household demands are modelled via a representative utility-maximizing household within a linear expenditure system (LES). Units of new industry-specific capital are cost minimizing combinations of Mongolian and imported commodities. Imperfect substitutability between imported and domestic varieties of each commodity is modelled using the Armington constant elasticity of substitution (CES) assumption.

The demand for any given Mongolian export commodity is inversely related to its foreign-currency price. The model recognizes consumption of commodities by government, and a variety of direct and indirect taxation instruments. It is assumed that all sectors are competitive and all markets clear. Purchasers' prices differ from producer prices by the unit value of indirect taxes and trade and transport margins. Further, ORANIMON has a top-down regional module which allows reporting the results of its applications both at the national level and at the provincial level. The aim of this chapter is to present the theoretical underpinnings of ORANIMON in detail.

3.2 The ORANIMON Equation System

The ORANIMON equation system closely follows the specification of ORANI model described by Dixon et al. (1982) and Horridge (2000). Dixon *et al.* describes the theory and background of the original model in detail while the layout of Horridge encompasses the modern version of the ORANI-G model, which contains modifications and technical innovations to the original model.

Let us look at the schematic view of ORANIMON in the base year 2005. In comparative static models, there is no time dimension. Hence, we compare one state of the economy (say, the state of Mongolian economy in 2005) with another state after perturbing the model.

ORANIMON can be written in a form of system of equations as

$$\begin{aligned} F_1(K, L, X) &= 0, \\ &\vdots \\ F_m(K, L, X) &= 0, \end{aligned} \tag{3.1}$$

where K is a vector of industry capital stocks in a base year (i.e., 2005 or 2012) and it is assumed to be determined by investment undertaken prior to the base year. L is a vector of labour employment in the base year. X is the vector of all other variables in ORANIMON. These variables include land use, rates of output, prices and policy instruments such as government spending and tax. The equations F_1 ... F_m are m differentiable functions which impose equilibrium relationships, i.e., demands equal supplies and costs equal revenues, on the ORANIMON variables. The short run effects are measured by the change in equilibrium values of variables in (3.1) when industry-specific capital stocks are fixed whereas capital stocks are affected by policy changes for the long run effects.

As we discussed in Chapter 2, CGE models like ORANIMON contains more variables than equations. If we denote n as the total number of variables (K, L, X) in ORANIMON, n is greater than m. Consequently, we need to determine n - m variables exogenously to solve the model. The closure, as we defined earlier in Chapter 2, is the partitioning of the variables into exogenous and endogenous sets and the selection of closure depends on the nature and purpose of the study. For instance, if we are interested in the effects of 50% increase in a world price of a certain mineral commodity, say copper price, we may not expect any change to government spending, therefore, keep it exogenous. Alternatively, if we wish to analyse the effects of copper price increase when government spends its windfall revenue gained on ‘spend as it earns’ basis, we would need to treat the government expenditure endogenous, perhaps linking it with private consumption.

After defining the closure and setting various parameters, we can solve (3.1) by the solution methods we discussed in Chapter 2.

In the short run, solutions of ORANIMON can be represented as

$$\begin{pmatrix} L \\ X_{endo} \end{pmatrix} = G(K, X_{exog}) \tag{3.2}$$

where (L, X_{endo}) and (K, X_{exog}) are respectively the endogenous and exogenous subsets of (K, L, X) and G is a vector function of length m. When K is treated as exogenous, industry rates of return (ROR) of are normally included in endogenous variables list $(ROR \in X_{endo})$. This means the short run effects of economic changes are assumed to be realized through the changes in industries’ rates of return rather than in the sizes of their capital stocks.

From (3.2) we can compute the short run effects of changes in any of the exogenous variables (i.e., export price of copper) on any of the endogenous variables (i.e., GNE) by

$$\begin{pmatrix} \Delta L \\ \Delta X_{endo} \end{pmatrix} = (\nabla G) \begin{pmatrix} 0 \\ \Delta X_{exog} \end{pmatrix} \tag{3.3}$$

where ∇G is $m \times n$ matrix of first-order partial derivatives of G. It is important to understand the interpretation of ΔX_{endo}. ΔX_{endo} is a vector of changes in short-run equilibrium prices and in short-run equilibrium rates of production, etc. which can be attributed to the exogenous shock ΔX_{exog}. Due to its implication of restoring the equilibrium conditions in (3.1), ΔX_{endo} is a vector of changes in equilibrium values. It should not be interpreted as a forecast of actual changes in price levels, rates of output, etc. over any actual time period. In fact, it is a projection of the deviations of endogenous variables induced from the effects of a particular set of exogenous changes alone. If we look at our example of an international price of copper, to project the effects of a 50% hike occurred in 2005 we set

$$\Delta X_{exog} = \begin{pmatrix} 0 \\ \vdots \\ 0 \\ +\Delta P4F(Copper) \\ 0 \\ \vdots \\ 0 \end{pmatrix} \quad \textbf{(3.4)}$$

where $+\Delta P4F(Copper)$ is an increase in export price of copper expressed in foreign currency. Now (3.3) generates the short run impacts of a change in copper price increase. Then we can say, for example, that as a result of the increase in international price of copper, the rates of output and the levels of prices will be 15% and 25% different, respectively, from what they would have been in the absence of the increase in international price of copper. It is a short run change so that there is no change in industry capital stocks.

ORANI style models such as ORANIMON are able to generate both short run and long run simulations. 'Given a shock *A*, in an assumed macroeconomic economic environment *B*, a variable *C* will differ by *x* per cent in the short run or by *y* per cent in the long run from the value it would have otherwise been without shock, *A*' (Dixon et al. 1984, p. 421). We need to introduce our assumptions about economic environment, *B* to enable our simulations. This is due to the three important macroeconomic aspects of the effects of shocks to the economy. ORANIMON needs guidance about them. These are:

- The extent to which induced changes in the labour market will be realized as changes in real wages or as changes in employment;
- The extent to which induced changes in national income will be realized as changes in aggregate absorption and/or as changes in balance of trade;
- The extent to which induced changes in the real exchange rate will be realised as changes in the domestic inflation rate relative to foreign rate or changes in the nominal exchange rate.

In economics, a short run is the period long enough for some of the resources (inputs) to be changed but not long enough for some resources (inputs), notably capital stocks, to be changed. Powell (1985, p. 39) advises that 'a natural way of thinking about the short run is as the gestation period of investment'. In our example above, a short run might be long enough for domestic and foreign investors to decide to make a new investment plans in Mongolian mining sector and start some exploration projects but not enough for completing them.

According to Dixon *et al*. (1982), the short run effects are measured by the change in equilibrium values of the variables in a case of exogenous, industry specific capital stocks. It is worth noting that 'exogenous' does not mean 'invariant', but rather determined outside of the model. Powell (1985, p. 39) writes: 'while undoubtedly there will be, in the real world, variations in this lag (short run) across industries, one to two years might accord with common sense for a typical industry'. The short run equilibrium would be reached in about two years according to some econometric evidence (Cooper, Powell & McLaren 1984).

In the short run

- ✓ Real wages are fixed so that induced changes in the flexibility of the labour market will be realized as changes in employment;
- ✓ Changes in national income will be realized by changes in the balance of trade ;
- ✓ Changes in the real exchange rate will be realized through changes in the domestic inflation rate relative to the foreign rate and not through changes in the nominal exchange rate. Thus, the change in nominal exchange rate is fixed exogenously at zero in our simulation; and
- ✓ Economy-wide and industry specific capital stocks are fixed.

Long run deviations could also be computed on the basis of (3.2). There are two major approaches of defining the long run in economic analysis. In case of CGE models, the long run is usually defined as a period of time required for new investment to be converted to capital stock. Hence, comparative static long run deviations are determined by allowing beginning-of-period (i.e., 2005 in our case) capital stocks to respond endogenously to the shocks since there is sufficient time for capital stocks to adjust to restore pre-simulation rates of return. Hence the capital stocks are in endogenous list and consequently industry rates of return are included in exogenous variables list. In our case, we swap the initial capital stock, K_{2005}, and the rates of return, (ROR_{2005}), between the lists of endogenous and exogenous variables. It means capital stocks would have to adjust to restore exogenous rates of return. The adjustment could take 10 or 15 years. This CGE modeling approach is also known as 'snap shot' approach. The comparative static models like ORANIMON capture the general equilibrium effects of a given shock as the difference from the state that would have otherwise been without the policy shock.

The other approach, often used in growth models, defines the long run in terms of convergence on the steady state. In his review of economic growth theories, Mankiw (1995, p. 277) notes ‘in the long run, the economy approaches a steady state that is independent of initial conditions’ as one of predictions from the classic growth models (i.e., Solow-Swan model) worth stating. Another prediction of long run is the constant ratio of investment and capital, which is used in ORANI long run theory. These two approaches are integrated in the extension of the GTAP model (Walmsley 1999).

In the long run

- ✓ Full employment is reached so that induced changes in the flexibility of the labour market will be realized as changes in real wages
- ✓ BOT balance is achieved so that the changes in national income will be realized by changes in GNE components
- ✓ Changes in the real exchange rate will be realized through changes in the domestic inflation rate relative to the foreign rate and not through changes in the nominal exchange rate. Thus, the change in nominal exchange rate is fixed exogenously at zero in our simulation.
- ✓ Pre-simulation rates of return is restored so that economy-wide and industry specific capital stocks are adjusted to clear the capital market

Both in short and long run, however, ORANIMON is atemporal: it does not tell us about adjustment paths between 2005 and 2007 or 2005 and 2012.

Following Dixon *et al*. (1982), ORANIMON consists of a system of equations describing the behaviors of all economic agents in the economy. These agents are industries, investors, households, foreign sector and government. ORANIMON only describes the real economy; that is, only the markets for factors of production and goods and services are considered.

Demand and supply equations for private-sector agents are derived from the solutions to the optimization problems (i.e., cost minimization and utility maximization) which are assumed to constitute the behaviour of the agents in conventional neoclassical microeconomics. Producers operate in competitive markets which prevent the earning of pure profits. Economic agents base their decisions on changes in relative prices and income. The model calculates a number of macroeconomic indicators such as GDP, GNE, CPI and other variables in the System of National Accounts (SNA). ORANIMON is homogenous in all prices. One price, typically the consumer price index, nominal wage or nominal exchange rate, can be chosen as a *numeraire*.

The theoretical framework of ORANIMON consists of following groups of equations:

- Equations describing industry demands for intermediate inputs and primary factors (section 4.3);
- Equations showing demand for investment inputs (section 4.4)
- Equations representing household, exports and other final demands (section 4.5-4.8);
- Pricing equations relating commodity prices to costs to set pure profits from all activities to zero (section 4.9);
- Market clearing equations for all commodities and primary factors and macro identities (section 4.10);
- Additional equations for national welfare measures (4.11).

Most of the equations of ORANIMON are derived from constrained optimization problems. We have introduced the functions used in ORANIMON to clarify the advantages and the limitations they encompass in Chapter 2. Focusing on the economic interpretations, we formulate the optimization problems in the levels of the variables and then provide the solutions in percentage change forms using notations presented in Chapter 2.

3.3 Structure of Production in ORANIMON

CoPS style models address the modelling of the production side of the economy by assuming that the production of commodities in each industry takes place by combining domestically produced and imported commodities, fixed capital, different types of labour, land and 'other costs' as inputs. These inputs are combined by a certain production technology to produce a specified level of output. Then outputs of commodities are distinguished at sales destination; exports and local use. The multi-input, multi-output production specification is kept manageable by a series of separability assumptions which reduce the number of parameters requiring explicit evaluation and lead to simplifications in the representation of systems of demand equations. As it is the case in COPS style CGE models, the production specification is nested in ORANIMON. The separability or nesting assumptions used in the COPS style models' production structure allows various input decision to be independent or separate of each other. The different nests or levels allow for the introduction of the appropriate elasticity of substitution.

Following Dixon et al. (1982), we describe the production technology of each industry in ORANIMON in two parts: (a) the relationship between the industry's input and its activity level and (b) the relationship the industry's activity level and its commodity outputs. Hence, the ORANIMON production technology can be shown by means of Figure 3.1. The production functions can be seen in two halves- the top half describing the technology for producing a range of commodities from a particular activity level (*that is* the relationship between the industry's activity level and its commodity outputs) and the bottom half describing the input technology for producing an activity level (*that is* the relationship between the industry's inputs and its activity level). If we consider the production function of an industry given as in (3.5):

$$F(inputs, outputs) = 0 \qquad \textbf{(3.5)}$$

Then we can write (3.5) by separating inputs and outputs as in (3.6):

$$G(inputs) = Z = H(outputs) \qquad \textbf{(3.6)}$$

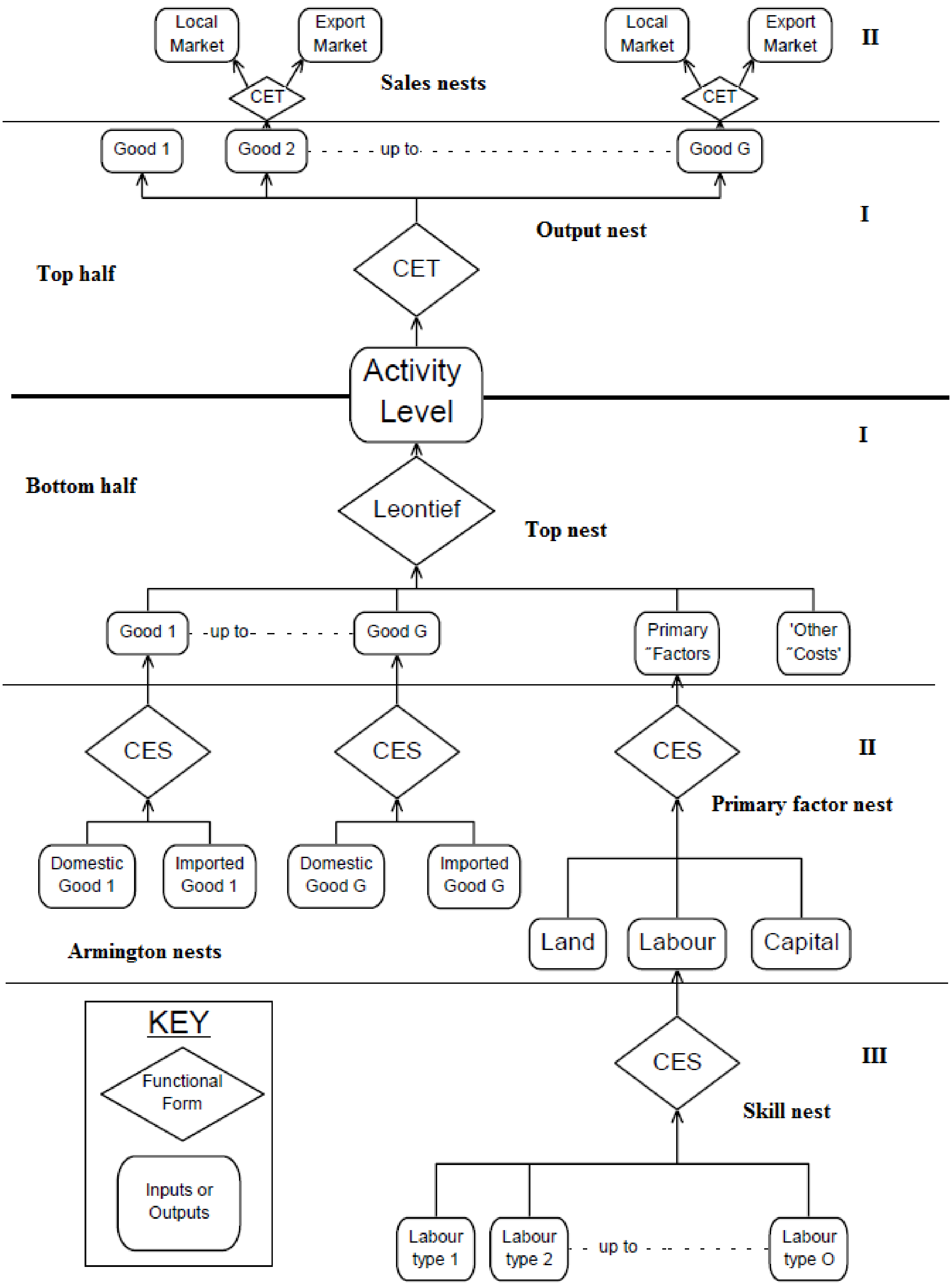
where Z is an index measuring industry activity.

The output-activity specification (*H* function), of a two level form, is shown in the top half of Figure 3.1. There are two types of nests in this specification; an output nest is CET function of activity level and commodity outputs and sales nest is CET function of local market and export market.

The input-activity specification (*G* function), of a three level form, is shown in the bottom half of Figure 3.1.

In the top production nest, the activity level is a Leontief combination of composite commodities (composite commodities 1 to *c*), primary factor composite and 'other costs'. At the first level in the bottom half, there is no substitution between different intermediate inputs (i.e., materials such as chemicals, steel, etc. for mining sector) or between intermediate inputs and primary factor composite in the creation of units of industry activity.

Figure 3.1 Production structure of ORANIMON



Source: Modified from Horridge (2014)

'Other costs', which allow for costs not explicitly modelled in ORANIMON, are also included in this nest. 'Other costs' are a device used by ORANI to admit production taxes, the cost of liquidity, inventory holdings and other miscellaneous production costs into the analysis (Rimmer 1990).

At the second level of the production structure, there are two nests: the Armington nests and primary factor nest. Each Armington nest is a CES function of a domestic good and an imported equivalent. The intermediate composites used by each industry *i* consist of a combination of domestically produced and imported goods. The primary factor nest is a CES function of land, capital and composite labour. At the third level, the composite labour is a CES aggregation of nine different occupations in skill nest.

As it was pointed out earlier, the nested functions are useful in CGE modelling because the nesting can reduce the number of substitution elasticities that must be assigned values substantially.

In addition, the nesting also provides a transparency for the substitutability assumptions to be introduced without arising complication (Dixon & Rimmer 2002). These assumptions include no substitution possibilities between intermediate inputs and primary factors, and substitutability between different types of primary factors and imported and domestic commodities.

Nesting can also be viewed as staged decision making process. For instance, the copper producer first decides how much chemical products to use based on its output. Then it decides on source (import vs. domestic) proportions depending on the relative prices of imported and local chemical products. In ORANIMON, all industries share common production structure but input proportions and behavioral parameters vary across its industries.

We also have assumed that producers are efficient. Hence, they are able select the combination of inputs which minimizes their cost and the combination of outputs which maximizes their revenue. Finally, the constant returns to scale (CRS) have been assumed in production decisions.

3.3.1 Inputs and activity level

In the bottom half of Figure 3.1 we start from the lowest level and work upwards to explain the optimization behaviour of an industry *i*. We start with determining the composite labour input using a CES specification to describe the substitutability between occupations. Then, we feed this composite labour into a CES function of primary factor inputs to define the composite or effective primary factor input. Subsequently, we determine effective inputs of goods in which a CES function is also used to describe the substitutability between imported and local goods. Finally, together with the composite primary factor input and 'other costs', effective inputs of goods are fed into a Leontief fixed coefficient function to produce industry *i*'s activity level.

At the third level, each industry *i* chooses inputs of occupation-specific labour to minimise total labour costs subject to a CES constraint in which the industry's requirements for labour type *o* are proportional to its overall demand for labour. The optimization problem for each industry *i* is to choose:

$$X1LAB(o,i), \quad o = \{\overline{1 \dots 9}\} \; or \; o \in O \tag{3.7}$$

to minimize total labour cost:

$$\sum_{o=1}^{9} P1LAB(o,i)X1LAB(o,i) \tag{3.8}$$

subject to:

$$X1LAB\_O(i) = CES[X1LAB\_O(i)] \tag{3.9}$$

where $X1LAB(o,i)$ is each industry *i*'s demand for labour type *o*, $P1LAB(o,i)$ is the price of labour type *o* that each industry *i* faces, and $X1LAB\_O(i)$ is each industry *i*'s overall labour demand.

For the CES specification, the elasticities of any pairs of occupation-specific labours are the same. For instance, the elasticity of substitution between labour inputs from occupations Managers and Professionals is the same as that between labour inputs from occupations Professionals and Technicians and associate professionals under the CES specification.

Following our discussion in Chapter 2, the solution of (3.9) subject to (3.8), in percentage change form, is:

$$x1lab(o,i) = x1lab\_o(i) - \sigma 1LAB(i)[p1lab(o,i) - p1lab\_o(i)] \tag{3.10}$$

where lower case *x1lab*, *x1lab_o* and *p1lab* are percentage changes in the variables represented by the corresponding uppercase symbols. $\sigma 1LAB(i)$, which equals to $1/(1+\rho LAB(o,i))$, is the elasticity of substitution between different labour types in each industry *i*. $p1lab\_o$, the percentage change in the average wage, is defined the share weighted average of the percentage changes in the prices (wages) of occupation types in each industry *i*:

$$p1lab\_o(i) = \sum_{o=1}^{9} S1LAB(o,i) \times p1lab(o,i) \tag{3.11}$$

where $S1LAB(o,i)$ are the value share of labour type ***o*** in the total wage bill of industry i.

Equation (3.10) states that the change in the demand for labour type *o* is proportional to the change in overall labour demand and it is negatively associated with the relative change in occupation specific wage to the average wage for labour in each industry *i*. The sensitivity of industry *i*'s demand for labour type *o* to the change in relative wages is determined by the elasticity of substitution between different labour types. The higher the elasticity, the more flexible the industry is to substitute away from a particular occupation. The negative relationship shows if the wage of occupation *o* (say, Clerical support workers) increases relative to the average wage, industry *i* substitute away from that occupation (in our example, Clerical support workers) towards other labour types and *vice versa*.

If the individual parts on the both sides of (3.10) is multiplied by corresponding elements of $S1LAB(i,o)$ and summed together, we get:

$$x1lab\_o(i) = \sum_{o=1}^{9} S1LAB(o,i) \times x1lab(o,i) \tag{3.12}$$

At the second level in the bottom half in Figure 3.1, we have depicted two types of nests; primary factor nest and Armington nests. In the primary factor nest, each industry *i* chooses capital, composite labour and land to minimise the total primary factor cost subject to a CES production constraint in which the industry's requirements for each primary factor are proportional to its overall demand for the composite primary factor. The optimization problem for each industry *i* is to choose:

$$X1PRIM(f,i), \qquad f = \{\overline{1 \ldots 3}\} \tag{3.13}$$

to minimize:

$$\sum_{f=1}^{3} P1PRIM(f,i) \times X1PRIM(f,i) \quad f = \{\overline{1 \ldots 3}\} \tag{3.14}$$

subject to:

$$X1PRIM(i) = CES\left[\frac{X1PRIM(f,i)}{A1PRIM(f,i)}\right] \quad \textbf{(3.15)}$$

where $X1PRIM(f,i)$ and $X1PRIM(i)$ are industry i's factor specific (capital, composite labour and land) demand and overall/composite demand for primary factors respectively. $P1PRIM(f,i)$ is the price/cost of primary factor f and $A1PRIM(f,i)$ is the primary factor f saving technical change in each industry i. A variation in $A1PRIM(i)$ can be interpreted as Hicks' neutral technical change since it will not alter the substitution rate between primary factors (i.e., the marginal rate of substitution of the composite labour for capital at a given capital-labour ratio).

The solution of **(**3.14**)** subject to (3.15**)**, in percentage change form, is:

$$\begin{aligned} x1prim(f,i) - a1prim(i) \\ &= x1prim(i) - \sigma 1PRIM(i) \\ &\times [p1prim(f,i) + a1prim(i) - p1prim(i)] \end{aligned} \quad \textbf{(3.16)}$$

where lower case *x1prim(f,i)*, $x1prim(i)$, $p1prim(f,i)$, $a1prim(f,i)$ and $a1prim(i)$ are percentage changes in the variables represented by the corresponding uppercase symbols and $\sigma 1PRIM(i)$ is the elasticity of substitution between the primary factors in industry i. $x1prim(f,i) - a1prim(i)$ is an effective input of primary factor f and $p1prim(f,i) + a1prim(i)$ is an effective price/cost of primary factor f. The 'effective input' of primary factor in our context means the demand of primary factors includes the effects of technical change. Likewise, the effective price/cost of primary factor is the price/cost of primary factors inclusive of technical change. $p1prim(i)$ is the percentage change in the average effective price/cost of primary factor composite. This is also a share weighted Divisia index of primary factor prices and technical changes shown in **(**3.17**)** below.

$$p1prim(i) = \sum_{f=1}^{3} S1PRIM(f,i) \times [p1prim(f,i) + a1prim(i)] \quad \textbf{(3.17)}$$

where $S1PRIM(f,i)$ are the value share of primary factor f in the total primary factor cost.

Equation (3.16) states that the effective demand for each primary factor is proportional to the change in overall or composite primary factor demand and the relative change in the effective price of factor *f* to the average effective price of primary factor composite.

Further, we can write the demand for each primary factor separately to allow factor specific modifications in ORANIMON as in (3.18)-(3.20).

$$x1lab\_o(i) - a1lab\_o(i) = x1prim(i) - \sigma1PRIM(i)[p1lab(i) + a1lab\_o - p1prim(i)] \quad \textbf{(3.18)}$$

where $x1lab\_o(i)$, $p1lab(i)$ and $a1lab\_o$ are the percentage changes in the demand, the price and the labour-augmenting technical change of composite/overall labour in each industry i. $x1lab_{o(i)} - a1lab\_o(i)$ is an effective composite labour input and $p1lab(i) + a1lab\_o$ is an effective composite labour price/cost in each industry *i*.

$$x1cap(i) - a1cap(i) = x1prim(i) - \sigma1PRIM(i)[p1cap(i) + a1cap(i) - p1prim(i)] \quad \textbf{(3.19)}$$

where $x1cap(i)$, $p1cap(i)$ and $a1cap(i)$ are the percentage changes in the demand, the price and the capital-augmenting technical change of capital input in each industry *i*. $x1cap(i) - a1cap(i)$ is an effective capital input and $p1cap(i) + a1cap$ is an effective capital price/cost in each industry ***i***.

$$x1lnd(i) - a1lnd(i) = x1prim(i) - \sigma1PRIM(i)[p1lnd(i) + a1lnd - p1prim(i)] \quad \textbf{(3.20)}$$

where $x1lnd(i)$, $p1lnd(i)$ and $a1lnd(i)$ are the percentage changes in the demand, the price and the land-augmenting technical change of land input in each industry ***i***. $x1lnd(i) - a1lnd(i)$ is an effective capital input and $p1lnd(i) + a1lnd$ is an effective capital price/cost in each industry *i*.

From equations (3.18)-(3.20), we can see that $\sigma1PRIM(i)$ determines the ease with which industry *i* can substitute one factor for another. The lower the values of the substitution elasticity, the less flexible industry *i* is to move away from that factor. The negative relationship between the percentage change in effective factor inputs and the changes in the relative prices of the primary factors to the average price/cost of primary factor composite input shows that the changes in the relative prices of the primary factor inputs induce substitution away from relatively expensive factors.

Following COPS style modelling tradition, we employ Armington assumption of imperfect substitutability using a CES specification for source specific intermediate commodity c used in the production of each industry *i*. Armington elasticity refers to the elasticity of substitution between domestically produced and imported commodities (Armington 1969). The higher Armington elasticity indicates the more substitutable the domestically produced commodity. Commodities produced and imported by the same industry in different countries are not seen by consumers as the same, regardless of similar production technologies. Mongolia's domestically-produced and imported commodities in the same industry are imperfect substitutes. Hence, the changes in relative prices of source-specific commodity c would not create an 'overhaul' effect or complete replacement of one source of supply by the other, In other words, there will not be a flip flop problem (i.e., tendency towards specialisation) as in linear programming model.

At the second level in Armington nest for composite good c, industry i chooses its current inputs of domestic and imported good $\boldsymbol{c}$ to minimize costs subject to a CES constraint in which the industry's requirement for good c is proportional to its activity level, *Z(i)*.

The optimization problem for each industry *i* is to choose:

$$X1(c,s,i), \qquad s = \{dom, imp\} \; or \; s \in S \tag{3.21}$$

to minimize:

$$\sum_{s \in S} P1(c,s,i)X1(c,s,i) \tag{3.22}$$

subject to:

$$Z(i) = CES\left[\frac{X1(c,s,i)}{A1(c,s,i)}\right] \tag{3.23}$$

where $Z(i)$ is each industry i's activity level, $X1(c,s,i)$ is each industry i's source-specific demand of commodity c, $A1(c,s,i)$ is the source specific technical change for commodity c and $P1(c,s,i)$ is the source specific price of commodity c for each industry *i*.

Solving (3.22) subject to (3.23), we get equations for the ratio of domestic to imported inputs of the form:

$$\left[\frac{X1(c,dom,i)}{X1(c,imp,i)} = \frac{\delta1(c,dom,i)}{\delta1(c,imp,i)} * \frac{P1(c,imp,i)}{P1(c,dom,i)}\right]^{1/(1+\rho(c,i))} \tag{3.24}$$

Values can be assigned to the parameters $\delta1(c,s,i)$ where s = *dom* and *imp*, to ensure that (3.24) is satisfied by the base year values for $X1(c,s,i)$ and $P1(c,s,i)$ together with the value for the substitution parameter, $\rho(c,i)$.

The percentage change form of (3.24) can be written as:

$$x1(c,dom,i) - x1(c,imp,i) = \sigma1(c) * [p1(c,imp,i) - p1(c,dom,i)] \tag{3.25}$$

where lower case *x* and *p* are percentage changes in the variables represented by the corresponding uppercase symbols and $\sigma1(c)$, which equals to $1/(1+\rho(c,i))$, is the elasticity of substitution in industry *i* between domestic and imported units of commodity *c*.

If we re-write (3.25) taking account of the technical changes and share-composite demand:

$$\begin{aligned} x1(c,s,i) - a1(c,s,i) \\ = x1\_s(c,i) - \sigma1(c)[p1(c,s,i) + a1(c,s,i) - p1\_s(c,i)] \end{aligned} \tag{3.26}$$

where $x1\_s(c,i)$ and $p1\_s(c,i)$ are the changes in commodity composite (local plus imported) ***c*** and the price of the commodity composite ***c*** respectively in each industry *i*. $x1(c,s,i) - a1(c,s,i)$ and $p1(c,s,i) + a1(c,s,i)$ are the changes in effective demand of source specific commodity input and the effective price of source specific commodity ***c*** in industry *i*.

In ORANIMON, a Leontief technology (i.e., demand proportions fixed and independent of relative prices) is assumed in the top production nest. At the first level of the bottom half in Figure 3.1 Production structure of ORANIMON , each industry *i* chooses a combination of effective inputs of intermediate commodities, effective inputs of primary factors, and effective inputs of 'other costs' in fixed proportions to minimize its costs subject to a Leontief production function.

The optimization problem for each industry *i* at this level is to choose:

$$X1PRIM(i), \qquad X1\_S(i), \qquad X1OCT(i) \tag{3.27}$$

To minimize the total costs:

$$P1PRIM(i)X1PRIM(i) + \sum_{c \in C} X1(c,i)P1(c,i) + P1OCT(i)X1OCT\,(i) \tag{3.28}$$

Subject to:

$$Z(i) = Leontief\left[A1\_S(i), \frac{X1(c,i)}{A1\_S(c,i)}, \frac{X1PRIM(i)}{A1PRIM(i)}, \frac{X1OCT(i)}{A1OCT(i)}\right] \tag{3.29}$$

where $A1\_S(i)$ is a Hicks' neutral technological change term affecting all inputs equally for each industry i and $A1\_S(1,i)$,…, $A1\_S(c,i)$ are intermediate commodity composite specific technical change terms.

The solutions of (3.28) subject to (3.29) are:

$$X1(c,i) = \ Z(i)\ A1(i)A1_{S(c,i)} \tag{3.30}$$

$$X1PRIM(i) = Z(i)\ A1(i)A1PRIM(i) \tag{3.31}$$

$$X1OCT(i) = \ Z(i)\ A1(i)\ A1OCT(i) \tag{3.32}$$

As we have shown, Leontief production function is a specific case of a CES function where the substitution elasticity is zero. Hence, there is no relative price effect so that equations (3.30)-(3.32) do not contain price terms.

The percentage change forms of (3.30)-(3.32) for each industry *i* can be re-written as:

$$x1\_s(c,i) - [a1\_s(c,i) + a1(i)] = z(i) \tag{3.33}$$

where $x1\_s(c,i)$, $a1\_s(c,i)$, $a1(i)$ and $z(i)$ are percentage changes in the variables represented by the corresponding uppercase symbols in (3.30).

$$x1prim(i) - [a1prim(i) + a1(i)] = z(i) \tag{3.34}$$

where $x1prim(i)$, $a1prim(i)$, $a1(i)$ and $z(i)$ are percentage changes in the variables represented by the corresponding uppercase symbols in (3.31).

$$x1oct(i) - [a1oct(i) + a1(i)] = z(i) \tag{3.35}$$

where $x1oct(i)$, $a1oct(i)$, $a1(i)$ and $z(i)$ are percentage changes in the variables represented by the corresponding uppercase symbols in (3.32).

Equations (3.33)-(3.35) state that the percentage changes in the demand of intermediate commodity composite, the demand of composite primary factor and the demand for 'other costs' follow the percentage change in overall activity level proportionally in each industry i when there is no technical change. So far in this subsection we have analyzed the bottom half of Figure 3.1. In the following subsection, we examine the top half.

3.3.2 Outputs and Activity level

In the top half of Figure 3.1, there are two types of nests; we name them as output nest and sales nests. ORANIMON allows multi-output production specification in which each industry i can potentially produce a mixture of all the commodities. The mix of outputs, depicted in output nest, vary from industry to industry depending on the relative prices of commodities. Some industries may also produce a single commodity yet multi-output specification is still useful for further analysis.

In the output nest, the Leontief combination of the commodity and primary factor composites are aggregated via a constant elasticity of transformation (CET) function to yield the output mix, from commodity 1 to commodity c. At any given activity level, *Z(i)*, industry i's optimization problem is to choose the output mix which maximizes its total revenue from all outputs. That is, industry i chooses:

$$Q1(c,i) \tag{3.36}$$

to maximize:

$$\sum_{c\in C} PQ1(c,i)Q1(c,,i) \tag{3.37}$$

subject to:

$$Z(i) = CET\left[\frac{Q1(c,i)}{A(c,dom,i)}\right] \tag{3.38}$$

where $Q1(c,i)$ is the output of commodity $\boldsymbol{c}$ by each industry i and $A(c,dom,i)$ is an output-augmenting technology in each industry i.

Activity level- $Z(i)$ and the basic price of domestically produced good ***c***- $P0(c, dom)$ are treated as exogenous variables. The solution of (3.37) subject to (3.38), in percentage change form, is:

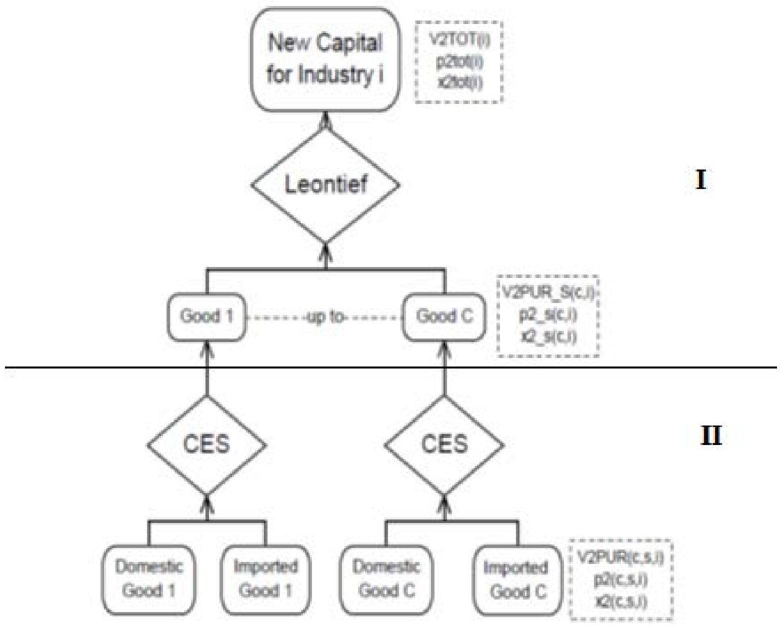
$$q1(c,i) = z(i) + \sigma 1OUT(i)[p0com(c) - p1tot(i)] \tag{3.39}$$

where $q1(c,i)$, $z(i)$ and $p0com$ are percentage changes in the variables represented by the corresponding uppercase symbols in (3.38). $\sigma 1OUT(i)$ is the CET transformation elasticity in industry *i* between pairs of commodities. $p1tot(i)$ is the average price of industry *i*'s output mix. The CET specification implies a same value for all pairwise transformational elasticities. For instance, the transformational elasticity of sheep and cattle is same as that of cattle and goats in Mongolian livestock industry. The transformational elasticity measures the magnitude of good *c*'s supply responsiveness to changes in the price of good *c* relative to other the prices of other products in the mix.

3.4 Demands for Inputs to Capital Formation

We assume that fixed capital is competitively and efficiently produced with inputs of domestically produced and imported commodities. The theory of investment in ORANIMON concerns the allocation of an aggregate private investment across the industries and does not consider the determination of the aggregate private investment level in Mongolian economy.

Figure 3.2 Structure of Investment Demand



Source: Modified from Horridge (2014)

Figure 3.2 shows the two stage nesting structure for the production of investment commodities in ORANIMON. We will also start with stage two and work up to stage one. At the stage two or at the bottom level, each investor (industry) *i* chooses a source specific investment commodity c to minimize total costs of investment commodity ***c*** subject to a CES production function.

Capital creation, however, does not require inputs of primary factors and 'other cost' tickets. Likewise in ORANI, the use of labour, capital and land, the payment of production taxes and the costs of holding inventories associated with the creation of fixed capital are recognized via the inputs of construction. This is considered as the usual practice of accounting in economy-wide modeling. For example, the construction industry in ORANIMON is modelled as using capital and labour in current production while capital creation is modeled as requiring substantial inputs supplied by the construction industry.

At the stage one or at the upper level, each investor (industry) *i* chooses a composite investment commodity *c* to minimize total costs of commodity composites subject to a Leontief production function.

The optimization problem for each investor industry *i* is to choose:

At the top level, the optimization problem for each industry ***i*** is to choose:

$$X2\_S(c,i) \tag{3.40}$$

To minimize the total costs:

$$\sum_{c \in C} P2\_S(c,i) X2\_S(c,i) \tag{3.41}$$

Subject to:

$$X2TOT(i) = Leontief\left[\frac{1}{A2TOT(i)}, \frac{X2\_S(c,i)}{A2\_S(c,i)}\right] \tag{3.42}$$

here $X2TOT(i)$ and $A2TOT(i)$ are the total amount of investment and Hicks neutral technological change term affecting all inputs equally for each industry *i* respectively, and $A2\_S(1,i)$,…, $A2\_S(c,i)$ are intermediate commodity composite specific technical change terms. $X2\_s(c,i)$ and $P2\_s(c,i)$ are the demand in investment commodity composite (local plus imported) ***c*** and the price of the investment commodity composite ***c*** respectively in each using industry *i*.

We note that the total amount of investment $X2TOT(i)$ for each industry is exogenous to the above cost minimization problem and we have not explained how it is determined. We pay a particular attention to the allocation of investment across industries and provide an analysis in section 4.10 because the thesis application of ORANIMON is related to the investment.

Solving the cost minimization problem above following steps we described in Chapter 2, we obtain:

$$x2\_s(c,i) - [a2\_s(c,i) + a2tot(i)] = x2tot(i) \quad \textbf{(3.43)}$$

where lower case x and p are percentage changes in the variables represented by the corresponding uppercase symbols in (3.42).

Equation (3.43) states that the percentage change in the demand of investment commodity composite follow the percentage change in total investment for each industry proportionally i when there is no technical change. It also shows, on the other hand, that the percentage change in total investment for each industry depends on the change in the demand of investment commodity composite and technical change variables $2\_s(c,i)$ and $a2tot(i)$.

3.5 Household demands

Representative household faces an optimization problem to maximize its utility subject to its budget constraint and the current prices of goods in the market. Figure 3.3 shows the two stage nesting structure for household demand in ORANIMON. At the lower level, a representative household chooses a source specific consumption commodity c to maximize utility from a composite commodity c subject to a CES function. Each commodity c from import source is treated as an imperfect substitute for domestically produced commodity c. This assumption is governed by a CES function.

The optimization problem for the household is to choose:

$$X3(c,s), \qquad s = \{dom, imp\}, \quad \textbf{(3.44)}$$

to minimize:

$$\sum_{s\in S} P3(c,s)X3(c,s) \quad \textbf{(3.45)}$$

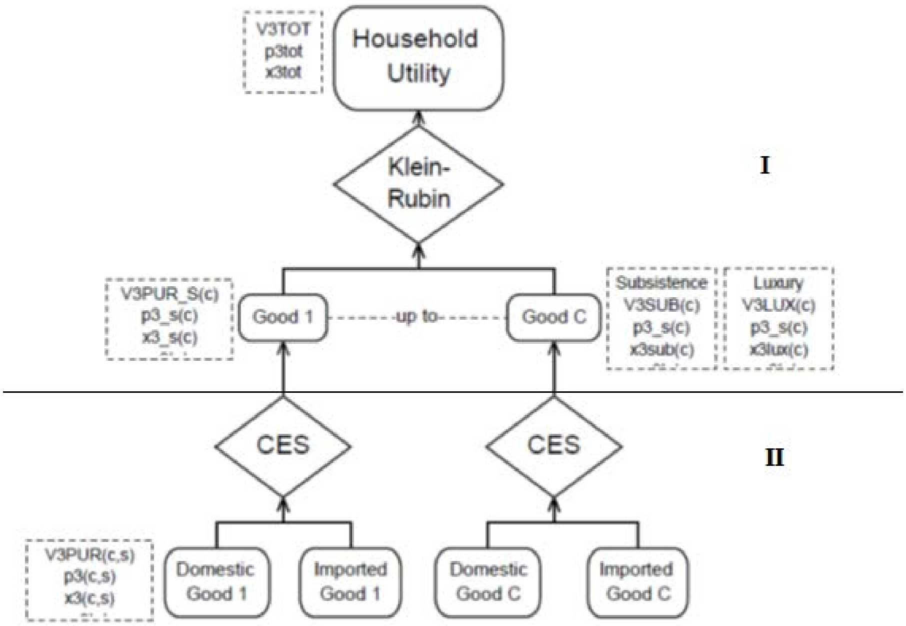
subject to:

$$X3\_S(c) = CES\left[\frac{X3(c,s)}{A3(c,s)}\right] \quad \textbf{(3.46)}$$

where $X3\_S(c)$ is household demand for each composite effective commodity c, $X3(c,s)$ is source-specific demand of commodity c, $A3(c,s)$ is the source specific taste coefficient for consumption commodity c and $P3(c,s)$ is the source specific price of commodity c for households. The source specific consumer price of commodity c can be different amount than that of other users due to taxes and distribution costs.

Unlike technological coefficients in production and investment demands, $A3(c,s)$ allows changes in household taste stay away or towards a source specific commodity c.

Figure 3.4 Structure of household demand



Source: Modified from Horridge (2014)

At the upper level, the household chooses composite commodities $X3\_S(c)$ to maximize its utility subject to a Klein-Rubin function. This would lead to the LES of which characteristics we described in Chapter 2. The total number of households in Mongolian economy is denoted by Q.

The optimization problem for the household, at this stage, is to choose:

$$X3\_S(c), \quad \textbf{(3.47)}$$

To maximize per capita utility:

$$U = \frac{1}{Q}\prod_{c\in C}\left(\frac{X3\_S_c}{A3\_S_c} - X3SUB(c)\right)^{S3LUX(c)} \quad \textbf{(3.48)}$$

Subject to a budget constraint:

$$V3TOT = \sum_{c\in C} P3\_S(c)X3\_S(c) \quad \textbf{(3.49)}$$

where U is utility, $X3SUB(c)$ and $S3LUX(c)$ are behavioural coefficients showing 'subsistence' requirements and the marginal budget shares, $V3TOT$ is the total budget/expenditure, $P3\_S(c)$ and $X3\_S(c)$ are the price and quantity of each commodity c paid and consumed by households. The $S3LUX(c)$ must sum to unity. We note that $V3TOT$ is explained elsewhere in ORANIMON or simply remains exogenous.

The maximization problem results in demand equations of the level form:

$$X3\_S(c) = X3SUB(c) + S3LUX(c)[V3TOT - \frac{\sum_{c\in C} P3\_S(c)X3SUB(c)}{P3\_S(c)}] \quad \textbf{(3.50)}$$

We can define 'luxury' or 'supernumerary' expenditure:

$$V3LUX\_C = V3TOT - \sum_{c\in C} P3\_S(c)X3SUB(c) \quad \textbf{(3.51)}$$

where $V3LUX\_C$ is 'luxury' or 'supernumerary' expenditure, that aggregate household expenditure minus aggregated subsistence expenditures.

Now we can write levels equations of household demand from (3.50)-(3.51) as following three equations:

$$X3\_S(c) = X3SUB(c) + X3LUX(c) \quad \textbf{(3.52)}$$

where $X3LUX(c)$ is the demand or use of each commodity composite *c* for 'luxury' consumption and the others are previously defined. (3.52) shows the total demand or use of each commodity composite *c* is the sum of 'subsistence' and 'luxury' usages of each composite commodity *c*.

$$X3LUX(c)P3\_S(c) = S3LUX(c)V3LUX(c) \quad \textbf{(3.53)}$$

Equation (3.53) states that the luxury expenditure for each composite commodity $\boldsymbol{c}$ follows the marginal budget share of expenditure for each composite commodity $\boldsymbol{c}$ in the total budget- $S3LUX(c)$. Together (3.52) and (3.53) are equivalent to (3.50).

$$X3SUB(c) = A3SUB(c)Q \tag{3.54}$$

where $A3SUB(c)$ is individual household subsistence demand for each composite commodity c.

Equation (3.54) states that the total subsistence demand for each composite commodity c is the product of the individual household subsistence demand for each composite commodity c- $A3SUB(c)$ and the number of households, Q. This is necessary because our demand system applies to the aggregate household instead of to individual households.

The percentage change form of linear expenditure equation (3.50) can be written as:

$$\begin{aligned} x3\_s(c) &= B3LUX(c)(w3lux(c) - p3\_s(c)) \\ &\quad + (1 - B3LUX(c))[a3lux(c) + q] \end{aligned} \tag{3.55}$$

where lower case variables denote percentage changes in the variables represented by the corresponding uppercase symbols; and is defined as:

$$B3LUX(c) = \frac{S3LUX(c)(V3TOT - \sum_{c \in C} P3\_S(c)X3SUB(c))}{P3\_S(c)X3\_S(c)} \tag{3.56}$$

If we substitute (3.51) in (3.56) and denote the consumption of composite commodity c by $V3PUR\_S(c)$, then we can re-write (3.56) as:

$$B3LUX(c) = \frac{S3LUX(c)V3LUX\_C}{V3PUR\_S(c)} \tag{3.57}$$

Let us define Frisch parameter as the inverse of the ratio between total final household expenditure and household supernumerary expenditure:

$$FRISCH = \frac{V3TOT}{V3LUX\_C} \tag{3.58}$$

The Frisch parameter shows the relationship between households' total expenditure and their supernumerary expenditure in the Klein-Rubin utility function. It is used in evaluating own and cross price elasticities of demand and in calculating the changes in the subsistence component of household consumptions.

The household expenditure elasticity for commodity *c* can be derived as:

$$\varepsilon(c) = \frac{S3LUX(c)}{S3\_S(c)} \qquad \textbf{(3.59)}$$

If we substitute (3.58) and (3.59) into (3.57), we can define the ratio of supernumerary expenditure and total expenditure for each commodity *c* as:

$$B3LUX(c) = \frac{\varepsilon(c)}{|FRISCH|} \qquad \textbf{(3.60)}$$

Now the percentage change form of household demand equations from (3.52) to (3.54) as:

$$x3sub(c) \;=\; q \;+\; a3sub(c); \qquad \textbf{(3.61)}$$

and

$$x3lux(c) \;+\; p3\_s(c) \;=\; w3lux \;+\; a3lux(c) \qquad \textbf{(3.62)}$$

as well as

$$x3\_s(c) \;=\; B3LUX(c) * x3lux(c) \;+\; [1 - B3LUX(c)] * x3sub(c) \qquad \textbf{(3.63)}$$

where lower case variables denote percentage changes in the variables represented by the corresponding uppercase symbols.

3.6 Exports demands in ORANIMON

There are two groups of export commodities in ORANIMON. These are:

- Traditional or individual
- Non-traditional or collective.

For each category, the model allows a different treatment of export demands. For an individual export commodity c, foreign demand is inversely related to a price of commodity c in foreign currency. For the collective export commodities, foreign demand is inversely related to the average price of all collective commodities.

For each commodity c in the individual export group, we can define the exports demand as:

$$X4(c) = FGEN \times F4Q(c) \times \left[\frac{P4(c)}{PHI \times F4P(c)}\right]^{\gamma(c)} \qquad \textbf{(3.64)}$$

where $\gamma 1(c)$ is a negative parameter showing the constant elasticity of demand; $X4(c)$ and $P4(c)$ are export volume/quantity and price of each export commodity c respectively; PHI is a nominal exchange rate between Mongolian currency, MNT and trading partner's currency, i.e., RMB and USD. The variables- $FGEN$, $F4Q(c)$ and $F4P(c)$ are shift variables.

Foreign price of a commodity c- $\frac{P4(c)}{PHI}$ is F.O.B price expressed in foreign currency, e.g., USD or RMB. The prices that are expected to influence Mongolia's exports (Foreign import demand; i.e., China's demand for iron ore) are the purchasers' prices in foreign countries. These equal to the sum of Mongolian exporters' F.O.B price value, transport, export duties, and other charges separating Mongolian port of exit and foreign sites of use. Since ORANIMON is a single country model, it does not have equations explaining the separating charges.

Abovementioned separating charges are observed into vertical shift of export demand curve, $F4P(c)$. Vertical shift variables can also be used to simulate changes in the prices of foreign products competing with Mongolia's exports of commodity c. A simple example may be Australia's coking coal price change relative to that of Mongolian coking coal as China imports high quality coals from both Australia and Mongolia.

Changes in world demand for good c and shifts in foreign preference towards or away from Mongolia's export good c can be accommodated by the horizontal and vertical shifts of export demand curve-$F4Q(c)$. The shifter $FGEN$ is used for an overall or general change affecting all exports commodities. The latter generates a uniform horizontal shift in all export demand curves while other two create commodity specific shifts.

The percentage change form of (3.64) is:

$$x4(c) = fgen + f4q(c) - ABS[\gamma(c)] \times \left(p4(c) - phi - f4p(c)\right) \tag{3.65}$$

where lowercase symbols represent percentage changes in the variables denoted by the corresponding uppercase symbols; ABS denotes absolute value function.

The collective export group include all those commodities for those where export volumes do not depend mainly on the corresponding price. We treat the collective exports as a Leontief aggregate of non-traditional commodities as:

$$X4\_NTRAD = Leontief[X_c] \quad c \in NTRAD \tag{3.66}$$

where $X4\_NTRAD$ is a collective demand and $NTRAD$ is a set of non-traditional commodities.

Demand for this aggregated collective its average price via a constant elasticity demand equation similar to (3.64). The percentage change form of the demand for collective export aggregate is:

$$\begin{aligned} x4\_ntrad = fgen + f4q\_ntrad - ABS[\gamma(c)] \\ \times (p4\_ntrad - phi - f4p\_ntrad) \end{aligned} \tag{3.67}$$

where $ntrad$ denotes that each corresponding variable is of non-traditional group and γ is a single constant elasticity of demand for collective exports.

3.7 Other final demands

In keeping with the input output conventions, governments (federal and local) are viewed as buying both domestically produced and imported commodities and services and do not directly demand labour and other primary factors. They buy the outputs of various industries, and, in turn, those industries employ primary factors of production.

As in ORANI, there are no formal theories explaining other final demands; government demands and inventory demands in ORANIMON. Hence, there is no optimization problem like we have shown for other users. Basically, following two equations in percentage change form describe how the government demands are handles in ORANI framework.

$$x5(c,s) = f5(c,s) + f5tot \tag{3.68}$$

and

$$f5tot = x3tot + f5tot2 \quad \textbf{(3.69)}$$

where $x5(c,s)$ is a source specific government demand for each commodity c; $f5(c,s)$, $f5tot$ and $f5tot2$ are shift variables; and $x3tot$ is a real aggregate household consumption.

Equations (3.68) and (3.69) determine government consumption. When both $f5(c,s)$ and $f5tot$ are exogenous, the level and composition of government consumption is exogenously determined. In this case (3.69) determines the value of which has no impact on the system.

Alternatively, when $f5tot$ is endogenous and $f5tot2$ is exogenous, changes in an aggregate government consumption is linked to a real aggregate household consumption effectively and thus it moves with $x3tot$.

The change in the volume of commodities going into inventories can be shown as:

$$delx6(c,s) = \frac{1}{100 \times LEVP0(c,s)}(V6BAS(c,s)x0com(c) + fx6(c,s)) \quad \textbf{(3.70)}$$

where $delx6(c,s)$ is a source specific ordinary change in inventory of each commodity c; $LEVP0(c,s)$ and $V6BAS(c,s)$ are 'levels' source specific basic prices and value of source specific inventory of commodity c respectively; $x0com(c)$ is an output of each commodity c; and $fx6(c,s)$ is a source specific shift variable. When $fx6(c,s)$ is endogenous, (3.70) is insulated from the equation system.

Equation (3.70) states that the percentage change in the volume of a source specific inventory of each commodity is the same as the percentage change in domestic production of that commodity.

Ordinary changes in the values of inventory demands can be shown as:

$$delV6(c,s) = \frac{1}{100}V6BAS(c,s)p0(c,s) + LEVP0(c,s)delx6(c,s) \quad \textbf{(3.71)}$$

where $delV6(c,s)$ is a source specific ordinary change in the value of inventory for commodity c; $p0(c,s)$ is a basic price for domestic users and the others are previously determined.

Hence $delx6(c,s)$ is an ordinary change variable, we use (3.71) to update the V6BAS coefficient. Simplified general value change formula is:

$$\Delta V = P \times X \left(\frac{\Delta P}{P} + \frac{\Delta X}{X}\right) = V \frac{p}{100} + P\Delta X \quad \textbf{(3.72)}$$

where V, P and X are value, price and quantity respectively. p is a percentage change in price.

3.8 Demands for margins

The supply of margins is determined independently of the supply of commodity being delivered. If, for example, the global price of copper doubles, export price as observed in Mongolia (inclusive of margins) may increase by a smaller proportion as there is no reason why the margin price should double.

Previously described demands for commodities by producers, investors, foreigners and governments create indirect demands for margins. The demands for margins are assumed to arise in proportion to the in direct demand in quantity terms for each commodity c. If we include the 'a' variables allowing for technical change in margins usage, we can write following five simple equations in percentage change form:

$$x1mar(c,s,i,m) = x1(c,s,i) + a1mar(c,s,i,m) \quad \textbf{(3.73)}$$

where $x1mar(c,s,i,m)$ is a source specific margin demand of commodity c for production in industry i and $a1mar(c,s,i,m)$ is the technological change in margins use for intermediate consumption.

$$x2mar(c,s,i,m) = x2(c,s,i) + a2mar(c,s,i,m) \quad \textbf{(3.74)}$$

where $x2mar(c,s,i,m)$ is a source specific margin demand of commodity c for investment in industry i and $a2mar(c,s,i,m)$ is a technology change in margins use for investment consumption.

$$x3mar(c,s,m) = x3(c,s) + a3mar(c,s,m) \quad \textbf{(3.75)}$$

where $x3mar(c,s,m)$ is a source specific margin demand of commodity c for private consumption, and $a3mar(c,s,m)$ is a technology change in margins use for private consumption.

$$x4mar(c,m) = x4(c) + a4mar(c,m) \tag{3.76}$$

where $x4mar(c,m)$ is a margin demand of commodity c for exports and $a4mar(c,m)$ is a technology change in margins use for exports.

$$x5mar(c,s,m) = x5(c,s) + a5mar(c,s) \tag{3.77}$$

where $x5mar(c,s,m)$ is a source specific margin demand of commodity c for government consumption and $a5mar(c,s,m)$ is a technology change in margins use for government consumption.

3.9 The price systems and zero pure profit condition equations

ORANIMON uses several types of commodity prices. These are purchasers' prices, basic values, prices of capital units, FOB foreign currency export prices and CIF foreign currency import prices. There are two assumptions which set out relationship between these prices.

We assume, firstly, that there are zero profits in any economic activity (producing, importing, exporting, transporting etc.). We also assume, secondly, that basic values are uniform across all users and across producing industries in the case of domestic commodities and importers in the case of foreign commodities.

In Chapter 5, we will have a look at the relationship of the prices in detail. For this section's discussion, we define basic values as the prices received by producers excluding sales taxes and margin costs. For importers, basic prices are the prices received by the importers excluding sales taxes and margin costs associated with transporting from the ports to domestic users somehow including import duties.

Zero pure profits dictate neo-classic assumption of competitive market equilibrium where industry input (cost) equals to industry output (income). Zero pure profit condition is viewed by some critics of CGE modeling as a pitfall in the methodology. However, the framework captures workings of a market economy and its agents' behaviors. When the particular application is needed, CGE models like ORANIMON can facilitate economic profit in the short run for some industries using its other costs ticket (OCT) feature.

Purchasers' prices for each of the first five users group (producers/importers, investors, households, exports and government) are the sums of basic values, sales taxes and margins. Sales taxes are usually treated as ad valorem on basic values, with the sales tax variables t in the linearized model being percentage changes in the powers of taxes. The power of a tax is one plus the ad valorem rate.

For illustration purpose to derive zero pure profit conditions, let us take an example of households. If we define the purchasers' value of households from the consumption of commodity c:

$$\begin{aligned} V3PUR(c,s) &= X3(c,s)P3(c,s) \\ &= X3(c,s)P0(c,s)T3(c,s) + \sum_{m \in M} X3MAR(c,s,m)P0(c,s,m) \end{aligned} \quad \textbf{(3.78)}$$

where $V3PUR(c,s)$ is a source specific purchasers' value for households; $T3(c,s)$ is the power of a tax on households and the others are previously defined.

Using a general value change formula in **(3.72)**, the percentage change form of **(3.78)** can be found as:

$$\begin{aligned} &V3PUR(c,s)[x3(c,s) + p3(c,s)] = [V3TAX(c,s) + V3BAS(c,s)] \times \\ &[x3(c,s) + p0(c,s) + t3(c,s)] + \sum_{m \in M} V3MAR(c,s,m)[x3mar(c,s,m) + p0(m,dom)] \end{aligned} \quad \textbf{(3.79)}$$

where $V3TAX(c,s)$ and $V3MAR(c,s,m)$ are the values of source specific taxes and margins; the other are previously defined and lowercase symbols represent percentage changes in the variables denoted by the corresponding uppercase symbols.

The reduced form of (3.79) can be found by using (3.75) as:

$$\begin{aligned} V3PUR(c,s)p3(c,s) &= [V3TAX(c,s) + V3BAS(c,s)] \times [p0(c,s) + t3(c,s)] + \\ &+ \sum_{m \in M} V3MAR(c,s,m)[p0(m,dom) + a3mar(c,s,m)] \end{aligned} \quad \textbf{(3.80)}$$

Equation (3.80) is the pure profit condition in supplying commodities and services to households.

The same procedure is used for the purchasers' price equations for other users. The equations, in turn, impose zero pure profit conditions in all domestic economic activities, where total revenues equal to total costs. For example, zero pure profit condition in capital creation assures that the value of a unit of capital is equal to the cost of its production. As we discussed in section 3.4, no primary inputs are used in the creation of new capital stocks so that the value of a unit of capital can be expressed as the sum of the value of the intermediate inputs used.

Zero pure profit condition in importing activity ensures that the revenue earned per unit of imports is equal to the cost per unit of imports. It means the domestic currency basic price of imports (post duty CIF price of imports) is equal to CIF foreign currency price in domestic currency plus import duties.

Hence, we define an equation for zero pure profit condition in importing in levels form as:

$$P0(c, imp) = PF0CIF(c) \times PHI \times T0IMP \qquad \textbf{(3.81)}$$

where $P0(c, imp)$ and $PF0CIF(c)$ are the domestic currency basic price and CIF foreign currency price of imported commodity c; PHI is a nominal exchange rate and $T0IMP$ is the power of tariff (one plus import duty rate). *0* signals basic price and hence applied to all users.

The percentage change form of (3.83) as zero pure condition in importing is:

$$p0(c, imp) = pf0cif(c) + phi + t0imp(c) \qquad \textbf{(3.82)}$$

where lowercase symbols represent percentage changes in the variables denoted by the corresponding uppercase symbols.

Equation (3.82) states that the change in the basic prices of commodities follows the changes in foreign prices, nominal exchange rate and the power of tariff.

As in ORANI and ORANI-G, ORANIMON allows for great flexibility in the treatment of indirect taxes. There are many types of user specific and general taxes. To simulate tax changes, we include additional equations into the ORANIMON equation system to facilitate them.

For illustration purpose, let us take an example of households again. The equation of the power of tax on sales to households can be described as:

$$t3(c, s) = f0tax\_s(c) + f3tax\_cs \qquad \textbf{(3.83)}$$

where $f0tax\_s(c)$ and $f3tax\_cs$ are shift variables; $f0tax\_s(c)$ can be used for simulating a commodity specific tax change and $f3tax\_cs$ can be used for simulating the change in user specific (households, in our case) tax. For more complex taxes, we can modify the equation. Similar to the case in determining purchasers' prices, the same procedure is used for determining the powers of commodity taxes on other users.

3.10 Market clearing equations and macro identities

ORANIMON assumes that demand equals supply for domestically consumed commodities and for the primary factors of production. Hence, the model contains sets of equations to ensure these conditions.

For each non-margin source-specific domestically consumed commodity *c*, the market clearing condition is:

$$X0(c,s) = \sum_{i \in I} X1(c,s,i) + \sum_{i \in I} X2(c,s,i) + X3(c,s) + X4(c,dom) + X5(c,s) + X6(c,s) \quad \textbf{(3.84)}$$

where $X0(c,s)$ is the quantity supplied of commodity c from source s to all users; and the other are previously determined.

For each margin commodity *m*, the market clearing condition is:

$$\begin{aligned} &X0(m) = \\ &\textstyle\sum_{i \in I} X1(m,i) + \\ &\textstyle\sum_{i \in I} X2(m,i) + X3(m) + X4(m) + X5(m) + \sum_{c \in C} \sum_{s \in S} \sum_{i \in I} [X1(c,s,i,m) + \\ &X2(c,s,i,m)] + \textstyle\sum_{c \in C} \sum_{s \in S} X3(c,s,m) + \sum_{c \in C} X4(c,m) + \sum_{c \in C} \sum_{s \in S} X5(c,s,m) \end{aligned} \quad \textbf{(3.85)}$$

where $X0(m)$ is the quantity supplied of margin commodity *m* to all users; and the other are previously determined.

We assume that all margin commodities are domestically produced and are used directly by users and indirectly included in commodity flows to users.

Gross domestic product (GDP) is determined from the expenditure side as the standard identity:

$$GDP = C + G + I + X - IMP + \Delta INV \quad \textbf{(3.86)}$$

where GDP is the value of real GDP which is the sum of private consumption of domestic commodities and services- C, government consumption of domestic commodities and services -G, investment -I, exports of domestic commodities and services- X and the change in inventories -ΔINV, less imports- IMP.

The percentage change form of (3.86) and the percentage change form of GDP price equation are:

$$x0gdpexp = \frac{1}{V0GDPEXP}[x3totV3TOT + x2tot\_iV2TOT\_I + x5totV5TOT + x6totV6TOT + x4totV4TOT - x0cif\_cV0CIF\_C] \quad \textbf{(3.87)}$$

$$p0gdpexp = \frac{1}{V0GDPEXP}[p3totV3TOT + p2tot\_iV2TOT\_I + p5totV5TOT + p6totV6TOT + p4totV4TOT - p0cif\_cV0CIF\_C] \quad \textbf{(3.88)}$$

where $x0gdpexp$ and $p0gdpexp$ are the percentage changes in real GDP and GDP price from expenditure side respectively; $V0GDPEXP$ is the nominal GDP from the expenditure side; the other components of both equations are the aggregates of the variables previously described. Both (3.87) and (3.88) are value weighted changes in its individual elements. These *Divisia* indices arise from homothetic functional forms of the ORANIMON equation system.

GDP is also determined from the income side as:

$$x0gdpfac = \frac{1}{V1PRIM\_I}[employ\_iVLAB\_IO + x1cap\_iVCAP\_I + x1land\_iV1LND\_I] \quad \textbf{(3.89)}$$

where $x0gdpfac$ is the percentage change in real GDP from income side; the other components of both equations are the aggregates of the variables previously described.

It is accounting identity that GDP from both expenditure and income sides must be equal both in the levels and in percentage changes.

3.11 Additional equations for national welfare measures

Due to the inflow of FDI associated with the recent mining boom, we need an appropriate measure of Mongolian welfare, a gross national income (GNI). Following Horridge (1985), we define the expenditure side of nominal GNI as:

$$GNI = Consumption + Government\ Purchases + National\ Saving + Balancing\ Item \quad \textbf{(3.90)}$$

In terms of percentage change, (3.90) can be shown as:

$$gni = \vartheta 1x3tot + \vartheta 2x5tot + \vartheta 3xsav + \vartheta 4bi \quad \textbf{(3.91)}$$

where lowercase symbols represent percentage changes in the variables denoted by the corresponding uppercase symbols; and $\vartheta 1, \vartheta 2, \vartheta 3$ and $\vartheta 4$ are the shares of corresponding components in GNI.

National saving (Savard) is equal to the sum Mongolian saving in the domestic economy (DSAV) and overseas (FSAV). FSAV, however, is a nominal. The shares of Mongolian savings held as domestic assets and foreign assets are assumed to be exogenously given and constant over time resulting same percentage change.

We define the income side of nominal GNI as:

$$GNI = GDP + Invisibles\ accruing\ to\ Mongolians - Invisibles\ accruing\ to\ Foreigners \quad \textbf{(3.92)}$$

In terms of percentage change, (3.92) can be shown as:

$$gni = \omega 1(q + k + pKL) + \omega 1othinc + \omega 1(kf + phi) \quad \textbf{(3.93)}$$

where $q + k$, $othinc$ and kf are the changes in income from the ownership of domestic capital, other non-capital sources and from the ownership of foreign capital. $\omega 1$, $\omega 2$ and $\omega 3$ are the shares of corresponding components in GNP. Foreigners are not allowed to own land legally in Mongolia. pKL is an index of the rental price of domestically owned capital and phi is the percentage change in the nominal exchange rate.

In order to implement these additional equations, we need to determine the percentage change in the proportion of industry specific capital stocks held by Mongolian nationals. In the short run, this proportion is fixed while it varies with the investments in the long run.

3.12 Summary

We have presented the theoretical framework of COPS style static CGE model ORANIMON in this chapter. ORANIMON consists of a set of simultaneous equations, which describe the behaviours of economic agents in the economy.

The purpose of this chapter has been to provide an overview of ORANIMON model and hence obtain thorough understanding of the model's equations, underlying theories and technical features. We have examined the equations in several groups paying particular attention to the economic interpretations. The ORANIMON equation system, in addition, has numerous other equations for calculating a number of real and nominal indicators of the SNA, explaining results from applications and for facilitating analysis associated with the labour market and regional extensions. These are too voluminous to include in the chapter.

Having obtained fundamental understanding of ORANIMON, we can now move on to the theoretical framework of its dynamic successor, MONAGE in next chapter.

Chapter 4. MONAGE: A Recursive Dynamic CGE Model of the Mongolian economy

4.1 Preamble

MONAGE, the first single-country COPS style recursive dynamic CGE model of the Mongolian economy, evolved from ORANIMON. The main advances in MONAGE over ORANIMON are in dynamics. MONAGE is built on mini-USAGE (Dixon & Rimmer 2005). Mini-USAGE, designed for teaching purposes and for adaptation to other countries, is a smaller version of the USAGE model.

From carrying out policy analyses to generating forecasts and from examining a period of history to decomposing the contributions of structural changes to the economic development, MONAGE is equipped to be used for a wide range of economic analyses. As it evolved from ORANIMON, MONAGE has 2005 and 2012 databases. This enables estimations of structural changes between 2005 and 2012 in greater detail. It also enables the examination of contributions that these changes made to the growth of the Mongolian economy during the recent mining boom for the identification and quantification of underlying key economic factors.

4.2 MONAGE Equation System

MONAGE can be represented as a system of m equations in n variables as:

$$F(X, Y) = 0 \tag{4.1}$$

where F is a vector of m functions, X is the vector of n-m variables chosen to be exogenous and Y is the vector if m variables chosen to be endogenous.

MONAGE is a national model with annual periodicity. The vector (X, Y) includes flow variables for year t at the national level representing quantities and values of demands and supplies. The vector also contains stock and level variables at an instant of time, i.e., at the end of year t. For instance, these can be capital stocks and the level of exchange rate at the end of year 2012. (X, Y), in addition, contains lagged variables such as the lagged consumer price index for year 2012 which is the consumer price index for year 2011.

The m equations include links between flow variables in year t provided by market clearing conditions, zero pure-profit conditions, and demand and supply equations derived from optimising problems. Industries choose the mix of their output to maximise their revenues derivable from any given set of inputs, and their compositions of inputs to minimise the costs of creating any given set of output. Investors in each industry choose the composition of their inputs to minimise the costs of creating any given level of capital. Households choose the composition of their expenditures to maximise utility subject to their budget constraints. As MONAGE is based on ORANIMON, the equations regard to the market clearing conditions, zero pure-profit conditions and demand and supply equations are structurally identical. However, we note that there are many other innovations in addition to the dynamics in MONAGE. These innovations are related to technology and tastes, welfare measures, facilitation for different types of simulations and the mathematics of the levels representations of the MONAGE price and quantity indexes. In order to avoid repetitions, we will focus on the dynamics and some additional innovations in this chapter, leaving out the equations regarding the market clearing conditions, zero pure-profit conditions and demand and supply equations that we have detailed in Chapter 3.

In addition to those equations we have discussed in Chapter 3, there are equations which impose links between stock and flow variables in (X, Y). For instance, end-of-year capital stocks are linked to start-of-year capital stocks via investment and depreciation during year t as in the perpetual inventory method (PIM). Lagged adjustment processes are also included among the equations. For example, wage rates in year t might be related to consumer prices in t-1. Hence, MONAGE is a system of equations connecting various types of variables for year t.

4.3 Closures in MONAGE

The COPS style of CGE models like MONAGE contain a large number of economic relationships linking observable features of the economy such as macroeconomic aggregates, commodity prices and outputs, household consumption composition and commodities with the structural features of the economy such as production technologies and household tastes.

In Chapter 2, we discussed closures for COPS style models in general. The further innovations in COPS style dynamic models are largely associated with closures (Dixon & Rimmer 2002). With different closures MONAGE is able to produce:

(a) Estimates of changes in technologies and consumer preferences using a historical closure;
(b) Explanations of historical episodes such as the recent mining boom in Mongolia employing a decomposition closure;
(c) Forecasts for industries, regions, occupations and households via a forecast closure; and
(d) Projections of the deviations from forecast paths that would be caused by the implementation of proposed policies and other shocks to the economic environment through a policy closure.

In the historical closure used to explain changes between two time periods, observations at a detailed commodity/industry level on movements in consumption, investment, government spending, exports, imports, employment, capital stocks and many other variables are exogenous and can be introduced to MONAGE as shocks. Put simply, variables that are usually endogenous but observable are made exogenous and shocked by their changes between two points in time.

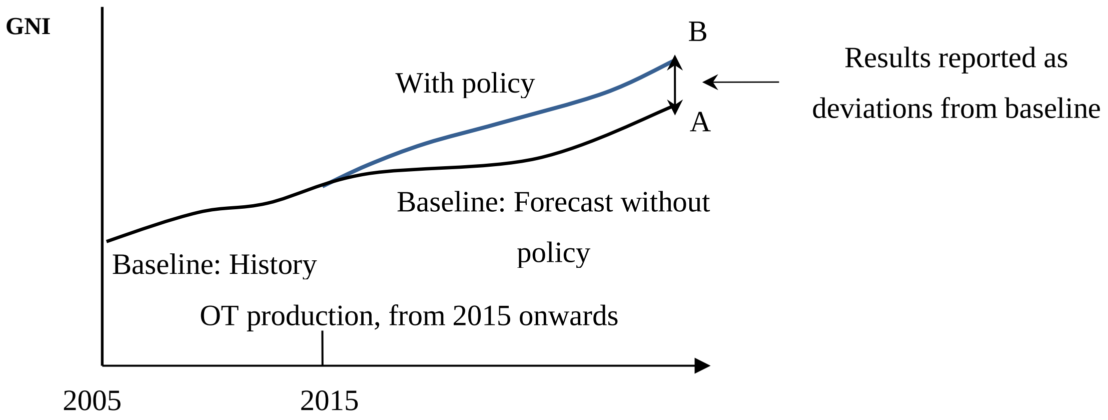
Computations with a historical closure are often used to generate up-to-date CGE database. In addition, they produce disaggregated estimates of movements in many naturally exogenous variables such as industry technologies, household preferences, required rates of return on capital and positions of export demand curves and import supply curves. Naturally exogenous variables are the variables that are not normally explained in CGE models whereas naturally endogenous variables are the variables that are normally explained.

In the decomposition closure, those naturally exogenous variables are exogenous and shocked with the movements estimated by an historical simulation. Computations with decomposition closure enable us to identify the roles in the growth of industry outputs and other naturally endogenous variables of changes in technology, changes in preferences and most importantly in our case, changes in positions of export demand curves of minerals products as well as changes in other naturally exogenous variables.

In the forecast closure, we exogenise variables for which we have forecasts. These may include macro variables, industry or commodity level variables such as exports by commodity, and demographic variables. Naturally exogenous technology, preference and trade variables in forecast simulations are often exogenous and are given shocks that are informed by trends derived from historical simulations.

In the policy closure, naturally exogenous variables are exogenous and naturally endogenous variables are endogenous. In policy simulations, most of the exogenous variables adopt the values they have, either exogenously and endogenously, in the forecast simulations except the policy variables of focus. For example, if we are interested in the impact of a change in the value-added tax (VAT), the relevant tax variable is moved away from its baseline forecast path and then the effects of tax change on macro variables and other endogenous variables are calculated by comparing their paths in the policy simulation with their paths in the baseline forecast simulation.

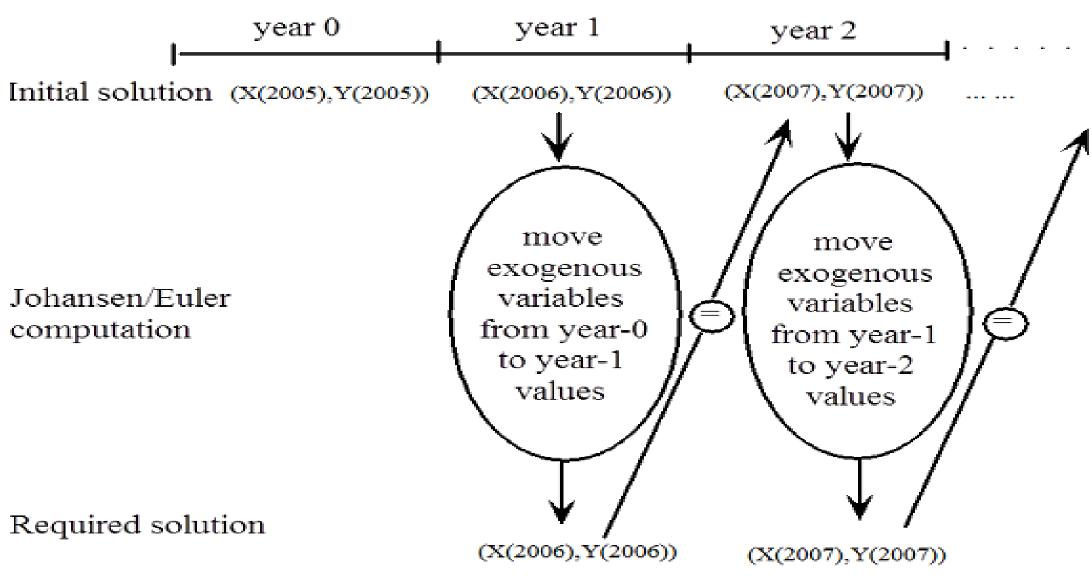
Figure 4.1 Analysis with MONAGE



MONAGE is capable of carrying out different types of simulations with the closures described above. Policy analysis with a model like MONAGE may require two broad steps making use of the closures. Firstly, the model generates a 'base case' (or baseline) which may consist of two parts: historical and forecast. Let us consider an example analysis, in Figure 4.1, for an illustration purpose. Evaluating the impact of the Oyu Tolgoi (OT) mine's production may involve historical, forecast and policy simulations and associated closures. The variable of our interest, GNI, is shown on the vertical axis. First, we may need to create a baseline (line A in Figure 4.1) through historical and baseline forecasting simulations. As can be seen from Figure 4.1, the baseline consists of parts covering history (2005 to 2015) and moving on to forecast (2015 onwards). We can define historical and forecast parts of the baseline through historical and forecast simulations respectively. The forecast part of a baseline excludes the policy under investigation (Part of Line A in Figure 4.1). Hence, it is a baseline business-as-usual simulation without the OT production for the period 2015 onwards. Secondly, the model generates a policy forecast that incorporates all exogenous features of the baseline forecast, but with the addition of policy-related shocks reflecting the details of the policy under investigation through a policy simulation. Line B in Figure 4.1 depicts policy forecasts. The economic implications of the policies are reported as deviations in values for model variables (say, GNI) between the policy and forecast simulations.

A historical simulation moves each of the observable components of the CGE database for year *t* to their value in year *t+1*, thereby recursively creating the picture of the Mongolian economy in year *t+1*. Historical and forecasting simulations include imposing available information on the model and letting the model determine structural changes in the economy which are accountable for these known outcomes. Their key difference is that the historical simulation makes use of available historical data on economic variables, whereas the forecast simulation makes use of available forecasts from international and national organisations. Using estimations from a historical simulation, we can partition and calculate the contribution of each structural variable through a decomposition simulation.

Figure 4.2 Sequence of solutions in MONAGE



4.4 Dynamics in MONAGE

Let us denote our solution in base year of 2005 as (X_{2005}, Y_{2005}). We can use this solution as an initial solution for year 2006:

$$(\bar{X}_{2006}, \bar{Y}_{2006}) = (X_{2005}, Y_{2005}) \quad \textbf{(4.2)}$$

From (4.2) we can employ the Johansen/Euler technique to generate the required solution for year 2006 by applying shocks reflecting the difference between X_{2005} and X_{2006}. The changes in the endogenous variables generated, *dY*, can be interpreted as growths of those variables between 2005 and 2006. We can create a sequence of solutions showing year-on-year growth through any desired simulation period. The sequence of annual solutions using the required solution for year *t-1* is depicted in Figure 4.2.

In a year-on-year sequence of solutions, start-of-year stock variables in the required solution for year *t* adopt the values of end-of-year stock variables in the required solution for year *t-1*.

In the tradition of COPS style dynamic models, MONAGE incorporates three types of inter-temporal links: physical capital accumulation, financial asset and liability accumulation, and lagged adjustment processes. Subsections 4.4.1 to 4.4.6 describe these dynamics in detail.

4.4.1 Physical Capital Accumulation

The linking of annual investment flows to capital stocks is one of the theoretical modifications for dynamics (Wittwer 2012, p. 39). In MONAGE, each *i* industry's capital stock accumulates according to the PIM as:

$$K_t^{end}(i) = K_t^{start}(i)(1 - DEP(i)) + INV_t(i) \quad (4.3)$$

where $K_t^{start}(i)$ the capital stock at the beginning of year *t*; $K_t^{end}(i)$ is the capital stock at the end of year t; $INV_t(i)$ is investment for industry *i* during year *t*; and $DEP(i)$ is a parameter giving industry *i*'s rate of depreciation.

In MONAGE, the initial solution for year *t* is the final solution for year *t-1*. The initial solution for industry *i*'s opening capital stock is the opening capital stock in the previous year. We can define the capital stock at the start of year *t* using the base year solution for year *t* as:

$$K_t^{start}(i) = \bar{K}_t^{start}(i) + \left(\bar{K}_t^{end}(i) - \bar{K}_t^{start}(i)\right) * U \tag{4.4}$$

where the barred coefficients are the initial solutions which are treated as parameters; and U is the homotopy variable whose initial value is zero and final value is one.

With U on zero, (4.4) is satisfied by the initial solution so that $K_t^{start}(i) = \bar{K}_t^{start}(i)$. When U moves to 1, $K_t^{start}(i)$ moves to its required level $\bar{K}_t^{end}(i)$.

The percentage change form of (4.3) can be written as:

$$K_t^{end}(i)k_t^{end}(i) = (1 - DEP(i))K_t^{start}(i)k_t(i) + INV_t(i)inv_t(i) \tag{4.5}$$

where $k_t^{end}(i)$, $k_t(i)$ and $inv_i(t)$ are percentage changes in the variables represented by the corresponding uppercase symbols from their values in the initial solution in year *t*.

In the year *t* computation, the percentage deviation $k_i(t)$ that should be imposed on the opening capital stock K_i^{start} is defined by:

$$k_t(i) = 100 * [\bar{K}_t^{end}(i) - \bar{K}_t^{start}(i)]/\bar{K}_t^{start}(i) \tag{4.6}$$

where $\bar{K}_t^{end}(i)$ and $\bar{K}_t^{start}(i)$ are the initial or base solutions for $K_t^{end}(i)$ and $K_t^{start}(i)$.

Using (4.3), we can re-write (4.10) equivalently as:

$$k_t(i) = 100 * [\overline{INV}_t(i) - DEP(i) * \bar{K}_t^{start}(i)]/\bar{K}_t^{start}(i) \tag{4.7}$$

where $\overline{INV}_t(i)$ is investment in the initial solution.

Re-writing (4.4) using (4.3), and adding a shifter variable allowing equation to be deactivated if it is not required in a particular year for some reason (e.g., idle capital), results in:

$$K_t^{start}(i) - \bar{K}_t^{start}(i) = [\overline{INV}_t(i) - DEP(i) * \bar{K}_t^{start}(i)] * U + F \tag{4.8}$$

where F is a shift variable and the others are previously defined.

Similar to the interpretation in (4.4), $K_t^{start}(i)$ equals $\bar{K}_t^{start}(i)$in our initial solution for year t when U and F are zero. By keeping F zero and moving U to one, we can have the correct deviation $[\overline{INV}_t(i) - DEP(i) * \bar{K}_t^{start}(i)]$ in the opening capital stock for year t from its value in our initial solution.

Now, we can impose (4.7) by including in MONAGE as:

$$K_t^{start}(i)k_t(i) = 100 * [\overline{INV}_t(i) - DEP(i) * \bar{K}_t^{start}(i)] * del\_U + 100 * del\_f \tag{4.9}$$

where del_U and del_f are the change variables of U and F. As U, del_U is normally shocked from zero to one.

Let us define the capital growth for industry i through year t as:

$$K\_GR_t(i) = \frac{K_t^{end}(i)}{K_t^{start}(i)} - 1 \tag{4.10}$$

where $K\_GR_t(i)$ is the proportionate growth in each industry i's capital stock between the start and the end of year t; and $K_t^{start}(i)$ and $K_t^{end}(i)$ are the opening and closing levels of capital stock.

Using (4.3) we can re-write (4.10) as:

$$\frac{INV_t(i)}{K_t^{start}(i)} = K\_GR_t(i) + DEP(i) \tag{4.11}$$

where $\frac{INV_t(i)}{K_t^{start}(i)}$ is *I/K* or the investment capital ratio.

4.4.2 Capital Supply Functions

In year-to-year simulations, MONAGE uses explicit capital-supply functions to help determine actual investment. Investment is driven by expected rates of return rather than actual rates of return. Hence, the expected rate of return in industry *i* determines its level of investment in a given period. In MONAGE, the expected rate of return $EROR_t(i)$ for each *i* industry is comprised of two parts:

$$EROR_t(i) = EEQROR_t(i) + DISEQ_t(i) \tag{4.12}$$

where $EEQROR_t(i)$ is the expected equilibrium expected rate of return (i.e., the return required to sustain the period *t* rate of capital growth indefinitely based on the current rate of capital growth in industry *i*) and $DISEQ_t(i)$ is the disequilibrium in the expected rate of return (the difference between the actual rate of return and investor expectations) in each industry *i*.

$EEQROR_t(i)$, an inverse logistic function of the rate of growth in the capital stock, is expressed as:

$$\begin{aligned} EEQROR_t(i) = {} & \left(RORN_t(i) + F\_EEQROR\_I_t(i) + F\_EEQROR_t\right) \\ & + \frac{1}{C(i)}[\ln(KGR_t(i) - K\_GR\_MIN_t(i)) - \ln(K\_GR\_MAX_t(i) \\ & - KGR_t(i)) - \ln(TREND\_K_t(i) - K\_GR\_MIN_t(i)) \\ & + \ln(K\_GR\_MAX_t(i) - TREND\_K_t(i))] \end{aligned} \tag{4.13}$$

where $TREND\_K_t(i)$ is the average observed rate of capital growth over a historical period; $RORN_t(i)$ is an estimated historic normal rate of return, defined as the average rate of return industry *i* exhibited while its capital stock grew at $TREND\_K_t(i)$; $KGR_t(i)$ is the simulated rate of capital growth defined by (4.10); $K\_GR\_MIN_t(i)$ is the minimum allowable rate of capital growth, set at the negative of $DEP(i)$; $K\_GR\_MAX_t(i)$ is the maximum allowable rate of capital growth, set at $K\_GR\_MAX_t(i) = TREND\_K_t(i) + s$, where $(0.05 < s < 0.15)$; $C(t)$ is a positive parameter determining the responsiveness of capital growth to movements in rates of return; and $F\_EEQROR\_I_t(i)$ and F_EEQROR_t are vector and scalar shift variables respectively allowing for shifts in industry *i*'s capital supply curve.

If the expected rate of return equals the normal rate of return ($EEQROR_t(i) = RORN_t(i)$), then via (4.13) the growth in capital through the year is at its trend value

($KGR_t(i) = TREND\_K_t(i)$) assuming that $F\_EEQROR\_I_t(i), F\_EEQROR_t$ and $DISEQ_t(i)$ are all exogenous at zero.

Capital growth will exceed trend if the expected rate of return is greater than the normal rate of return ($EEQROR_t(i) = RORN_t(i)$). Capital growth will never move above $K\_GR\_MAX_t(i)$ and it will never move below $TREND\_K_t(i)$. By choosing suitable values for these parameters, we can ensure that MONAGE always implies growth rates for capital in a realistic range.

Assuming that $F\_EEQROR\_I_t(i), F\_EEQROR_t$ and $DISEQ_t(i)$ are all zero, equations (4.12) and (4.13) imply that for industry *i* to attract sufficient investment funds to achieve a capital growth rate of $TREND\_K_t(i)$ in year t, it must have an expected rate of return on capital of $RORN_t(i)$.

For industry *i* to attract sufficient investment funds to exceed $TREND\_K_t(i)$ in year *t*, its expected rate of return must be greater than $RORN_t(i)$. If the expected rate of return for industry *i* is less than the observed in the historical period, then provided that there is no disequilibrium, equation (4.12) and (4.13) imply that investors will restrict their supply of capital to industry *i* to below the level required to generate capital growth at the historically observed rate.

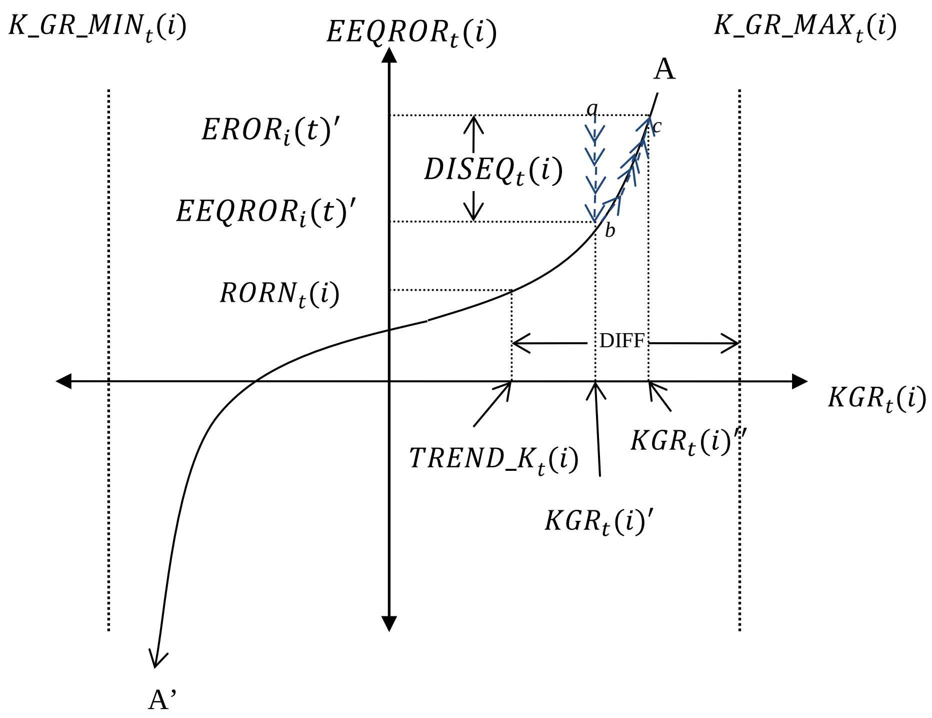
The capital supply schedule in Figure 4.3 shows the relationship between the equilibrium expected rate of return and the growth rate of capital for industry *i* in year *t*. In drawing *AA'*, we assume that $F\_EEQROR\_I_t(i)$ and $F\_EEQROR(t)$ are fixed at zero. If $F\_EEQROR(t)$ is non-zero, the capital supply curves to all industries are vertically moved by a uniform amount from the position of the AA' curve shown in Figure 4.3.

Non-zero values for $F\_EEQROR\_I_t(i)$ can be used to impose non-uniform shifts in the positions of the *AA'* curves. This is done endogenously in long-run comparative-static and historical simulations, as in our applications. The shift in the capital supply schedule results from the changes in confidence or perceived risks in industry *i*. An increase in confidence means that lower equilibrium expected rate of return are required for a given amount of investment or capital growth and vice versa.

Hence, the downward shift of *AA'* exhibits the increasing confidence of investors. As a result, higher growth rates of capital could be financed for the same equilibrium expected rate of return. In these simulations we do not use the *AA'* curves in the determination of the relationship between the rates of return and capital growth, hence (4.13) is turned off by the endogenising variable $F\_EEQROR\_I_t(i)$.

The difference between trend capital growth rates and maximum capital growth rates, *DIFF*, is used in setting the maximum allowed capital growth rates.

Figure 4.3 The Inverse Logistic Function: The equilibruim expected rate of return schedule for industry *i*



In policy and forecasting simulations for which the change in expected rate of return is central to the determination of capital growth rate, the sensitivity of industry *i*'s equilibrium expected rate of return to changes in industry *i*'s capital growth is controlled by $C_i(t)$ in (4.13). We denote the reciprocal of the slope of industry *i*'s capital supply curve at $KGR_t(i) = TREND\_K_t(i)$ by *SMURF* and assign a value. Then we can determine the parameter $C_i(t)$ as:

$$C_i(t) = SMURF \cdot \left[\frac{K\_GR\_MAX_t(i) - K\_GR\_MIN_t(i)}{(K\_GR\_MAX_i(t) - TREND\_K_t(i))(TREND\_K_t(i) - K\_GR\_MIN_t(i))}\right] \quad \textbf{(4.14)}$$

In year *t*, the year *t-1* capital growth data and the expected rate of return (either the simulated solution or observed data) will not typically give a point on the inverse logistic curve, *AA'*. Therefore, $DISEQ_t(i)$ will be non-zero. This disequilibrium will be gradually eliminated over time by reductions in $DISEQ_t(i)$ through the lagged mechanism, which will be described in section 4.4.6. As $DISEQ_i(t)$ approaches zero from above when $EROR_i(t) > EEQROR_t(i)$, or below when $EROR_i(t) < EEQROR_t(i)$, $EEQROR_t(i)$ must increase or decrease, respectively, given $EROR_i(t)$.

With the value of $EEQROR_t(i)$ determined in this way via (4.13), the only free variable in (4.13) is the rate of capital growth-$KGR_i(t)$. As $DISEQ_t(i)$ falls, $KGR_t(i)$ responds by increasing at a rate determined by the parameter values in (4.13). When $DISEQ_t(i)$ increases, $KGR_t(i)$ responds by decreasing at a rate determined by the parameter values in (4.13). Thus, capital growth rates in the horizontal axis of Figure 4.3 are determined by the elimination of disequilibria between the simulated expected rates of return and that given by the capital supply function.

For example, the MONAGE industries that are exhibiting capital growth rates below their historical trend values, given the expected rate of return, will have higher forecast capital growth rates and vice versa. In Figure 4.3, *a* denotes a simulated or observed point where the expected rate of return $EROR_i(t)'$ is larger than that which is required to sustain the rate of capital growth- $KGR_t(i)'$. As $DISEQ_t(i)$ falls in value over time (a movement from point *a* to point *b* in Figure 4.3), industry *i*'s $EEQROR_t(i)$ rises (a movement from point *b* to point *c* in Figure 4.3) resulting in an increase in *i*'s capital growth towards $KGR_t(i)''$. $EEQROR_t(i)$ can be thought of as investors' required rate of return – the minimum return required to convince them to invest to industry *i*. As investors respond to the higher-than-required capital growth rate by providing more funds, they become progressively less willing to invest in the marginal dollar until the required rate of return increases to the level of the expected rate of return, as depicted through *AA'* becoming steeper.

Once the rate of capital growth in a given period is known, the investment during the period can be calculated. Rearranging (4.11) we get:

$$INV_i(t) = K_i^{start}(t)[KGR_t(i) + DEP_i] \quad \textbf{(4.15)}$$

Instead, if the value for investment, which is traditionally known from 'outside' the model (i.e. the value of $KGR_t(i)$ is exogenous as in our historical applications), is made endogenous to move with the expected rate of return, it adjusts to eliminate disequilibria. In Figure 4.3, for given $KGR_t(i)'$, the expected rate of return would fall over time from $EROR_i(t)'$ towards $EEQROR_i(t)'$ as $DISEQ_t(i)$ lowers over time.

To be implemented in MONAGE, (4.13) needs to be in a form of:

$$del\_ror(i) = d\_f\_eeqror\_j(i) + d\_f\_eeqror + \frac{1}{C(i)}\left[\frac{1}{(K\_GR(i) - K\_GR\_MIN(i))} + \frac{1}{(K\_GR\_MAX(i) - K\_GR(i))}\right] del\_k\_gr(i) - \frac{1}{C(i)}\left[\frac{1}{(K\_GR(i) - K\_GR\_MIN(i))} + \frac{1}{(K\_GR\_MAX(i) - K\_GR(i))}\right] d\_trend\_k(i) \quad \textbf{(4.16)}$$

where $del\_ror(i) = del\_eeqror(i) - del\_rorn(i)$ and lower case variables are the changes of corresponding upper case variables. t subscript is dropped for simplicity.

We use change variables because $EEQROR_t(i)$, $RORN_t(i)$ and $K\_GR(i)$ are variables for which zero is a sensible value (their signs can be changed).

4.4.3 Actual and Expected Rates of Return

The calculation of the rate of return on capital in MONAGE starts with the calculation of the present value (*PV*) of a unit of physical capital as:

$$PV_t(i) = -\Pi_t(i) + \frac{Q_t(i)[1 - TAX_{t+1}(i)] + \Pi_{t+1}(i)[1 - DEP(i)]}{1 + INT_{t+1}[1 - TAX_{t+1}(i)]} \quad \textbf{(4.17)}$$

where $Q_t(i)$ is the rental rate on industry *i*'s capital (marginal revenue product or gross rental) in period *t*; $TAX_t(i)$ is an industry-specific estimated tax rate applying to capital income in period *t*; and $\Pi_t(i)$ is the cost of buying or constructing a unit of capital in year *t* for use in industry *i*;

In (4.17) there are two benefits in year *t*+1when the acquisition in year *t* of a unit of physical capital in each industry *i* would involve an immediate outlay of $q_i(t)$. The first benefit is the post-tax rental value, $Q_t(i)[1 - TAX_{t+1}(i)]$, of an extra unit of capital in year

$t+1$. The second benefit is the opportunity value, $\Pi_{t+1}(i)[1-DEP(i)]$, at which the depreciated unit of capital can be sold in year $t+1$. To derive a rate of return, $ROR_t(i)$, as the present value of one dollar of investment, we divide both sides of (4.17) by $\Pi_t(i)$ and get:

$$ROR_t(i) = -1 + \left[Q_t(i)[1-TAX_{t+1}(i)]/\Pi_t(i) - \Pi_{t+1}(i)[1-DEP(i)]/\Pi_t(i)\right]/[1 + INT_{t+1}(1-TAX_{t+1})] \qquad \textbf{(4.18)}$$

As discussed earlier, the determination of capital growth and investment in MONAGE depends on expected rates of return rather than actual ones in (4.18). Hence, in policy and forecasting simulations, it is assumed that capital growth and investment in year *t* are dependent upon expectations held in year *t* regarding $ROR_t(i)$.

COPS style models allow static (recursive) and rational (forward looking) expectations in the mechanism for determining capital growth and investment. These expectations are hypotheses concerning the formation of expectations which economists can adopt in the study of economic behavior. Under static expectations, investors expect no change in the tax rate ($TAX_{t+1}(i) = TAX_t(i)$) and that the rental rates $Q_{t+1}(i)$ and asset prices $\Pi_t(i)$ would increase by the current inflation rate INF_t. Therefore, the expected rate of return under static expectations $EROR\_ST_t(i)$ of $ROR_t(i)$ can be given by:

$$EROR\_ST_t(i) = -1 + [Q_t(ti)[1-TAX_t(i)]/\Pi_t(i) + (1-DEP(i))]/[1 + R\_INT\_PT\_SE_t] \qquad \textbf{(4.19)}$$

where $R\_INT\_PT\_SE_t$ is the static expectation of the real post-tax interest rate defined by:

$$R\_INT\_PT\_SE_t = -1 + [1 + INT_t(1-TAX_t(i))]/[1 + INF_t] \qquad \textbf{(4.20)}$$

4.4.4 Financial Asset and Liability Accumulation

The second important link for dynamics is that between current account flows and net foreign liabilities (*NFL*). Given that Mongolia's net foreign liabilities are a substantial share of GDP, moving MONAGE from one year to the next without imposing any economic shocks would still have impacts as annual interest payments on net foreign liabilities accrue. This 'momentum' effect is an example of an initial condition (i.e., substantial foreign debt) that matters in a dynamic framework but not relevant in comparative static analysis. In addition, NFL is an important variable for determining the measure of welfare, GNI, as it excludes that part of GDP paid to foreigners. MONAGE is equipped to trace changes in Mongolia's NFL which include net foreign debt (*NFD*) and net foreign direct investment (*NFDI*). Further discussions of Mongolia's international accounts will be presented in Chapter 5.

We assume that at the start of year *t+1*, the value of Mongolia's net foreign liabilities equals the value of *NFL* at the beginning of year *t*, plus aggregate investment by Mongolian industries during year *t*, minus savings during year *t* by Mongolian residents, and minus any net transfers from foreigners to the Mongolian government and residents.

$$NFL_{t+1}^{start} = NFL_t^{start} + INV\_I_t - S_t - NFTR_t \qquad \textbf{(4.21)}$$

Where NFL_{t+1}^{start} and NFL_t^{start} are NFL at the starts of year *t+1* and year *t*; and INV_I_t, S_t and $NFTR_t$ are an aggregate investment, savings and net foreign transfers in year *t* respectively.

The aggregate investment can be defined through changes in capital stocks according to (4.3) summing over industry dimension as:

$$INV\_I_t = \sum_i^I INV_t(i) = \sum_i^I [K_t^{end}(i) - K_t^{start}(i)(1 - DEP(i))] \qquad \textbf{(4.22)}$$

The aggregate savings in year *t* equals the average propensity to save (*APS*) multiplied by GNP in year t as:

$$S_t = APS_t GNP_t \qquad \textbf{(4.23)}$$

If we substitute (4.22) and (4.23) into (4.21), the value of NFL at the start of year *t+1* is:

$$\begin{aligned} NFL_{t+1}^{start} = NFL_t^{start} + \sum_i^I [K_t^{end}(i) - K_t^{start}(i)(1 - DEP(i))] \\ - [APS_t GNP_t + NFTR_t] \end{aligned} \qquad \textbf{(4.24)}$$

Net foreign liabilities are often expressed in foreign currency (USD in the case of Mongolia), while investment, saving and net foreign transfers are denominated in MNT. We note that foreign transfers are often expressed in foreign currency in official statistics but we convert them into MNT in MONAGE. Hence net foreign liabilities in foreign currency at the start of year *t+1* can be defined as:

$$NFL_{t+1}^{start} = NFL_{t}^{start} + \frac{1}{PHI_t}\left[\sum\nolimits_{i}^{I} \Pi_t(i)[K_t^{end}(i) - K_t^{start}(i)(1 - DEP(i))]\right] \\ - \frac{1}{PHI_t}[APS_t GNP_t + NFTR_t] \tag{4.25}$$

where $NFL_f^{start}(t+1)$ and $NFL_f^{start}(t)$ are net foreign liabilities in foreign currency at the starts of year *t+1* and *t*; PHI_t is the average exchange rate in year *t*; and the others are previously defined.

As we have added $\Pi_t(i)$ into (4.25), now we are dividing the value of capital into price and quantity terms so that *K* denotes the quantity of capital afterwards.

For period of τ year (i.e., say 7 years instead of one year) starting from year *t* (i.e., say 2005), net foreign liabilities in foreign currency at the start of year *t*+ τ (i.e., 2012) can be defined as:

$$NFL_{t+1}^{start} = NFL_{t}^{start} \\ + \sum\nolimits_{s=0}^{\tau-1}\left\{\frac{1}{PHI_{t+s}}\left[\sum\nolimits_{i}^{I} \Pi_t(i)[K_t^{end}(i) - K_t^{start}(i)(1 - DEP(i))]\right]\right\} \\ - \sum\nolimits_{s=0}^{\tau-1}\left\{\frac{1}{PHI_{t+s}}[APS_t GNP_t + NFTR_t]\right\} \tag{4.26}$$

Investment tends to be more volatile than capital stock. In NFL equations from (4.24) to (4.26), investment is expressed as the change of capital.

4.4.5 Public Sector Accounts

Public sector outlays, incomes, budget deficits and debt are often key variables in policy discussions in any country. Hence, they are given detailed treatments in some COPS style dynamic models. These treatments offer a wide range of approaches to the issue of budget neutrality or zero impact on the budget deficit. Budget neutrality reflects the idea that increases in any category of public expenditure and cuts in any types of tax must be offset by either decreases in other categories of public expenditure or increases in other types of taxes. The variables to be neutralized in the models could be public sector deficit, public sector debt, real national savings and real national wealth. Available instruments to achieve neutralisation are the rates of direct taxes on labour, capital and land; rates of indirect taxes on trade, production and sales; rates of various social security payments; and public consumption of commodities.

For example, in simulations of reducing or annulling VAT, we may assume that Mongolian government replaces lost revenue from reducing or annulling VAT by additional income taxes or introducing sales tax. Whether to change into sales tax or to keep and lower VAT has been a subject of economic debate in Mongolia for last few years. In this case, we need to be able to exogenise tax revenue and to endogenise the rate of income tax or a new rate of sales tax. In other words, in simulations of VAT reduction in Mongolia, we may need an assumption that the government replaces lost VAT revenue by a controversial increase in royalty rate. Thus, we can exogenise tax revenue and endogenise the rate of royalty.

MONAGE is capable of generating forecasts of public sector outlays, revenue and deficit/surplus with the inclusion of the detailed public sector account described in Chapter 5. As we emphasised earlier, one of the main function of the public sector account is that it is a tool for policy simulations. Policy simulations, in general, require the measures of tax collections and government expenditure so that modellers can implement assumptions such as revenue neutrality or zero impact on the budget deficit.

The public sector deficit is defined as the difference between total outlays and total revenue. Outlays include public consumption, public investment, transfer payments and other capital expenditure. Transfers consist of benefits to households, grants and net interest payments on the public debt. Revenue comprises of indirect taxes collected on sales to households, intermediate use, investment, exports, public expenditure, production and imports, direct taxes collected on labour, capital and land, and other revenue which includes income from public sector enterprises and/or privatisation.

There are no theoretical guidance for grants, other capital expenditure and other revenue components of the public sector account. Therefore, their movements have been related to that of GDP. For benefits and direct taxes we use specific driving factors such as the changes in overall wage rates, the total population, wage income, capital income and land income. Public investment is not for seeking profit. Two rules are readily available for public investment: follow industry investment as a fixed share or differ from an industry investment. These are achieved by turning on and off these rules by endogenising and exogenising shifter variables.

Public sector debt contains accrued loans borrowed by the government from foreigners and domestic residents. Public sector debt at the end of year t in foreign currency $\mathrm{FDATTGF\_F}_t^{end}$ can be defined as:

$$FDATTGF\_F_t^{end} = \quad FDATTG\_F_t^{start} + [-SAVINGS\_G_t + INVEST\_G_t - GOVASSETSALE_t - DDEBTISSUE_t]PHI_t \qquad \textbf{(4.27)}$$

where $FDATTGF\_F_t^{end}$ and $FDATTG\_F_t^{start}$ are public sector debt at the end and start of year t; $SAVINGS\_G_t$ and $INVEST\_G_t$ are government savings and investment respectively; $GOVASSETSALE_t$ is the privatization revenue or revenue generated from selling government assets; $DDEBTISSUE_t$ is the government debt issue; and $\mathrm{PHI_t}$ is the level of exchange rate.

4.4.6 Lagged Adjustment Processes

As we discussed in previous chapter, one of the following two assumptions is made about the national real wage rate and national employment in comparative static analysis:

(i) The national real wage rate adjusts so that any policy shock has no effect on aggregate employment (a typical long-run assumption); or

(ii) The national real wage rate is unaffected by the shock and employment adjustments (a typical short-run assumption).

One of the dynamic features of MONAGE is the allowance for a third, intermediate position, in which real wages can be sticky in the short run but flexible in the long-run, and employment can be flexible in the short-run but sticky in the long-run. For year-to-year policy simulations, it is assumed that the deviation in the national real wage rate increases through time in proportion to the deviation in national employment from its base case-forecast level. The coefficient of adjustment is chosen so that the employment effects of a shock are largely eliminated after about ten years. In other words, the benefits of favourable shocks such as outward shifts in export demand curves as in our case are realized eventually almost entirely as increases in real wage rates. This is consistent with macroeconomic modelling in which the non-accelerating inflation rate of unemployment (NAIRU) is exogenous. The idea is expressed through the equation:

$$\left(\frac{W_t^p}{W_t^f} - 1\right) = \left(\frac{W_{t-1}^p}{W_{t-1}^p} - 1\right) + \alpha\left(\frac{LTOT_t^p}{LTOT_t^f} - 1\right) \qquad \textbf{(4.28)}$$

where $W^p(t)$ and $W^f(t)$ are the real before-tax wage rate in the policy and forecast runs in year *t*; $LTOT^p(t)$ and $LTOT^f(t)$ are aggregate employment in the policy and forecast runs in year *t*; α is a positive parameter governing the speed at which employment in the policy simulation returns to its base case value.

Equation (4.28) states that while employment in the policy simulation is, above its base case forecast level, for example, the real wage rate moves further above its forecast level. This leads to lower demand for labour, and employment adjusts downward over time until it returns to the base case forecast level, at which point adjustment pressure on the wage rate ceases. The important implication of this idea is that favourable shocks such as outward shifts in export demand curves, as in our case, generate a short-run gain in aggregate employment and a long-run gain in real wages (Dixon & Rimmer 2002).

We have defined $DISEQ_t(i)$, the disequilibrium in the expected rate of return (the difference between the actual rate of return and investor expectations) in each industry *i*, in section 4.4.2. In modeling investment, it is often the case that a base year data and/or a simulated solution for the previous year imply disequilibria. In other words, the data for year *t-1* in relation to its expected rates of return and capital growth in industry *i* will often not produce a point on *i*'s AA' curve in Figure 4.3.

Hence, we assume $DISEQ_t(i)$ disappears over time according to lagged adjustment process:

$$DISEQ_t(i) = (1 - \Phi_i)DISEQ_{t-1}(i) \qquad \textbf{(4.29)}$$

where $DISEQ_t(i)$ and $DISEQ_{t-1}(i)$ are disequilibrium values in the current year and in the previous year; and Φ_i is a parameter with a values between zero and one, usually set at 0.5.

4.5 Additional innovations in technology and tastes

To facilitate applications of MONAGE, we add new technology, taste and twist variables to the equations which we have derived in the preceding chapter. To avoid repetitions, we use two examples of MONAGE, comparing them to their initial versions in ORANIMON. In the first instance, the percentage change equation of the demand for capital will be used as an example. The MONAGE equation of the demand for capital, an extended version of ORANIMON equation (3.19), is:

$$x1cap(i) - a1cap(i) = x1prim(i) + a1(i) - SIGMA1PRIM(i) \qquad \textbf{(4.30)}$$

$$* [p1cap(i) - p1prim(i)] - SIGMA1PRIM(i) * [a1cap(i) - a1lkn(i)] - [V1LAB\_O(i)/V1PRIM(i)] * twistlk(i)$$

where newly added variables $a1(i)$ and $a1lkn(i)$ and $twistlk(i)$ are all-input augmenting technical change in production, all-primary factor augmenting technical change and the cost-neutral labour/capital preference twist respectively.

$a1(i)$ is also added to the demand equations of all primary and intermediate inputs in production enabling us to impose a uniform change across all of the inputs.

Similarly, $a1lkn(i)$ is added to all primary factor demand equations enabling us to impose a uniform shift across all of the primary inputs. $twistlk(i)$ is a variable that captures changes not explained through conventional substitution between capital and labour as a result of relative price changes. With technical changes restricted to $twistlk(i)$, the percentage changes in the demand of capital and labour are dependent on the share of other factors in primary factor composition. Using this variable, we gain the ability to conveniently introduce change in technology affecting labour/capital choice by industries. In other words, it is a convenient device for introducing technical changes that alter the ratio of labour to capital.

Further, $a1cap(i)$ in (4.30) is defined as:

$$a1cap(i) = -[V1LAB\_O(i)/(V1PRIM(i) * (1 - SIGMA1PRIM(i)))] * twistlk(i) + f\_a1cap(i) + a1capgen \quad \textbf{(4.31)}$$

where $f\_a1cap(i)$ and $a1capgen$ are industry-specific capital saving technology change and the uniform change in capital productivity respectively and the others are previously defined.

$twistlk(i)$, in turn, is also defined by the equation:

$$twistlk(i) = twist\_i + ftwistlk(i) \quad \textbf{(4.32)}$$

where $twist\_i$ and $ftwistlk(i)$ are the scalar-shift for labour/capital twist and industry-specific labour/capital twist shift variables.

Equation (4.31) allows us to convert $twistlk(i)$ into the technical change in production. In forecasting, it is convenient to use twist variables to accommodate information on primary factor inputs. The twists, $twistlk(i)$, allow exogenously specified growth in aggregate capital stock or employment of labour to be accommodated by a cost neutral change in the capital/labour share in production. We can observe that a change in

$twistlk(i)$ can be converted into the capital saving technology change when the shift variables in (4.31) are set exogenously on zero. In policy analysis, we usually endogenise $f\_a1cap(i)$ and $a1capgen$ and exogenise $a1cap(i)$. This ensures that the capital saving technical changes in policy forecast is the same as those in baseline forecast. If we exogenise the twists in policy, then we may impart different technical changes in policy than in forecast. This is because capital/labour shares $(V1LAB\_O(i)/(V1PRIM(i))$ may differ between the policy and forecast runs. With different technical changes in policy simulation than in forecasting, a twist in policy may not be cost-neutral (Dixon & Rimmer 2004a).

Twists are used to fit observations which do not match the default (CES) theory of the model. *K/L* twists are equivalent to cost-neutral technological changes in capital (+ or -) and labour usage (- or +). However, these twists will not remain cost-neutral relative to forecast if the policy run uses a different combination of capital and labour technical shocks to accommodate the twist. Therefore, the twist that is used in the policy run is converted to accommodate, for example, a real wage target. This twist is enacted via endogenous changes to capital and labour technologies, e.g., *a1cap* in (4.31). Then in the policy run, the technologies are made exogenous and set to the forecast changes so that technical changes do not drift off base changes.

Equation (4.32) allows us to determine $twistlk(i)$ endogenously so that we can impose a uniform twist in the labour/capital ratios of the same sector to adjust capital demands to be consistent with the observed capital growth when there is a different level of dis-aggregation between MONAGE variables and the observed or forecasted values of those variables. Hence, it helps to facilitate historical and forecasting simulations.

In MONAGE, the import/domestic twist variable $twist\_src$ is also added to the number of equations, enabling us to introduce changes in technology affecting domestic/import choice by producers, investors and households. In addition, we will take an example of source-specific demands for input in capital creation to explain the use of $twist\_src$. Note that capital formation, capital creation and investment are used interchangeably throughout this thesis.

The MONAGE equation of a source-specific demand for investment commodity, an extended version of ORANIMON equation (3.43) is:

$$x2(c,s,i) = x2\_s(c,i) + a2(i) - \sigma2(c) * \{p2(c,s,i) - p2\_s(c,i)\} \qquad \textbf{(4.33)}$$

$$+ a2csi(c,s,i) - \sigma 2(c) * \{a2csi(c,s,i) - a2csi\_s(c,i)\}$$
$$- \{SDOM(s) - S2(c,"dom",i)\} * twist\_src(c)$$

where the added variables $a2(i)$, $a2csi(c,s,i)$ and $a2csi\_s(c,i)$ are all-input augmenting technical change, source-specific commodity saving technical change (equivalent of $a2(c,s,i)$ in 4.45) and composite commodity c saving technical change; and $twist\_src(c)$ is a cost-neutral change in technologies and preferences in favour of imported commodity c against domestic commodity c.

Intuitively, $twist\_src(c)$ may be thought of as a variable capturing changes not explained through conventional substitution between domestic and import sources as a result of relative price changes. Holding constant domestic and import prices and all other variables on RHS of (4.33), $twist\_src(c)$ is equal to the difference between the percentage change in demands of imported and domestically sourced commodity c ($x2(c,'imp',i) - x2(c,'dom',i)$). The percentage change in the ratio of import to domestic usage of commodity c will be discussed later in Chapter 7.

Shocks to the twist variable have no direct effect on the price of commodity input c in the capital creation, therefore they have no direct effect on the quantity of commodity c per unit of capital creation or on costs per unit of capital creation. Thus, shocks to $twist\_src(c)$ create cost-neutral changes in domestic/import ratio without affecting the overall inputs of commodity c.

Using $twist\_src(c)$, we are able to introduce technical changes which the initial impact is a certain percent increase in the ratio of imported to domestic inputs of commodity c to the production of units of capital.

Further, $a2csi(c,s,i)$ is defined by the equations:

$$a2csi(c,"dom",i) = [S2(c,"imp",i)/(SIGMA2(c) - 1)] * twist\_src(c) + f\_a2csi(c,"dom",i) \quad \textbf{(4.34)}$$

and

$$a2csi(c,"imp",i) = -[S2(c,"dom",i)/(SIGMA2(c) - 1)] * twist\_src(c) + f\_a2csi(c,"imp",i) \quad \textbf{(4.35)}$$

where $f\_a2csi(c,s,i)$ is a shifter variable and the others are previously defined.

f_a2csi allows the exogenisation of source-specific commodity saving technical change in industry i's capital creation, $a2csi$. $f\_a2csi(c, "dom", i)$ and $f\_a2csi(c, "imp", i)$ are used for domestic and import commodity saving changes respectively.

Equations (4.34) and (4.35) show the cost neutral changes are equivalent to domestic-and import-saving technical changes and convert the twists into source-specific commodity saving technical changes. These are calculated in the equations (4.34) and (4.35) when the shift variables are set exogenously on zero. In policy analysis, we usually endogenise $f\_a2csi(c, s, i)$ and exogenise $a2csi(c, s, i)$. This, in turn, ensures that the domestic and import-saving technical changes in policy forecast simulation are the same as those in baseline forecast. For all intermediate, investment, household and government uses of commodity c, $twist\_src(c)$ produces percentage changes in demand for the domestic and imported varieties via equations similar to (4.35).

We define $twist\_src(c)$ via:

$$twist\_src(c) = twist\_c + ftwist\_src(c) + twist\_eff(c) \quad \textbf{(4.36)}$$

where $twist\_c$ and $ftwist\_src(c)$ are general and commodity-specific twist shifters.

We determine $twist\_eff(c)$ through:

$$\begin{aligned} twist\_eff(c) = {} & C\_TWIST\_SRC(c) * [x0dom(c) - x0gdpinc] \\ & + ftwist\_eff(c) \end{aligned} \quad \textbf{(4.37)}$$

where $C\_TWIST\_SRC(c)$ is the sensitivity of $twist\_src(c)$ to growth in output relative to GDP; $x0dom(c)$ is domestic output of commodity c; $x0gdpinc$ is the change in real GDP; and $ftwist\_eff(c)$ is a shifter for twist effect.

The first term on the RHS of (4.37) allows for demand pressures when output of commodity c in the domestic economy is growing rapidly, there is a tendency for demand shifts to occur to towards imports and vice versa. Underlying reasons are shortages and lengthening queues that are not related to movements in relative prices. The second term, a shifter for twist effect, allows for twists in import/domestic mixes beyond those that can be explained by changes in relative prices and demand pressures.

Using (4.36) and (4.37) we can set according to:

$$twist\_src(c) = C\_TWIST\_SRC(c) * [x0dom(c) - x0gdpinc] \quad \textbf{(4.38)}$$

(4.38) will be effective when RHS variables of (4.36) are all set exogenously at zero. With the positive values of $C\_TWIST\_SRC(c)$ in (4.38), growth-related movements in demands for imports relative to domestic substitutes are introduced. When there is a rapid growth in the output of commodity c relative to GDP, it is likely to be associated with a twist in favour of imports of c and, conversely, that slow growth in the output of c is associated with a twist against imports of c.

Equations (4.37) and (4.38) also help facilitate historical simulation where we have observations of movements in import volumes. Endogenising $ftwist\_src(c)$ while setting $twist\_c$ and $ftwist\_eff(c)$ are exogenously at zero, we can determine the value of each $ftwist\_src(c)$ which can be interpreted as a difference between the $twist_src(c)$s necessary to explain observed movements in imports and the growth related import/domestic twist for each commodity c arising from changes in technology and preferences.

Let us now have a look at the innovation related to a composite commodity c saving technical change in industry i's capital formation- $a2csi\_s(c,i)$. It is defined as:

$$a2csi\_s(c,i) = ac(c) + fa2c(c) + fa2ci(c,i) \tag{4.39}$$

where $ac(c)$ is a uniform commodity c using technical and taste change shifter; $fa2c(c)$ and $fa2ci(c,i)$ are a general shifter for composite commodity input c saving technical change in investment and a shifter for composite commodity input c saving technical change in each industry i's capital formation.

Equation (4.39) states that the composite commodity c saving technical change in industry i's capital formation is determined by the uniform technical and taste change of three factors: the use of composite commodity c, the composite commodity input c saving technical change in capital formation, and industry-specific composite commodity input c saving technical change. $ac(c)$ is added to all demand equations where composite commodity c is used or consumed. When the shifters on RHS of (4.39) are set exogenously at zero, $a2csi\_s(c,i)$ is equal to $ac(c)$. The endogenisation of $a2csi\_s(c,i)$ allows the equalisation of technical change in all investment uses of commodity c. The main role of (4.39) is to allow MONAGE to reconcile the observed percentage movement in the demands for composite commodity c with the data on the percentage movement or supply of commodity c via a uniform commodity c-using technical and taste change across, when there is an inconsistency between observed demand and supply data for commodity *c*. If commodity *c* is used as a margin, then the associated technical change applies to margin services as well through equations similar to (4.39) across all users.

4.6 Further equations for facilitating historical and forecast simulations

In historical and forecasting simulations, there are usually three broad problems. The first problem is related to the use of information supplied in different dimensions of industry and commodity. For instance, when they carried out the first historical simulation for the Australian economy spanning 1987 to 1994, Dixon and Rimmer (2002) had to work out how to use data on: outputs disaggregated into 104 commodities; on consumption disaggregated into 38 commodities; and so on. The second problem is associated with resolving conflicts between information supplied from different sources. For example, when she analysed the structural changes in the Vietnamese economy during 1996 and 2003, Tran (2007) had to reconcile inconsistent data from different sources. The third problem is related to an extrapolation of results from historical simulations into trends which are used in forecast simulations.

To overcome these problems, COPS style modellers make allocations and adjustments within the models themselves instead of relying on external approaches, such using a spreadsheet. There are three disadvantages in the external approach. The first is related to data housekeeping. With external methods, it is easy to lose track of allocations and adjustments that are implemented. The second disadvantage is that the incorporation of data revisions and of new data, in particular those for historical simulations as in our application case, is labour-intensive and error-prone. The third is the fact that it is difficult to design allocative rules outside the model (Dixon & Rimmer 2002). Hence, COPS style models contain a number of equations which relate concepts for which there are reliable information to facilitate data conciliation and to resolve the conflicts within the model. Following this tradition, MONAGE has a number of equations for facilitating historical and forecasting simulations. It is also equipped with equations to extrapolate historical results into forecasts. Those equations allow us to link the extrapolation of a certain variable to forecast results for another variable. As MONAGE has the start (2005) and end (2012) of a two-period database, the level of disaggregation of many value variables is the same. Hence, the use of mappings related to overcoming the first two problems is not as extensive as those in previous historical simulation analysis carried out by others. MONAGE contains a large number of the equations to facilitate historical and forecasting simulations, and some examples of those equations are presented in next subsections. For simplicity, the index for time *t* has been excluded in our notations for the equations in next subsections. We note that the equations below are defined for each year *t*.

4.6.1 Linking equations for variables with same level of disaggregation

If the observed data are at the same disaggregation level as that of MONAGE, they are linked to the corresponding variables by the following two equations:

$$h_k^u = h_{obs\_k}^u + f_{H^u,gen} \tag{4.40}$$

where h_k^u is the percentage change in variable H_k^u (i.e., quantities or prices) for component *k* by user *u*; $h_{obs\_k}^u$ is a change in the observed value of H_k^u and $f_{H^u,gen}$ is a general scale shift variable.

$$\sum_k S_k^u h_k^u = h^u = h_{obs}^u \tag{4.41}$$

where $h_{obs}^u$is the percentage change in the observed aggregate value for H and S_k^u is the share of component k in aggregate value for H.

In our application of historical simulation, $h_{obs_k}^u$and h_{obs}^u are set exogenously and shocked with their observed changes over the simulation period. The endogenised variable $f_{H^u,gen}$ is determined by MONAGE to scale $h_{obs\_k}^u$ to satisfy (4.41).

Let us take an example of the variables for exports of commodity c to consider the specific case of generalized case in equation (4.40) .

To facilitate the use of information on values and prices of exports, we have added following equations:

$$w4(c) = x4(c) + p4(c) - phi \tag{4.42}$$

where $w4(c)$, $x4(c)$ and $p4(c)$ are the percentage changes in the export value, quantity, and price of commodity c respectively and phi is the change in exchange rate.

$$pf4(c) = p4(c) - phi \tag{4.43}$$

where $pf4(c)$ is the percentage change in foreign export price of commodity c and the others were previously defined.

$$pf4tot = p4tot - phi \tag{4.44}$$

where $pf4tot$ and $p4tot$ are the changes in overall export price in foreign currency and domestic currency, and was previously defined.

$$wf4(c) = wf4\_obs(c) \ + f\_wf4gen \qquad \textbf{(4.45)}$$

where $wf4(c)$ is previously defined; $wf4\_obs(c)$ is the observed change in the export value of commodity c; and f_wf4gen is a general scale shift variable for the value of exports.

$$pf4(c) = pf4\_obs(c) \ + f\_pf4gen \qquad \textbf{(4.46)}$$

where $pf4(c)$ was previously defined; $pf4\_obs(c)$ is the observed change in the export price of commodity c; and f_pf4gen is a general scale shift variable for the price of exports.

$$w4tot = \sum_{c}^{C} S4\,(c)w4(c) \qquad \textbf{(4.47)}$$

where $w4tot$ is the change in the value of exports; $S4(c)$ is the value weighted share of export of commodity c in total exports; and $w4(c)$ is the export value of commodity c in domestic currency.

Equations (4.42) to (4.44) relate changes in export values and prices in foreign currency to those in domestic currency for our year-on-year historical simulation where we utilise available statistics data from the NSO and UNCTAD in foreign currency. Equations (4.45) and (4.46) link observed data with MONAGE values on foreign currency prices and values. Equation (4.47) calculates change in aggregate exports value as the share weighted sum of the changes in values of exports at the commodity level. It also serves as the balancing condition as (4.41).

We note that in our one-off historical simulation between two base years, 2005 and 2012, observed values of $w4(c)$ are available, hence (4.42) to (4.45) will be changed to reflect it.

4.6.2 Linking equations for variables with different level of disaggregation

Some statistical data used in our application have different disaggregation levels than the MONAGE disaggregation. Each of the 44 MONAGE industries belongs to one of the 32 sectors or to one of more aggregated 20 composite sectors. Each of the 54 MONAGE commodities belongs to one of the 32 composite commodities or to one of more aggregated 20 composite commodities. For consumer prices, data are available for only 12 composite commodities and services. The different levels of disaggregation are handled through the three stage approach commonly used in COPS style modelling. Firstly, relevant variables are aggregated to the same level of aggregation as our observed data. Secondly, certain assumptions are used to relate those variables at the aggregated level to the variables at the disaggregated level. Thirdly, the data is scaled if there is an inconsistency.

Let us take the following example to illustrate the approach. If our observed reliable employment data is for 32 aggregate sectors, we aggregate 44 MONAGE industries into 32 sectors according to the formula:

$$x1lab(s) = \sum_{s}^{32} S_{x1lab(i)/x1lab(s)}\, x1lab(i) + f_{x1lab,gen}^{u} \qquad \textbf{(4.48)}$$

where $x1lab(s)$ is the percentage change in employment for each s aggregate sector of 32 aggregate sectors; $S_{x1lab(i)/x1lab(s)}$ is the share of employment hours of each industry i in sector s; $x1lab(i)$ is the percentage change in employment for industry i; and $f_{x1lab,gen}^{u}$ is the scale shift variable to adjust to the observed aggregate value when required.

We exogenise and shock the aggregate level $x1lab(s)$ variable with its observed values in the historical simulation. Changes in labour productivity are assumed to be the same for all industries within the same sector during the simulation period. This is a plausible assumption because the aggregation is for small manufacturing industries where their technologies are similar.

Labour productivity is commonly defined as output per hour worked or man hours in COPS style models. Hence, the percentage change form of labour productivity can be defined as:

$$labprod(i) = z(i) - x1lab(i) \qquad \textbf{(4.49)}$$

where $labprod(i)$ is the percentage change in labour productivity; and $z(i)$ and $x1lab(i)$ are the percentage changes in output and employment respectively.

Then we add following equation to MONAGE:

$$labprod(i) = labprod(s) + f\_labprod(i) \qquad \textbf{(4.50)}$$

where $labprod(i)$ and $labprod(s)$ are labour productivity in industry i and sector s; and $f\_labprod(i)$ is an industry- specific shifter.

When $f\_labprod(i)$ is exogenous and set on zero, $labprod(i)$ for each industry i would take same value as $labprod(s)$. If there is extra information regarding the productivity of certain industry in sector s, we use the shifter to utilise the information and in turn, it will impact on $x1lab(i)$ in (4.49).

The method is used for some other variables such as industry outputs when their observed level of disaggregation is different from the MONAGE disaggregation level.

4.7 Welfare measures

The effect on growth measured by the policy-induced deviation in real GDP can be considered as a measure for economic performance due to a proposed policy change. From the viewpoint of economic welfare, real GDP is often a poor indicator of the net benefits of the proposed policy change since positive deviations in real GDP can be offset by negative deviations in the terms of trade and increased foreign ownership of domestic capital. Alternatively, positive deviations in real GDP cannot capture additional benefits brought by positive deviations in the terms of trade and by increased domestic ownership of foreign capital. The developments in the Mongolian economy associated with the recent mining boom have heightened the need for using additional economic welfare measures in policy analysis. Hence we have included GNI, household disposable income and savings and national wealth in MONAGE.

4.7.1 Gross National Income (GNI)

The distinction between GDP (which measures income generated in a country) and GNI (which measures income belonging to the residents of a country) is crucial for analysing impacts of policy changes on living standard and socio-economic sustainability of Mongolia.

Nominal GNI is defined as the difference between nominal GDP and net income payables to foreigners. As defined earlier, net income payable to foreigners is the net interest payment on net foreign liabilities which is the sum of interest payments on net public and private foreign debts and dividends on net FDI. Therefore, the equation for nominal GNI in year *t* is:

$$GNI(t) = GDP(t) - ROIFOREIGN(t)NFL_f^{start}(t)PHI(t) \tag{4.51}$$

where $ROIFOREIGN(t)$ is the ratio of income payable to foreigners to NFL in year *t* and the others are previously defined.

Real GNI is calculated by deflating nominal GDP by CPI in year *t*. As GNI is a measure of Mongolians' income, using CPI deflator is appropriate for determining real GNI. MONAGE defines average propensity to consume out of GNI (*APCGNI*) as the ratio between nominal aggregate final consumption (C+G) and nominal GNI. The average propensity to save out of GNI (*APSGNI*) is consequently equal to one minus APCGNI (*APSGNI =1- APCGNI*).

GNI was formerly called gross national product (GNP). International organizations, such as World Bank, use GNI which is identical to GNP nowadays. Hence, GNI has replaced GNP as an official terminology in the SNA.

4.7.2 Household disposable income and household savings

Household disposable income in year *t* is defined as:

$$HOUS\_DIS\_INC(t) = GNI(t) - INCTAX(t) + TRANS(t) + FTRANS(t) \quad \textbf{(4.52)}$$

where $HOUS\_DIS\_INC(t)$ is household disposable income; $INCTAX(t)$ is government's income tax consisting of capital, labour and land taxes; and $TRANS(t)$ and $FTRANS(t)$ are transfers to households from government and foreigners respectively.

4.7.3 National Wealth

By combining the measure of NFL given in section 4.4.4 with the value of capital in each industry, MONAGE is able to generate results for national wealth at the start of each year *t* as:

$$Wealth(t) = \sum_{i}^{I} VCAP_i(t) - NFL_f^{start}(t)PHI(t) \quad \textbf{(4.53)}$$

National wealth is important in the assessment of welfare effects.

4.7.4 Cost difference indices

Movements in real GDP, real consumption, the GDP deflator, the CPI and many other macro variables are represented in MONAGE as percentage changes in Divisia indexes. In the Divisia formulation, the percentage change in a quantity or price index is calculated with weights that are averages of expenditure shares from the initial (2005) and final (2012) years. Divisia indices arise naturally in models like MONAGE which is represented and computed largely in a system of equations connecting changes in variables. Moreover, Divisia indices are attractive as they use up-to-date weighting schemes. However, it is possible for a policy shock to cause increasingly negative deviations in the Divisia index for aggregate capital without having negative deviations in the capital stock of any industry due to weight changes. The issue arising from weight changes is called the Divisia problem.

There are two indicators of overall welfare that are free from the Divisia problem: Laspeyres and Paasche cost differences in MONAGE. The Laspeyres cost difference is an upper bound on equivalent variation while the Paasche cost difference is a lower bound on compensating variation. When the Laspeyres and Paasche cost differences for year t are of similar size, either the cost differences or their average is an adequate measure of the net welfare effect of the proposed policy change. We use Laspeyres and Paasche price and quantity indices for the calculation of MONAGE variables to deal with the Divisia problem.

4.8 Summary

In this chapter we have presented theoretical framework and technical advances of COPS style recursive dynamic model for the Mongolian economy, MONAGE focusing on the dynamic features, closures and technical innovations. Examples were used to illustrate the technical advances as the MONAGE equation system contains a vast number of equations.

A CGE model consists of two parts: theoretical structure and database. Having defined the theoretical structures of ORANIMON and MONAGE, we now move on to databases and validity analysis in next chapter.

Chapter 5. Database for models and Validation tests

5.1 Preamble

In building a CGE model the crucial step is to set up a database formulated in a given year. The theories of the model we have discussed in previous chapters are largely a set of equations which describe how the cells of the input-output database move through time and move in response to given shocks. Even though IO data provide the core data for CGE models, there are many other types of data and information concerning every aspect of the economy. Thus the database creation requires painstaking interpretation of statistics and frequent interactions with statistical agencies (Dixon & Rimmer 2002). Fortunately, the National Statistical Office of Mongolia (NSO) provided various unpublished data and involved the author in its discussions and projects related to IOTs, enabling the creation of twin databases for 2005 and 2012.

5.2 Core database

Figure 5.1 is a schematic representation of the core database for our models. It reveals the underlying structure of both ORANIMON and MONAGE. From Figure 5.1, we can see that a core database consists of three parts: an absorption matrix, a joint production or MAKE matrix and a vector of import duties.

The column headings in the absorption matrix identify the following demanders:

(1) domestic producers divided into *i* industries;

(2) investors divided into *i* industries;

(3) a single representative household;

(4) an aggregate foreign purchaser of exports representing ROW;

(5) government demands; and

(6) changes in inventories.

The entries in each column show the structure of the purchases made by economic agents or users identified in the column heading. Each commodity *c* identified in our models can be obtained locally or imported from abroad. These source-specific commodities are used by industries as intermediate inputs to current production and capital formations, are consumed by households and governments, and are exported, or are added to or subtracted from inventories.

Figure 5.1 The basic format of the COPS-style CGE model

Absorption matrix

			Intermediate use	**Final use**				**Future use**
			1	2	3	4	5	6
			Industries	Investors	Household	Export	Government	Inventories
		Size	← I →	← I →	← 1 →	← 1 →	← 1 →	← 1 →
1	Basic Flows	↑ C×S ↓	V1BAS	V2BAS	V3BAS	V4BAS	V5BAS	V6BAS
2	Margins	↑ C×S×M ↓	V1MAR	V2MAR	V3MAR	V4MAR	V5MAR	n/a
3	Taxes	↑ C×S ↓	V1TAX	V2TAX	V3TAX	V4TAX	V5TAX	n/a
4	Labour	↑ OCC ↓	V1LAB					
5	Capital	↑ 1 ↓	V1CAP					
6	Land	↑ 1 ↓	V1LND					
7	Production Taxes	↑ 1 ↓	V1PTX					
8	Other Costs tickets	↑ 1 ↓	V1OCT					

C = Number of commodities (55 in 2005, 68 in 2012)
I = Number of industries (55)
S = Sources (domestic, imported) (Cockburn)
OCC = Number of occupation types (9)
M = Number of commodities used as margins (Cockburn)

	Joint production matrix
Size	← I →
↑ C ↓	MAKE

	Tariffs
Size	← 1 →
↑ C ↓	V0TAR

Source: Modified from Horridge (2014, p. 9)

Only domestically produced goods appear in the export column, as we assume that there is no direct exporting of imported commodities. *M* of the domestically produced goods is used as margins services (i.e., trade and transport), which are required to transfer commodities from their sources to their users. Commodity taxes are indirect taxes payable on the purchases made by users. As well as intermediate inputs, current production requires inputs of three categories of primary factors: labour (divided into *O* occupations), fixed capital, and land. Production taxes include output taxes or subsidies that are not user-specific. The ‘other costs’ are unspecified costs incurred by industries, e.g., the costs of holding inventories. It is also a useful device to include various miscellaneous taxes on industries, such as municipal taxes or charges.

Each cell in the illustrative absorption matrix in Figure 5.1 contains the name of the corresponding data matrix. For example, V2MAR is a 4-dimensional array showing the cost of *M* margins services on the flows of *C* commodities, both domestically produced and imported (*S*), to *I* investors.

Commodity flows are valued at basic prices; thus, they do not include any user-specific taxes or margins. The basic price is the amount receivable by the producer from the purchaser for a unit of a good or service produced as output, minus any tax payable (i.e., VAT and excise duties), and plus any subsidy receivable, on that unit, as a consequence of its production or sale. The basic price of an imported good (s = 'imp') is the landed-duty-paid price, i.e., the price at the port of entry just after the commodity has cleared customs. In COPS-style CGE models like ORANIMON and MONAGE, basic prices are uniform across all users, including all industries, for the reasons described above.

The producer price is the amount receivable by the producer from the purchaser for a unit of a good or service produced as output, minus VAT, or similar deductible tax, invoiced to the producer, but it includes other taxes and subsidies. It excludes any transport charges invoiced separately by the producer (UN 2009).

The purchaser price is the amount paid by the producer, excluding any deductible VAT or similar deductible tax, in order to take delivery of a unit of good and service at the time and place required by the purchaser. The relationship between the prices is shown in Figure 5.2 below.

Figure 5.2 Price relationship

	Output at basic prices
plus	taxes on products (excluding VAT)
less	subsidies on products
equals	**Output at producer prices**
plus	trade and transport margins
plus	non-deductible VAT
equals	**Output at purchaser prices/market prices**

Let us have a look at the components of Figure 5.1, starting from row one. In the first row, the first matrix, V1BAS, can be interpreted as the direct flow of commodity *c*, from source *s*, used by industry *i* as an input into current production. V2BAS shows the direct flow of commodity *c*, from source *s*, used by industry *i* as an input to capital formation. V3BAS shows the flow of commodity *c* from source *s* that is consumed by a representative household. V4BAS is a column vector and shows the flow of commodity *c* to exports. V5BAS and V6BAS show the flow of commodity *c* from source *s* to the government and change in inventories, respectively. Each of these matrices has *C*x*S* rows, one for each of *C* commodities from *S* sources. In standard applications, MONAGE recognizes one household, one foreign buyer, one category of public demand and one category of inventory demand. In the database, no imported commodity is directly exported or there are no re-exports. Hence, BAS4(c, s) is zero for s = 'imp'.

Costs separating producers or ports of entry from users appear in Figure 5.1 in the margins and sales tax matrices. The second row shows the values of margins services used to facilitate the flows of commodities identified in the BAS matrices in the first row. The commodities used as margins are domestically produced trade and transport services in our databases. Imports are not used as margin services. Each of the margin matrices has *C*x*S*x*M* dimension. This corresponds to the use of *M* margin commodities in facilitating flows of *C* commodities from *S* sources. Inventories (column 6) are assumed to comprise mainly unsold products, and therefore do not bear margins. As with the BAS matrices, all the flows in the MAR matrices are valued at basic prices. Consistent with the UN convention (UN 2009), we assume that there are no margins on services. In the case of margin flows, we assume that there is no cost separation between producers and users, i.e., there are no margins on margins. Hence, there is no distinction between prices received by the suppliers of margins (basic prices) and prices paid by users of margins (purchaser prices).

The third row shows commodity taxes on flows to different users. Unlike production taxes and import duties (both of which are included in the basic prices of commodities), these taxes can be levied at different rates on different users. In other words, commodity tax rates can differ between users and between sources. For example, the tax rate on a commodity used as an intermediate input to producers can be lower than that on household consumption of the same commodity. Some commodities such as tobacco products are subject to excise taxes. In the TAX matrices, negative entries indicate subsidies. For example, V1TAX('ElectWatHeat', 'dom') = -3,573.6 million MNT and

V1TAX('ElectWatHeat', 'imp') = -146.6 million MNT, respectively, in the 2005 benchmark database.

Payments by industries for *O* occupational groups are recorded in Figure 5.1 in the matrix V1LAB. The vectors V1CAP and V1LND show payments by industries for use of fixed capital and land. In our databases, we require non-zero land rentals only for agricultural and mining industries. Other industries are treated as though they use no scarce land. The vector V1OCT records other costs incurred by industries, e.g., the costs of holding inventories.

One of the distinguishing features of COPS-style models is the satellite multi-production matrix MAKE in Figure 5.1. A commodity in ORANIMON may be produced by several industries or an industry in ORANIMON may produce several commodities. The share of 'Meat products' commodity in total private consumption was significantly higher at 11.6 per cent in 2005. This commodity is produced by both 'Livestock' and 'Meat products' industries. MAKE is derived usually from the Supply Table, whose main part is a matrix of commodities by industry that shows which industry supplies or makes which product.

Together, the absorption and joint-production matrices satisfy two balance conditions. First, the column sums of MAKE, which are values of industry outputs, are identical to the values of industry inputs. Second, the row sums of MAKE, which are basic values of outputs of domestic commodities, are identical to basic values of demands for domestic commodities.

Table 5.1 ORANIMON database

Notation	**Name**	**2005**	**2012**
Sets			
COM	Commodities	55 Commodities	68 Commodities
IND	Industries	55 Industries	55 Industries
SRC	Sources	2 Sources	2 Sources
MAR	Margin commodities	2 Margin	2 Margin
OCC	Occupations	9 Occupations	9 Occupations
REG	Set REG regions	5 Regions	22 Regions
1. Coefficients in the core database			
V1BAS	Intermediate basic		COM*SRC*IND

V2BAS	Investment basic	COM*SRC*IND
V3BAS	Household basic	COM*SRC
V4BAS	Exports basic	COM
V5BAS	Government basic	COM*SRC
V6BAS	Inventories basic	COM*SRC
V1MAR	Intermediate margins	COM*SRC*IND*MAR
V2MAR	Investment margins	COM*SRC*IND*MAR
V3MAR	Household margins	COM*SRC*MAR
V4MAR	Export margins	COM*MAR
V5MAR	Government margins	COM*SRC*MAR
V1TAX	Intermediate tax	COM*SRC*IND
V2TAX	Investment tax	COM*SRC*IND
V3TAX	Household tax	COM*SRC
V4TAX	Export tax	COM
V5TAX	Government tax	COM*SRC
V1CAP	Capital Rentals	IND
V1LAB	Labour	IND*OCC
V1LND	Land Rentals	IND
V1PTX	Production tax	IND
V1OCT	Other costs	IND
MAKE	Multi-product matrix	COM*IND
V0TAR	Tariff revenue	COM

2. Parameters and elasticities

SIGMA0	Elasticity of transformation	IND
SIGMA1	Armington elasticity – intermediate inputs	COM
SIGMA2	Armington elasticity – capital inputs	COM
SIGMA3	Armington elasticity – household consumption	COM
SIGMA1PRIM	Elasticity of substitution for Primary factors	IND
SIGMA1LAB	Elasticity of substitution between labour types	IND
FRISCH	Frisch parameter	1
DELTA	Household marginal budget share	COM
EXP_ELAST	Export elasticity	COM

Table 5.1 shows two types of data in ORANIMON along with corresponding sets and dimensions in the base years of 2005 and 2012. The coefficients of the core database are obtained from input-output accounts, while we impose or use from different sources or estimate various types of parameters and elasticities.

The CGE database is in values, but updating of the database occurs via changes in prices and quantities. The equations, derived from utility maximization and cost minimization problems discussed in previous chapters, are satisfied with prices that are equal to one and the resulting quantities implied by the core data via calibration of the parameters or the introduction of shift variables. The equations in the models contain sufficient free parameters and shift variables so that they can be satisfied by the initial input-output data.

With setting up of the required core database in detail, we now move on to the construction of the ORANIMON database. We discuss parameters and elasticities for ORANIMON in section 5.5 separately.

5.3 Construction of ORANIMON Database

5.3.1 Input-output Data

Mongolia compiled its first input output table in 1963 during the communist era. Subsequent communist era tables were produced in 1966, 1970, 1977, 1980 and 1983. These tables were produced in accordance with the Material Product System used in member countries of the former Council for Mutual Economic Assistance (COMEC).

After the collapse of communism, the Material Product System was replaced by the United Nations System of National Accounts (UNSNA) framework in 1991. Mongolia compiled experimental input output tables in 1997 and 2000 in order to implement the System of National Accounts (SNA). Subsequently, in 2008, Mongolia compiled official IOTs for 2005 in line with the standards of UNSNA 1993. The starting point for the ORANIMON and MONAGE database was the 2005 IOTs constructed by the National Statistical Office (NSO) of Mongolia in 2008. The 15 sector IOT is available in the public domain in the National Statistics Office Yearbook 2008. However, unpublished 55-industry-commodity IOTs and related data were used in the creation of the first ORANIMON database. Fifty-five industries/commodities are listed in Appendix 1. In one of the first applications of CGE analysis involving the Mongolian economy, Fisher *et al*. (2011) used the same IOT data for assessing the macroeconomic consequences of the development of the OT copper mine by BAE's general equilibrium model of the world economy, MINCGEM. The country database for GTAP based on the same IOTs was prepared by Begg *et al*. (2011) and was included in GTAP 8 Database (2012). Further, the NSO compiled Supply and Use Tables (SUTs) for the year 2008 in 2011. Subsequently, it produced 2010 IOTs in 2013 and 2011, 2012 IOTs in 2014, and 2013 IOTs in 2015. The 2012 ORANIMON database is based on unpublished 2012 IOTs with more disaggregated industries and commodities. The NSO's IOTs for 2005 and 2012 both contain information listed in Table 5.2.

Table 5.2 IOTs

An industry-by-commodity multi-production matrix (source-specific with domestic and imported subdivisions)
A vector of the usage of labour (wages)
A vector of net operating surplus (or net mixed income)
A vector of indirect taxes on production
A vector of taxes on products
A vector of depreciation
A vector of private consumption
A vector of government consumption
A vector of consumption by not-for-profit organizations and institutions
A vector of gross fixed capital
A vector of net change in valuables
A vector of net change in stocks (working capital)
A vector of exports on FOB

NSO generously provided all supplementary data used for compiling two types of IOTs (competitive and non-competitive) in each year. These are listed in Table 5.3.

Table 5.3 Supplementary data

SUTs (2005 SUTs at producer prices; 2012 SUTs at both basic and producer prices)
Import matrices
Transport margin matrix
Trade margin matrices
Taxes matrix
Subsidies matrix
Net taxes matrix
Domestic VAT matrix
Import VAT matrix

VAT refund matrix
Import duty matrix
Export duty matrix
Domestic Excise tax matrix
Import Excise tax matrix

5.3.2 Checks, adjustments and calculations

Due to the requirements shown in section 5.2, the following adjustments and checks were made in seven stages. Each of these stages, further, comprises steps associated with different checks and adjustments undertaken. Figure 5.3 illustrates the check and adjustment process. In each stage, we alter part of the database created in the previous stage. Due to the availability of data, relatively fewer adjustments were made compared to some other studies in which extensive data manipulations were needed.

Stage One. All necessary data were stored in input data file through the TABLO-generated program, which combines data into a single input file. We identified extra columns and rows in SUTs and IOTs. Extra row vectors of Supply Tables (STs) are the row vectors reflecting different types of producers (output for own final consumption, output of unincorporated market producers and output of other non-market producers), and the row vectors of CIF/FOB adjustments on exports and direct purchases abroad by residents. Extra columns in ST were vectors of Imports (CIF), Trade margins, and Net taxes, and were used to calculate Total supply at Purchasers' price. We also identified extra rows in Use Tables (UTs). These include:

- CIF/FOB adjustments on exports
- Direct purchases abroad by residents
- Direct purchases in domestic markets by non-residents
- Wages
- Other production taxes
- Production subsidy
- Depreciation
- Net/Mixed income

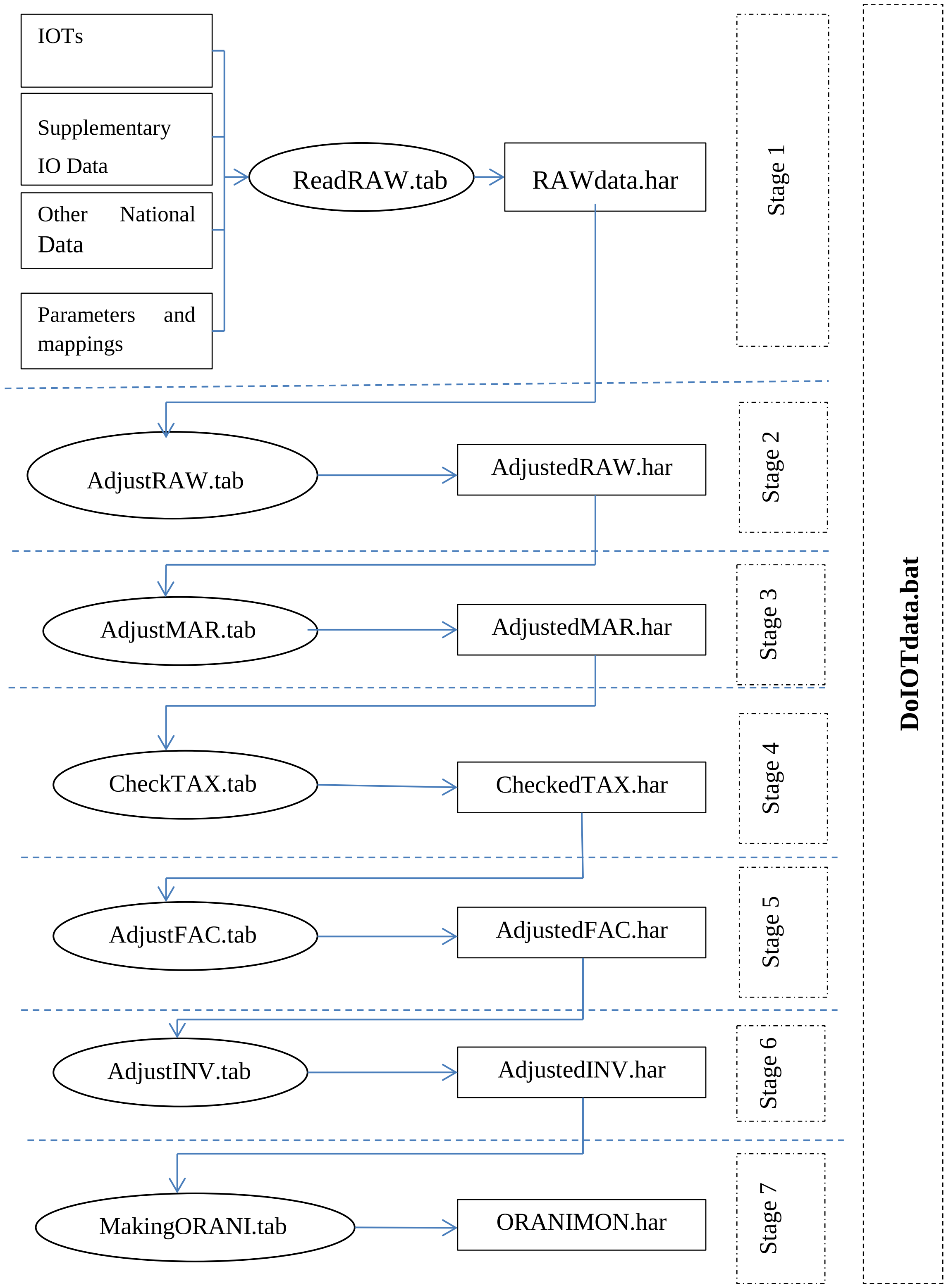
The 1993 SNA added another item in capital formation termed valuables, which are acquired and held as a store of value and not used primarily for production or consumption. In the 2005 IOT, there was a column vector for valuables. The range of products held as valuables is quite extensive and it is an area where existing goods may feature. Hence, we added valuables into inventories. There was a vector of consumption by not-for-profit organizations and institutions. This user consumes only the ‘Other community, social and personal service activities’ commodity. After inquiring about its composition from the NSO, we split it into households and exports accordingly.

Stage Two. The TABLO-generated program undertakes preliminary consistency checks between various types of matrices through three steps. The program also checks flows in SUTs and IOTs for balance conditions and sign restrictions in the first step. The balance conditions verify that total demand equals total supply and that total cost equals total output for each industry. IOTs and SUTs sometimes contain a few industries with negative gross operating surpluses. This is incompatible with the assumption of non-negative returns to fixed factors. Sign restriction checks verify these conditions. The following adjustments related to re-exports were undertaken in the second step. In this step, re-exported commodities were identified, because ORANIMON has no mechanism to accommodate re-exports, and, also, re-exports inflate export earnings and import expenditure. In 2005, there were three commodities with the nominal value of re-exports: ‘ClothingFurs’, ‘FuelPrd’ and ‘MachineryEqp’. The values of re-exports were removed from both exports and imports to inventories. As their values were relatively small, there were no additional complications which might have been related to the removal, i.e., import flows having a changing sign or getting negative values.

Step three diagnoses if there is an excessive inventory accumulation of commodities. Even where available data are model-compatible, atypical features like an unusually large inventory need to be adjusted. Mongolian IO data typically display a large movement in the inventory of ‘Livestock’. For instance, the 2012 benchmark IO data show an accumulation of inventories of ‘Livestock’ of MNT 480 billion, that is BAS6(‘Livestock’, ‘dom’) = MNT 480,191 million.

Unlike Australia and other meat exporting countries, young animals (less than one year old) are not slaughtered in Mongolia. According to the guideline for measurement of GDP in Mongolia (Dixon & Jorgenson 2013), young animals (born in the current year) are treated as work-in-process inventories and hence are accounted in livestock inventories along with other livestock (i.e., cows, etc.), excluding those accounted in capital (mostly male animals such as bulls are accounted in capital). When measuring the change in inventories, they are treated as an addition to the change. For instance, a lamb born in a certain year (say, spring in 2011) is counted as a production-in-process

Figure 5.3 Check and Adjustment process



in 2011. As a result, those young animals less than one year old are added into inventories (thus resulting in positive changes in inventories).

The benchmark data in both 2005 and 2012 also show large inventories in 'Meat', which is a joint commodity produced by the 'Livestock' and 'Meat products' industries. In accordance with the NSA, there should be no margins for services and inventories.

Hence, we carried out checks for margins and the changes associated with removal of re-export. Both 2005 and 2012 benchmark input-output tables show small amounts of margins and taxes associated with changes in inventories. In some cases the signs of the inventory change and the associated margins and taxes are opposite. For example, the 2012 IOTs show a de-accumulation of inventories of 'Other minerals' in the amount of MNT 926.3 million, that is BAS6('Other Minerals', 'dom') = - 926.3 million. At the same time, the margin matrices show trade usage of MNT 5.2 million associated with the flow of 'Other minerals' to inventories. Sign reversals of this type can occur when there is a change in the composition of inventories within an input-output commodity category or a change in the composition of the holders of inventories.

Because of sign reversals, margins and taxes associated with inventory changes are hard to model. For this reason, and because the values of the flows are quite small, we have eliminated inventory-related margin and tax flows. In the case of taxes we have simply assumed that there are no taxes on inventories. This poses no balancing problems. In the case of margins, we have transferred margins on inventories to V6BAS. This implies that we have allowed for direct inventory use rather than margin inventory use of margin commodities, thereby retaining input-output balance.

Stage Three. We disaggregate margins between those used to facilitate flows of domestic goods and those used to facilitate flows of imported goods. The disaggregation is performed as:

$$MAR(c,s,u,m) = MAR(c,u,m)\frac{BAS(c,s,u)}{\sum_s BAS(c,s,u) + TINY} \qquad \textbf{(5.1)}$$

where $MAR(c,u,m)$ is the margin service m used in facilitating the flow of commodity c to industry or final demander u; $BAS(c,s,u)$ is the basic-value flow of commodity c from source s (domestic or imported) to industry or final demander u; and $TINY$ is a very small number, 10^{-12}, to prevent divisions by zero.

Stage Four. Various checks for all types of taxes and subsidy matrices were completed. For instance, net taxes should equal taxes less subsidies, taxes should be the sum of all types of indirect taxes, and import duty matrix should be consistent with import matrixes, and so on.

Stage Five. Necessary adjustments for primary factors were made through TABLO-generated programs AdjFAC.tab. IOTs often lack adequate detail on value added for CGE modelling. The value-added section of IOTs provides the main data for ORANIMON and MONAGE on resource constraints. The 2005 and 2012 IOTs divide value added for each industry in Mongolia into four categories:

- Compensation of employees;
- Other net taxes on production;
- Consumption of fixed capital; and
- Net operating surplus.

We require, however, the measures of labour input, capital input in each industry and land input for land-using industries.

To adjust to the required measures, each ORANIMON industry was carefully analysed. Let us take an example of the Livestock sector. We started with setting other net taxes on production (MNT 1,039.8 million) in value added in production taxes, that is V1PTX('Livestock') = 1,039.8 million. The share of compensation of employees by the Livestock industry in its total value added was approximately 4 per cent in 2005, showing the nature of the industry, where the majority of herders are self-employers. When creating labour input, we adjusted the compensation of employees to that implied by the number of people employed in the Livestock industry times the official average wage rate for the industry. In order to define the use of land by agricultural industries, we analysed the GTAP 7 database, in which Mongolia was not included. We considered Kazakhstan's agriculture sector to be quite similar to that of Mongolia. Land accounts for around 30 per cent of total value added in the case of Kazakhstan's agriculture sector in GTAP 7. Hence, we allocated 30 per cent of the value added, excluding other net taxes, in production into the land input in Livestock industry. For 2012 ORANIMON data, we had more detailed and disaggregated data on employment, wages and other earnings from the NSO and the Economic Research Institute (ERI). Due to the increased labour share, the land share in primary input composition slightly declined to

27.3% in the 2012 ORANIMON database. We note that the share of ‘ctl’ (GTAP equivalent of ORANIMON Livestock) in primary factor endowment is 29% for Mongolia in GTAP 8.

Furthermore, we split labour input into nine occupation-specific inputs, namely:

1. Legislators, senior officials and managers
2. Professionals
3. Technicians and associate professionals
4. Clerical workers
5. Service workers and shop and market sales workers
6. Skilled agricultural and fishery workers
7. Craft and related trade workers
8. Plant and machine operators and assemblers
9. Elementary occupations

When splitting the industry labour input into occupation-specific labour inputs, we used additional data from the NSO and the Institute for Labour Studies (Wilson) of the Ministry of Labour in Mongolia.

Stage Six. Adjustments for investments were completed through the TABLO-generated program in this stage. In ORANIMON there is an investor for each industry, as we have discussed in the theoretical section. The investors buy commodities to construct capital specific to their industries. However, the original IO data have only a single investor for the whole economy, represented in a single column showing the commodity composition of the investment. We needed to split the investment vector into a matrix (55 columns corresponding to 55 industries). We created an investment matrix in four steps. In the first step, we calculated the value of total investment at purchaser prices – $TOTINV$. This should be equal to the GDP estimate of economy-wide investment from the SNA and thus the related automated check was done. In the second step, we calculated the share for each industry of value added in the total value added (GDP) – $SHRVALADD(i)$ and the share of capital input in the aggregate capital input – $SHRCAP(i)$. Then we defined the investment share of each industry – $SHRINV(i)$ as the average of two calculated shares – $(SHRVALADD(i) + SHRCAP(i))/2$.

In the third step, we allocated the total amount of investment in the economy to each industry according to the shares found in previous step: $TARGINV(i) = SHRINV(i)TOTINV$. In the fourth step, we calculated the commodity-composition in the investment of each industry – $Invest(c,i)$ as:

$$Invest(c,i) \; = \; COMINV(c) * TARGINV(i)/TOTINV \qquad \textbf{(5.2)}$$

Using the total investment by industries – $TOT(i)$ (column total), and by commodities – $TOT(c)$ (row total), we scaled rows and columns of the investment structure shares in (5.2).

<u>Stage Seven</u>. Through the TABLO-generated program, we created ORANIMON coefficients and parameters using the data constructed in previous stages and parameters from GTAP, as well as own estimations and calibrations. Let us take an example of investment again. In the previous stage, we estimated the investment structure shares. Since we have an imports table (a separate imports matrix as well as an imports part in the non-competitive IOT), we can determine a source-specific investment use of commodities at basic price – $INVBASIC(c,s)$. Thus, $V2BAS(c,s,i)$ can be found by:

$$V2BAS(c,s,i) \; = \; INVSHR(c,i) * INVBASIC(c,s) \qquad \textbf{(5.3)}$$

Similarly $V2MAR(c,s,m,i)$ and $V2TAX(c,s,i)$ were determined in this stage.

All stages are automated via a DOS batch file doIOdata.bat, shown in Figure 5.3 on page 141, altogether or individually.

5.3.3 Validation tests for ORANIMON

Validity is a key issue for stakeholders of a CGE modelling analysis. A CGE analysis can be considered valid when it: (a) is computationally sound, (b) uses accurate up-to-date data, (c) adequately captures behavioural and institutional characteristics of the relevant part of the economy, (d) is consistent with history, and (e) is based on a model that has forecasting credentials (Dixon & Rimmer 2013). This section is concerned with (a), for which test simulations are used exhaustively as a practical method.

Will an ORANIMON analysis be computationally sound?

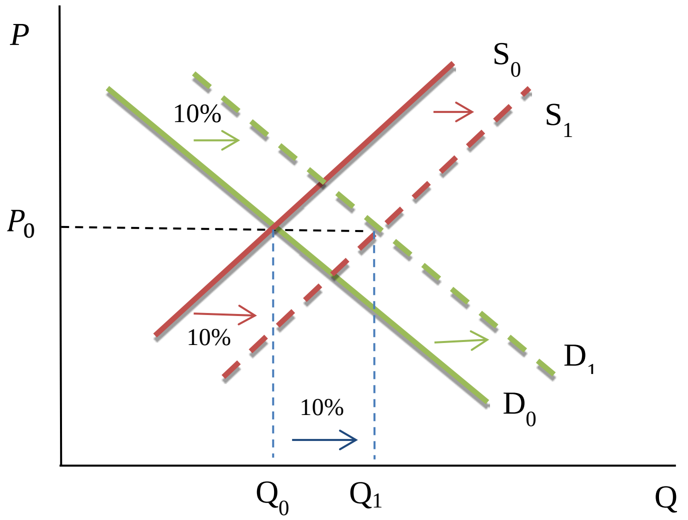
To answer this question, we need to conduct extensive test simulations. The most basic form of validation is checking for coding and data handling errors. One of the most effective methods is to run simulations for which the correct answers are known a *priori*, e.g., the base period values for the endogenous variables.

5.3.3.1 Homogeneity tests

The first two tests that we carried out were nominal and real homogeneity tests. If ORANIMON is set up with no nominal rigidities, then a 10% shock to all of the exogenous nominal variables should increase all endogenous nominal variables by 10%, while leaving all real variables unchanged. According to the theory in Chapter 3, almost all the price and value variables are endogenous. ORANIMON is a single country model in which the exchange rate and 'seemingly nominal' variables – foreign currency prices of imports – are exogenous. Foreign currency prices of imports do not involve domestic currency (MNT) in their definition, so that they are real variables in the setting of ORANIMON. Thus, the exchange rate is the nominal variable that should be shocked. As a result, all absolute prices change and no relative prices alter, hence there should be no real impacts.

The next commonly used test is a real homogeneity test. If ORANIMON is set up with constant returns to scale in all production activities, then a 10% shock to all real exogenous variables should increase all real endogenous variables by 10%, while leaving all nominal variables unchanged. For a real homogeneity test, shocks should be applied to exogenous quantities of factor inputs and exogenously specified real demand.

Figure 5.4 Real homogeneity test



In addition, we need to shift export demand curves 10% to the right to represent a 10% increase in the size of the world economy to match the 10% increase in the domestic economy in order to avoid induced real effects via changes in the terms of trade. When we move both demand and supply curves to the right reflecting a 10% increase in real demand and supply, we expect there is now a change in market price. Figure 5.4 shows a real homogeneity test.

The ORANIMON results for both 2005 and 2012 passed the tests.

5.3.3.2 Validation through the GDP Identity

We have described how GDP is determined from the income and expenditure sides in section 5.2. Using the data input file ORANIMON.har, the Tablo-generated program Formula.tab calculates aggregate variables in ORANIMON, including calculating GDP via both income and expenditure approaches. This check is powerful, because the two approaches involve distinct sets of variables that are linked through a large number of equations in ORANIMON. Table 5.4 shows the components of GDP and their respective shares calculated from ORANIMON in 2005.

Table 5.4 GDP components in ORANIMON, 2005 (MNT million)

Expenditure side

Components	2005	
	Value	Share in GDP (%)
Consumption	1,866,678	61.4
Investment	849,709	28.0
Government	344,488	11.3
Stocks/Inventories	57,586	1.9
Exports	1,429,886	47.1
Imports	-1,509,888	-49.7
GDP	**3,038,458**	**100.0**

Income side

Components	2005	
	Value	Share in GDP (%)
Land	250,360	8.2
Labour	972,671	32.0
Capital	1,411,739	46.5
Net indirect taxes	403,689	13.3
GDP	**3,038,458**	**100.0**

5.3.3.3 Other Checking Simulations

In our next check, we shifted export demand and import supply curves vertically upwards by 10%. This implies a 10% increase in the foreign currency price. If the exchange rate is exogenous and held constant, all endogenous nominal variables should be changed by 10%, while there is zero change in endogenous real variables.

5.3.4 Elasticities and parameters

Behavioural elasticities and parameters for ORANIMON are presented in Table 5.5, along with their algebraic notations. The adopted and estimated values for each of them are shown in Appendix 3 and Appendix 4. Thus this section's purpose is to describe the methodologies and sources, to discuss ongoing and potential analysis regarding elasticities and parameters.

Table 5.5 Elasticities and parameters

Name	Algebraic notation
Elasticity of substitution between primary factors	$\sigma 1PRIM(i)$
Elasticity of substitution between labour occupations	$\sigma 1LAB(o,i)$
Elasticity of transformation between industry outputs	$\sigma 1OUT(i)$
Armington elasticity of substitution between domestic and imported intermediate inputs	$\sigma 1(c)$
Armington elasticity of substitution between domestic and imported inputs to capital formation	$\sigma 2(c)$
Armington elasticity of substitution between domestic and imported commodities – household consumption	$\sigma 3(c)$
Export demand elasticities, by commodity and by trading partners	$\gamma(c)$
Household expenditure elasticities	$\varepsilon(c)$
Frisch parameter	$FRISCH$

We classify and analyse these elasticities and parameters in four groups. The first group is composed of the parameters related to input demand and commodity supplies in MONAGE. As discussed in Chapter 3, there are two tiers in the production technology, showing the relationship between each industry's inputs and its activity level, and the relationship between each industry's activity level and its outputs.

The first two elasticities in the first group are related to the substitutability between factors of production. The elasticities of substitution between primary factors, $\sigma1prim(i)$, are concerned with the relationship between each industry's primary inputs and its activity level. We adopted the values for the elasticity of substitution between primary factors from GTAP 7. Mapped values of elasticities of substitutability between primary factors for 55 industries are included in Appendix 3.

We note that the attempts have been made to estimate the elasticity of substitution between labour and capital across broad industry classes in the case of Mongolia. Firstly, we have attempted to extend an approach initially used by Phipps (1983), and further developed by Rimmer (1990), adopting the zero pure profit constraint, in keeping with the assumptions in ORANI. The attempts to utilize the panel estimation techniques with the fixed and random effects, as well as the error correction models, have been made. Due to lack of detailed data, these are still a work in progress. Ideally, we could estimate short- and long-run general equilibrium elasticities if there is adequately detailed data. However, we will see in the next chapter that the validity and sensitivity analysis reveal the robustness of elasticities– in particular, of the elasticities of substitution between primary factors.

For the elasticity of substitution between labours of different occupations – $\sigma1LAB(o,i)$ we adopted the MONASH value of 0.35. The last parameter $\sigma1OUT(i)$ in the first group is a vector of the elasticities of substitution which govern the choice of alternative outputs in industries with CET output functions. We borrowed the ORANI value of 0.50 across all industries for this study.

Second group elasticities are vectors of elasticities which govern the substitutability of commodities from different sources for producers, investors and households, respectively. ORANIMON treats domestic and imported products as imperfect substitutes, with the degree of substitutability governed by these Armington elasticities. These elasticities are important for determining the behaviour of trade flows and are explained in Chapter 3. However, they are very difficult to estimate, and the available estimates vary widely due to the availability and quality of data for their estimation, as well as the differences in the econometric models used to estimate them (Hertel et al. 2007; McDaniel & Balistreri 2003; Okagawa & Ban 2008). Due to the lack of any estimate of these elasticities of substitution between domestic and foreign sources of supply for Mongolia, we adopted the elasticities from the GTAP 7 database. We assume that the commodity-specific Armington elasticities are the same for producers, investors and households.

The third group of parameters is a vector of foreign demand elasticities for Mongolian exports – $\gamma(c)$. Export demand elasticities are crucial in determining the effects of changes in the volumes of exports on the changes of the terms of trade and hence in analysing the impacts of mining boom.

We calculated the export demand elasticities for commodities in ORANIMON through a synthetic method often used in COPS-style modelling. We note that the attempts to estimate export elasticities at the commodity level by trading partners have been undertaken as well. For this study, however, we use the general commodity-specific export elasticities.

In Chapter 3, ORANIMON distinguishes two major groups of export commodities. The first group of commodities, which exports 20% or more of their total sales, are considered individual exports. They have individual export demand curves, and thus require individual export demand elasticities. There are 28 such commodities in the ORANIMON benchmark database. The remaining 27 commodities are considered collective exports; their export volumes move with the average price index for the collective group.

For the individual exports, we calculate export demand elasticities using the estimates of importers' elasticities of substitution between different sources of imports and the theory suggested by Dixon and Rimmer (2002).

Foreign importers are assumed to be profit-maximisers who consider importing various commodities from different sources. In addition, they treat these commodities as imperfect substitutes. Finally, foreign importers choose import commodities from different sources to minimise their costs, subject to a CES function. Solving this optimisation problem results in Mongolia's export demand elasticity for commodity c with regard to its FOB export price as:

$$\gamma(c) = \left[\eta(c)S_{mng}(c) - \phi(c)\left(1 - S_{mng}(c)\right)\right]S_{FOB}(c) \qquad \textbf{(5.4)}$$

where $\gamma(c)$ is export demand elasticity for commodity c from Mongolia; $\eta(c)$ is the price elasticity of world demand for commodity c; $S_{mng}(c)$ is a share of Mongolia in ROW's imports of good c; $\phi(c)$ is a foreign importers' elasticity of substitution between alternative sources of supply; and $S_{FOB}(c)$ is the proportion of the FOB price of commodity c from Mongolia in the purchaser price of c in foreign countries.

(5.4) provides a way of calculating export demand elasticities that are consistent with the Armington parameters in a global model such as the GTAP.

If Mongolia is very small in international trade for commodity c ($S_{mng}(c) \approx 0$), and if there is no difference between FOB price and purchaser price of c ($S_{FOB}(c)$), then the export demand elasticity of commodity c ($\gamma(c)$) would be equal to the negative of the foreigners' Armington elasticity of substitution between alternative imports ($\phi(c)$). This is, in fact, the case for most of Mongolian exports commodities. However, Mongolia is likely to have non-trivial shares of the foreign markets for main commodities (notably, copper ore and cashmere articles) of its exports. Thus we calculated the values for $S_{mng}(c)$ and $S_{FOB}(c)$ to compute Mongolia's export demand elasticities.

The elasticities were calculated first for 55 commodities using the values of $\phi(c)$ from the GTAP 8 database on world imports and Mongolia's imports and exports of commodities. Mongolia's export share in world imports of commodity c was calculated as:

$$S_{MNG}(c) = \frac{Mongolia's\ Exports\ of\ c}{[World\ Imports\ of\ c - Mongolia's\ Imports\ of\ c]} \qquad \textbf{(5.5)}$$

Mongolia's export share in world imports of the 'wol' (wool, silk-worm cocoons) commodity in the GTAP was the largest at 2%, followed by 'omn' (minerals nec) and 'col' (coal) with 0.5 and 0.1%, respectively. In the calculations, we adopted the world price elasticity of commodity c pf -0.5 ($\eta(c) = -0.5$), the value for the share of FOB price in the importers' purchaser price of 0.7 ($S_{FOB}(c) = 0.7$) for all merchandise commodities and of 1 for all services, following Dixon and Rimmer (2002). The range of $\gamma(c)$ are included in Appendix 4. The last group in Table 5.5 contains elasticities and a parameter relating to household consumption. We adopted expenditure elasticities from the GTAP 7 database and then scaled them to satisfy the Engel aggregation property of demand systems. The aggregation requires that the sum of the products of income elasticity of each good and its budget proportion must equal unity.

The Frisch parameter shows the relationship between households' total expenditure and their supernumerary expenditure in the Klein-Rubin utility function. Frisch parameters are used in evaluating own- and cross-price elasticities of demand for households, and in calculating the changes in the subsistence component of household consumptions. The Frisch parameter is defined as the negative of the ratio between total final household expenditure and household supernumerary expenditure. The Engel law states that, as income increases, the proportion of income spent on foods decreases. Similarly, we can expect that the proportion of income spent on subsistence items falls as income increases. That is, on the other side of the token, the supernumerary proportion of household consumption rises as income increases. Hence, the Frisch parameters for developing countries are generally higher than those for developed economies. Likewise, the Frisch parameters for low-income groups are expected to be higher than those for higher-income groups in Mongolia. Even though MONAGE is capable of having a number of household types, we include, for this study, a representative household.

5.4 Additional Data for MONAGE

The database for COPS-style dynamic CGE models consists of three main parts:

(a) ORANIMON core data of the base years (2005 and 2012), which provide the initial solutions to MONAGE;

(b) Behavioural parameters, elasticities and miscellaneous indexing coefficients; and

(c) Ancillary base year data including industry capital stocks and interest rates (5.4.1), government accounts (5.4.2), balance of payments and the net foreign liability positions of the private and public sectors (5.4.3), all of which are required for the dynamic features that we detailed in Chapter 4.

5.4.2 Data and parameters for investment and the capital accumulation process

The data and parameters given in Table 5.6 are those required to operationalise the rate of return and capital accumulation theory, which we have discussed in Chapter 4, in MONAGE.

5.4.2.1 Capital stocks and capital growth rates

We employed the stepwise procedure typically used in COPS style dynamic CGE modelling to determine values of capital stocks in our benchmark data of year 2005.

i. Trends in output growth

Initially, we estimated various forms of trend equations (linear, logarithmic and quadratic) for the growth of value added in each sector between 1995 to 2005 and 1995 to 2012. Ideally, we can estimate trend equations which could be used for both 2005 and 2012 if we have adequate time series data. But the fits of the trend equations were poor and they overestimated 2005 trend growth rates.

Table 5.6 Data and parameters for the capital accumulation process

Description	Notation
Value of capital stock in the base year (2005 and 2012)	$K(i)$
Depreciation rates	$DEP(i)$
Trend growth rates of capital	$K\_GR(i)$
Rental price of capital in industry *i*	$Q_t(i)$
Difference between max. and trend growth rates of capital	$DIFF$
Average sensitivity of capital growth to variations in expected rates of return	$C(i)$
Level of the CPI – lagged	CPI_{t-1}
Level of the CPI	CPI_t
Interest rate	INT_t

Therefore, we calculated the average annual growth rates of value added for each industry between 1995 and 2005 and between 2000 and 2012 in order to determine trend in output growth based on the geometric average formulas:

$$z_{ave,2005}(i) = \left(\frac{Z_{1995}(i)}{Z_{2005}(i)}\right)^{1/10} - 1 \quad \textbf{(5.6)}$$

where $z_{ave,\ 2005}(i)$ is the annual average growth rate of value added in industry *i* during 1995-2005: $Z_{1995}(i)$ and and $Z_{2005}(i)$ are industry *i*'s value added in 1995 and 2005 respectively.

$$z_{ave,2012}(i) = \left(\frac{Z_{2000}(i)}{Z_{2012}(i)}\right)^{1/12} - 1 \quad \textbf{(5.7)}$$

where $z_{ave,2012}(i)$ is the annual average growth rate of value added in industry *i* during 2000-2012: $Z_{2000}(i)$ and and $Z_{2012}(i)$ are industry *i*'s value added in 2000 and 2012.

The annual average growth rates of value added in each industry for base years of 2005 and 2012 can be found in Appendix 2.

ii. Preliminary industry-specific capital growth

Secondly, we calculate the preliminary industry-specific capital growth – $kgr0_{2005}(i)$ – via:

$$kgr0_{2005}(i) = kgr\_mng_{\ 2005} + \alpha(z_{\ 2005}(i) - z_{ave,2005}) \qquad \textbf{(5.8)}$$

where $kgr\_mng_{\ 2005}$ is the economy-wide capital growth rate in 2005; $z(i)$ is the percentage change in output of industry i in 2005; $z_{ave,2005}$ is the share weighted average change in output (value added); and α is a parameter with a value less than 1.

The share weighted average change in output is defined as:

$$z_{ave,2005} = \sum_i SZ(i)\, z_{\ 2005}(i) \qquad \textbf{(5.9)}$$

where $SZ(i)$ is the share of industry *i*'s value added in gross value added; and the others are defined previously.

$kgr\_mng_{\ 2005}$ in (5.8) was calculated from the share weighted contribution identity to the real GDP growth of primary factors and the total factor productivity (TFP) as follows.

Let us define the contributions to $rgdp$ as:

$$rgdp = S_L l + S_K k + S_N n + S_T tax + a \qquad \textbf{(5.10)}$$

where $rgdp$ is the percentage change in real GDP; a is the percentage change in technology term, A or TFP; *l* is the percentage change in the employment of labour, L; *k* is the percentage change in aggregate capital, K or $kgr\_mng_{\ 2005}$; *tax* is the percentage change in net taxes; and S_L, S_N, S_K and S_T are the shares of returns to labour, land and capital and net taxes in the GDP.

We also calculated aggregate capital stock growth using The Federal Reserve Bank of the Eighth District (FRED) economic time series data on Mongolia capital stocks (FRED 2012) and compared this with the value resulting from our method .

iii. Adjusted capital growth rate

With $kgr\_mng_{\ 2005}$ determined, we adjusted the initial capital growth rates determined by (5.8) for each industry *i* through:

$$kgr1_{2005}(i) = \frac{kgr\_mng}{kgr\_w(i)} \quad \textbf{(5.11)}$$

where $kgr1_{2005}(i)$ is the adjusted capital growth rate; kgr_mng is the economy-wide capital growth rate; and $kgr\_w(i)$ is the capital rental weighted capital growth rate.

The capital rental weighted capital growth rate- $kgr\_w(i)$ is determined by:

$$kgr\_w(i) = \sum_{i} kgr0_{2005}(i)V1CAP(i) \quad \textbf{(5.12)}$$

where $V1CAP(i)$ is capital rental value in industry i; and the others are as previously defined.

The average of capital rental weighted capital growth rates taken from the ORANIMON database (4.74 %) was slightly higher than the economy-wide capital growth rate (4.72 %). Hence, we scaled down $kgr\_w(i)$ by a factor of 0.996.

iv. Rates of Return

In order to determine the rates of return in each industry, we define them as:

$$ROR_{2005}(i) = ROR\_MNG_{2005} + \beta(kgr1_{2005}(i) - kgr\_mng_{\ 2005}) \quad \textbf{(5.13)}$$

where ROR_MNG_{2005} is the economy-wide ROR; β is a parameter and the others as defined in (5.11).

The economy-wide ROR is equal to the real interest rate in 2005 and is taken from the WB's World Development Indicators (WDI) database.

v. Preliminary values of industry-specific capital stocks

After determining $ROR_{2005}(i)$, we can now calculate the initial values of industry-specific capital stocks as:

$$K0_{2005}^{start}(i) = \frac{V1CAP_{2005}(i)}{ROR_{2005}(i) + DEP(i)} \quad \textbf{(5.14)}$$

where $V1CAP(i)$ and $ROR(i)$ are the capital rental and the rate of return in each industry i; and the others are as previously defined.

vi. Defining required investments

In the next step, we determined the required investment for maintaining $K0_{2005}^{start}(i)$ by rewriting equation 4.17 derived in Chapter 4 as:

$$INV0_{2005}(i) \; = \; K0_{2005}^{start}(i)[kgr1_{2005}(i) + DEP(i)] \qquad \textbf{(5.15)}$$

where $INV0_{2005}(i)$ is the required investment for industry *i* during year 2005; $DEP(i)$ is a parameter giving industry *i*'s rate of depreciation; and the others are as defined in previous steps.

For $DEP(i)$, we relied on the detailed estimations of industry-specific depreciation rates by the Economic Research Institute (ERI) in Mongolia. It used extensive data from 2006 and 2011 national censuses of business entities carried out by the NSO with support from the WB and Asian Development Bank (ADB). The ERI analysed the composition of assets in each industry. The ERI's industry-specific depreciation rates reflect economic depreciation (actual loss of productive capacity rather than rates used for taxation purposes). We note that there is a difference between the implied economy-wide depreciation rate in the GTAP 8 for Mongolia (4%) and that of the ERI's database (6%). We also note that 6% is the commonly used depreciation rate in analysis related to Mongolian economic growth (Cheng 2003; Ianchovichina & Gooptu 2007).

vii. Adjusted values of industry-specific capital stock

In the next step, we adjusted the preliminary values of industry-specific capital stocks found in step v using the aggregate investment value of ORANIMON core data as:

$$K1_{2005}^{start}(i) = K0_{2005}^{start}(i)\frac{V2TOT\_I}{\sum_i \; INVR0_{2005}(i)} \qquad \textbf{(5.16)}$$

where $K1_{2005}^{start}(i)$ is the adjusted values of industry-specific capital stock in industry *i*; $V2TOT\_I$ is the aggregate investment value of ORANIMON; and the others are as defined earlier.

Since we adjusted the values of industry-specific capital stocks, we re-adjusted $INV0_{2005}(i)$ accordingly as:

$$INV1_{2005}(i) \; = \; K0_{2005}^{start}(i)[kgr1_{2005}(i) + DEP(i)] \qquad \textbf{(5.17)}$$

After this step, $INV1_{2005}/K1_{2005}^{start}$ ratio was 0.10 at the aggregate level.

viii. Balancing the matrices in the benchmark database

With newly determined investment values, we needed to balance the tables of our database via the RAS method, using a series of Tablo-generated programs. The RAS or bi-proportionate adjustment method was initially used for updating the direct requirements matrix by Stone (1962), who proposed its use in constructing UTs for IOTs (McDougall, RA 1999).

ix. Final capital growth rates

After balancing our database in the previous step, we got final investment values – $V2TOT(i)$, which in turn determine the final capital growth rates, through:

$$kgr(i) = \frac{V2TOT(i)}{K1_{2005}^{start}} - DEP(i) \tag{5.18}$$

x. Final capital stock values

With $V2TOT(i)$ and $kgr(i)$, we are now able to calculate the values of industry-specific capital stocks as:

$$K_{2005}^{start} = \frac{V2TOT(i)}{kgr(i)} - DEP(i) \tag{5.19}$$

$INV_{2005}/K_{2005}^{start}$ ratio was 0.09 at the aggregate level.

The results from the step-wise procedure described above are included in Appendix 5.5.

5.4.2.2 Parameters

We set the average sensitivity of capital growth to variations in expected rates of return at 1.0, the same as commonly adopted in COPS-style dynamic CGE models. Levels of capital asset prices for all industries are normalised at 1 in the base year. The maximum allowable rate of industry-specific capital stocks is needed to configure the capital supply functions, as we have discussed in previous chapter. We set the difference between maximum and trend growth rates (DIFF) at 20% in order to accommodate sudden increases in Mongolia during the mining boom. The values for the CPI in 2004 and 2005 are 0.91 and 1.0, respectively, showing inflation of 9.9%. The real interest rate is adopted at 8.72% from World Development Indicators for Mongolia in 2005.

5.4.3 Government account data

MONAGE has detailed government accounts:

(a) Revenues:

1. Corporate income tax (CIT)
2. Personal income tax (PIT)
3. Value Added Tax (VAT)
4. Social security tax (SST)
5. Export duties (ExpDuties)
6. Import duties (Tariffs)
7. Excise taxes (ExciseTaxes)
8. Other taxes on commodities (OthComTax)
9. Business fees (FeesCharges)
10. Royalty/Land use tax (Royalty)
11. Transfers and Grants from foreigners (ForeignGrant)
12. Other government revenues (NonTaxRev)

(b) Operating Expenditure

1. Government consumption (V5TOT)
2. Interest payment on foreign debt (INTFD)
3. Interest payment on domestic debt (INTDD)
4. Benefits paid to households (BENEFITS)
5. Subsidies (Subsidies)
6. Other expenditure (OTHEXP)

(c) Government saving (=a-b)

(d) Government investment

(e) Overall balance (=c-d)

(f) Financing (=e)

1. Net foreign borrowing (FDEBIT)
2. Net domestic borrowing (DDEBIT)
3. Change in assets (GOVASSETSALE)

Above, we report different categories in the government finance statistics. In MONAGE, some items may be identified in detail (such as production taxes), but others may be aggregated (such as returns on investment), while some items may serve as a balancing item (e.g., other expenditure). Table 5.7 describes the values of the government account items as of 2005 and 2012.

Table 5.7 Government account items in MONAGE (in millions MNT)

Item	2005	Sources / Notes
Corporate income tax	120,552.6	Ministry of Finance
Personal income tax	57,986.6	Ministry of Finance
Social security Tax	95,596.7	Ministry of Finance
Export duties	3,804.3	Ministry of Finance, General Customs Office
Import duties	53,170.0	Ministry of Finance, General Customs Office
Excise duties	78,959.2	Ministry of Finance
VAT	181,039	Ministry of Finance, IOT
Royalty	31,674.9	Ministry of Finance
Other taxes on commodities	52,094.9	Ministry of Finance
Business fees	16,270.2	Ministry of Finance
Transfer from foreigners	106,063.8	BoP data
Other government revenues	136,242.8	Balancing item, comprising mainly of non-tax revenues, and residuals
Total revenue	**837,858.3**	
Consumption	344,488	IO table
Interest payment on foreign debt	18,337.9	Ministry of Finance
Interest payment on domestic debt	2,344.9	Ministry of Finance
Benefits paid to households	183,981.2	Pension, other benefits including social assistance
Subsidies	8,118.1	Subsidies
Transfer to foreigners	787.1	BoP data
Other expenditure	42,231.6	Balancing item, comprising mainly of consumption expenditure unaccounted for by the government in IO table expenditure
Total operating expenditure	**600,288.8**	
Government savings	**237,569.5**	
Capital expenditure / Investment	89,818.1	
Net lending	74,490.3	
Overall balance	**73,261.1**	
Net foreign borrowing	89,980.0	
Net domestic borrowing	-7,115.8	
Change in Assets	4,953.1	

Besides the aggregated data, MONAGE budget database contains detailed budget revenue and outlays. The aggregated data are calculated from the GEMPACK header array data file on detailed government revenues and expenditures. This file contains time series data from 1995 to 2012.

In Mongolia, there are three traditionally subsidized industries: electricity, water, heating (ElecWatrHeat), land transport (LandTransprt) and crops (wheat, in particular). Table 5.8 contains the information regarding subsidies which were actually implemented in 2005 and 2012. We classify the first two as commodity subsidies and the third one as production subsidy.

Table 5.8 Government subsidies (million MNT)

Item	2005	2012	MONAGE industries
Subsidy on Energy	4,404.3	37,104.4	ElecWatrHeat
Subsidy on Public transportation	3,713.8	40,656.2	LandTransprt
Subsidy on Wheat	0	14,840.9	Crops
Total	**8,118.1**	**92,601.5**	

We found the sectoral composition of government investment in two stages. In the first stage, we explored the expenditures of each 'general budget governor'[4] and collected investment expenditure, as in Table 5.9 below.

Table 5.9 Budget investment (by general budget governors), 2005 (million MNT)

General Budget Governor	Budget investment	Share	Assigned industry
Head of the Secretariat of Mongolian Parliament	299.4	0.39%	Government Administration and Defence
Prime Minister	693.9	0.90%	Government Administration and Defence
Head of the Cabinet Office	2,325.7	3.01%	Government Administration and Defence
Minister of Foreign Affairs	652.3	0.85%	Government Administration and Defence
Minister of Finance	2,502.8	3.24%	Government Administration and Defence
Minister of Justice	1,134.4	1.47%	Government Administration and Defence
Minister of Environment	1,058.2	1.37%	Government Administration and Defence
Minister of Defence	355.8	0.46%	Government Administration and Defence
Minister of Social Security and Labour	3,086.4	4.00%	Health and Social Securities
Minister of Education, Arts and Culture	9,237.5	11.97%	Education
Minister of Trade and Industries	2,032.2	2.63%	Government Administration and Defence

[4] An official who is authorized to plan budgets for the area within his authority and allocate, oversee, manage and report on the execution of the approved budgets in accordance with legislation. Source: Mongolian Budget Law 4.1.36.

Minister of Food and Agriculture	675.2	0.88%	Broad Agriculture
Minister of Health	3,459.8	4.48%	Health and Social Securities
Chief judge	24.5	0.03%	Government Administration and Defence
Head of the General Council of the Courts	365.0	0.47%	Government Administration and Defence
Chief Prosecutor	88.4	0.11%	Government Administration and Defence
Head of the National Statistical Office	20.0	0.03%	Government Administration and Defence
Head of the Commission for Repression Imbursement	99.0	0.13%	Government Administration and Defence
Minister of Construction and Urban Development	790.8	1.03%	Construction
Minister of Roads, Transportation and Tourism	27,652.2	35.84%	Land transportation
Minister of Fuel and Energy	15,528.3	20.13%	Electricity, Heat, Water Supply
Deputy Premier	63.5	0.08%	Government Administration and Defence
Minister of State Inspection	110.1	0.14%	Government Administration and Defence
Minister of National Emergency	4,889.5	6.34%	Health and Social Securities
Total	**77,145.0**	**100.00%**	

In the second stage, we allocate government investment to each industry based on the information about the destination of government development expenditure above. Direct investment of the government is needed to derive aggregates consistent with government finance statistics.

The following items that appear in government finance statistics should be consistent with their international account equivalents:

- Interest payable on general government external debt;
- Grants to general government from non-residents;
- Net external financing; and
- External assets and liabilities.

5.4.4 Accounts with the rest of the world

MONAGE contains a quite detailed modelling of balance of payment account and changes in the international investment position. The data items required for these accounts include: trade balance account; investment income account; financial and capital accounts; stocks of foreign liabilities and foreign assets. We also need exchange rates in order to convert assets and liabilities from foreign currency to domestic currency, and the other way round when necessary.

The international accounts for Mongolia summarize the economic relationship between residents of Mongolia and non-residents. They provide an integrated framework for the analysis of an economy's international economic relationships, including its international economic performance, exchange rate policy, reserves management and external vulnerability. The international accounts in MONAGE are divided into the aggregated balance of payments (BOP) and the aggregated international investment position (IIP).

5.4.4.1 The Balance of Payments (BOP)

The BOP in MONAGE summarizes economic transactions between residents and non-residents during a specific time period – a year in our case. The different accounts within the BOP are distinguished according to the nature of the economic resources provided and received.

The BOP in MONAGE consists of three accounts: the current account (CA), the capital account (KA) and the financial account (FA). The CA shows flows of goods, services, primary income, and secondary income between residents and non-residents. The CA balance (CAB) shows the difference between the sum of exports and income receivable and the sum of imports and income payable, where exports and imports refer to both goods and services, while income refers to both primary and secondary income. The value of CA balance equals the savings-investment gap for the economy. With inclusion of the CA, MONAGE is able to generate year-to-year results for the current account deficit, which has an important implication for national economy.

The KA shows credit and debit entries for non-produced nonfinancial assets and capital transfers between residents and non-residents, while the FA shows net acquisition and disposal of financial assets and liabilities.

The sum of the balances on the current and capital accounts represents the net lending (surplus) or net borrowing (deficit) by the economy with the ROW. This is conceptually equal to the net balance of the financial account. Hence, the financial account measures how net lending to or borrowing from non-residents is financed.

The financial account plus the other changes account explain the change in the IIP between beginning and end-periods.

Table 5.10 Aggregated Balance of payment, 2005 and 2012 (in millions USD)

Item	2005	2012
Current Account Balance (A+B+C)	**87.5**	**-3,362.3**
A. Goods and Services account	-85.9	-2,653.6
Exports	1,485.9	3,013.3
Imports	1,571.8	5,666.9
B. Income account	-51.7	-947.7
Net compensation of employees	2.8	-243.5
Net income from abroad	-54.5	-704.2
C. Current transfer	225.2	239.9
Transfers from foreigners to Mongolians		501.8
Transfer from Mongolians to foreigners		-262.4
Capital Account Balance (KAB)	0.0	120.4
Financial account balance balance (FAB)	**48.8**	**4,809.5**
New foreign equity held by Mongolians (DIA)	0.0	-43.2
New foreign equity in Mongolia (FDI)	185.3	4,451.8
New foreign debt, government		124.5
New foreign debt, private		276.4
Errors and omissions		-195.5
Balance of Payment	***134.5***	***1,371.7***
Changes in foreign reserves	-134.5	-1,371.7
Additional information		
GDP current (million USD)	2,523.6	12,292.6
Share of Current Account Balance in GDP	*3.30%*	*-32.70%*
Official exchange rate (USD 1.0)	*1205.2*	*1357.6*
Real interest rate	*8.72%*	*5.45%*

Source: The Central Bank of Mongolia[5]

[5] The Central Bank of Mongolia, equivalent of the Reserve Bank of Australia

5.4.4.2 International Investment Position (IIP)

The IIP measures the stock of Mongolia's foreign financial liabilities and foreign financial assets at a point in time. The difference between foreign financial liabilities and foreign financial assets is referred to as Mongolia's net international investment position or net foreign liability (NFL).

The NFL represents either a net claim on or net liability to the ROW. Aggregated accumulation accounts, such as the KA, FA and other changes in financial assets and liabilities accounts (OCA), show the accumulation of assets and liabilities, their financing, and other changes that affect them. Accordingly, they explain changes between the opening and closing assets and liabilities in the IIP.

Whereas the CA is concerned with resource flows oriented to the current period, the accumulation accounts deal with the provision and financing of assets and liabilities, which are items that will affect future periods. That is, net liabilities imply that interest must be paid to foreigners.

The FA shows the net acquisition of financial assets and net incurrence of liabilities during the specified period. In contrast, the OCA shows flows that do not result from BOP transactions. The OCA covers changes in volume, other than BAP transactions, revaluation due to exchange rates, and other revaluation.

Table 5.11 International Investment Position, 2012 (in millions USD)

Item	2012
Assets	
DIA by Mongolians abroad	1,297.0
Foreign credit, total	5,183.0
Foreign credit, government	*4126.1*
Foreign credit, private	*956.9*
Total Foreign assets	**6,380.0**
Liabilities	
FDI stock in Mongolia	13,458.24
Foreign debt, total	4,451.90
Government debt	*2,184.10*

Private debt	*2,267.80*
Total Foreign liabilities	**20,599.50**
Net Foreign Liabilities	**14,219.40**
GDP in current USD	*12,292.6*
Net foreign liabilities as percent of GDP (%)	*115.7*
Foreign debt as percent of GDP (%)	*36.2*

Source: The Central Bank of Mongolia

5.5 Concluding remarks

In this chapter, we have presented databases for ORANIMON and MONAGE and have described the procedures, methods and sources to create them. IO data are the main input data to CGE models, as they play two important roles: providing an initial solution and serving as data for the evaluation of numerous coefficients in ORANIMON and MONAGE equations. In addition to IO data, our databases contain several other types of data on capital stocks, investment, depreciation and rates of return, government accounts and accounts with the ROW. Enhancing the information content of CGE models is crucial for the development of CGE modelling as a mainstream contributor to policy dialogue and a practical aid to economic decision making. With two base years' data in 2005 and 2012, the models can be used in different analysis: forecasting, policy, historical and decomposition.

Part III. Application

Overview

CGE models are useful for analyzing a developing small economy such as Mongolia, which recently transitioned from a centrally planned to a market-oriented economy.

Today, a market mechanism plays a crucial role for resource allocation in Mongolia. The prices of goods and services are determined by supply and demand in their respective markets. During the communist period, the government, a central planner, set and fixed the prices of all goods and services and planned the production, consumption and other economic activities of all agents. The fixed price system ensured the stability and predictability of the planned economy yet it eventually led to the demise of the system (Chuluunbat 2012).

Second, there was a major change in economic structure due to the transition. After 70 years of socialist development, the sudden collapse of communism in 1990 resulted in a massive economic contraction and devastation in the Mongolian economic structure and its industrial base between 1989 and 1993. The contraction was almost double that experienced by the United States during the Great Depression of the 1930s in terms of the plunge in domestic absorption (Boone 1994).

Third, positive or negative external shocks that have occurred to Mongolia recently are unprecedented. The sizes of those shocks were extremely large for a small economy like Mongolia's. For example, the value of Mongolian mineral exports increased by 125% in 2006 due to an unprecedented improvement in terms of trade. Hence, it is helpful to use CGE models for evaluating impacts and clarifying thinking relating to the likely consequences of shocks for which there is no equivalent historical example in the Mongolian economic context.

Metaphorically speaking, CGE models are like economic 'operating theatres' where modelers or users can be considered economic 'surgeons'. Of course, economic 'surgeons' do not remove 'an infected part' of the economy. They do have to look at all parts and interconnections of the economy inside and out, and can identify the issues and may offer policy alternatives. The models are not, however, remedies to Mongolia's economic problems or fortune tellers for the roller coaster economy. It is true that no single model could ever serve as a sole base for policy making on any significant issue.

There are some other aspects of the Mongolian economy, notably the lack in governance and institutional quality (particularly corruption), which the models do not capture directly. But we think that ORANIMON and MONAGE can serve as laboratories for analyzing important economic issues and simulating potential impacts of various shocks to help develop informed views on policy in Mongolia.

The application part of the thesis is concerned with the analysis of the mining boom during 2005-2012. We apply ORANIMON for studying the impacts of early commodity price increases, started around 2005, and the associated sudden growth of investment in the Mongolian economy. The analysis and findings are presented in Chapter 6. We will then move to the MONAGE simulations in Chapters 7. The MONAGE simulations are concerned with the analysis of the structural changes in the Mongolian economy between 2005 and 2012. Chapter 7 describes historical simulation, which provides detailed estimation of changes in structural variables such as technologies, preferences and the movement in export demand and supply curves and discusses decomposition simulation, which analyses the contributions of the structural changes to the macro- and industry-level economic performance of the economy during the period.

Chapter 6. A Resources Boom: ORANIMON Short and Medium run Simulations

6.1 Preamble

The simulations of ORANIMON serve three purposes: assessing impacts of a mining boom, evaluating a policy measure and providing validation in the modeling. The latter may be more important, as the dynamic model we have constructed can assess historical events in a complex fashion. According to Dixon and Rimmer (2013), validation in CGE modeling has multiple meanings and purposes. Put simply, it refers to a demonstration that results from ORANIMON have been computed correctly. Generally speaking, validation refers to a demonstration that a modeler's explanation of results is a legitimate reflection of the way the model works. Chronologically speaking, validation refers to a demonstration of a model's consistency with history. Thus we focus on the validation in ORANIMON and employ different types of validation analysis.

ORANIMON applications aim to identify differences between two alternative states of the Mongolian economy at some past point in time: one state in which the mining boom had occurred and the other in which the boom had not occurred. We have not made any attempt to identify how the economy might have evolved from a particular point in time (2005, say) to another under any particular set of assumptions.

In this chapter we describe the ORANIMON simulations on the Mongolian macro economy and on the economic sectors of the effects of the mining boom (mineral price increases and associated investment growth). The simulations are concerned with the implications of the mining boom for macroeconomic performance, employment, the balance of trade, the overall price level and the level of output in each ORANIMON industry. In addition, we can identify the winners and losers as a result of the mining boom. Further, these simulations enable us to investigate the 'Dutch disease' in the Mongolian economic context.

The chapter contains eight sections. Section 6.2 provides the historical background of economic episodes in the mid-2000s. In section 6.3 we introduce the setting up of the simulations. With twin simulations, we aim to separately evaluate the impact of mineral price increases and the combined effects of mineral price increases and investment growth on the Mongolian economy. BOTE-1 calculations are used to provide macroeconomic effects of a mineral price increase in section 6.4. Section 6.5 analyses the combined effects of a mineral price increase and an associated tide in investment. BOTE-2 analysis is employed for interpreting the ORANIMON results. We present industry level results from the simulations tracking winners and losers in section 6.6. In this section, the outcomes from the statistical methods to summarize the industry results at the economy-wide level are also provided. With the help of statistical analysis such as non-parametric tests and regressions we identify certain parameters that should be assessed by the systematic sensitivity analysis (SSA). The results of SSA are set out in section 6.7. The summary section 6.8 concludes the chapter.

6.2 Background

Mineral commodities have been Mongolia's largest export goods since the 1970s. Mongolia used to supply concentrates of copper, molybdenum and fluorspar, as well as raw uranium, to the Soviet Union during the last decades of the communist period. The Mongolian economy plunged into a recession and had negative growth over three consecutive years till 1993 after the collapse of communism in 1990. The economy eventually recovered with the substantial help of the mineral sectors – copper concentrate and gold, in particular. From the mid-1990s to 2005, mineral commodities contributed on average 40% of the value of total exports and played an important role in Mongolia's economic growth. During that period, mineral rent in terms of GDP share on average was 15%. Between 2006 and 2012, the annual share of minerals in total export and the annual contribution of total exports to GDP rose to 75% and 25% respectively, on average.

In terms of mining boom analysis, the Mongolian case offers rather an interesting scenario. Gregory (2011) characterized the recent mining boom as 'being driven, overwhelmingly, by export price changes and not export volume growth', as was not the case in the 1970s. Australia has experienced two different types of mining booms: one generated mainly by mineral export volumes during the 1970s, and the recent one generated overwhelmingly by the mineral price increase during 2000s, over a period of 30 years. However, Mongolia has experienced a boom in export prices of its main export commodities in the middle of experiencing another type of mining boom: export volumes increased largely due to the Tavan Tolgoi (TT) and the Ouy Tolgoi (OT) developments over a period of 10 years. Mongolia started experiencing the boom in mineral prices before these large projects came online. A spike in mineral commodity prices (in particular, a jump in copper prices) boosted export income and government revenue from 2005.

The copper price, at USD 3,170 per ton in January 2005, jumped to USD 8008 per ton in October 2007, resulting in an increase of 150%.

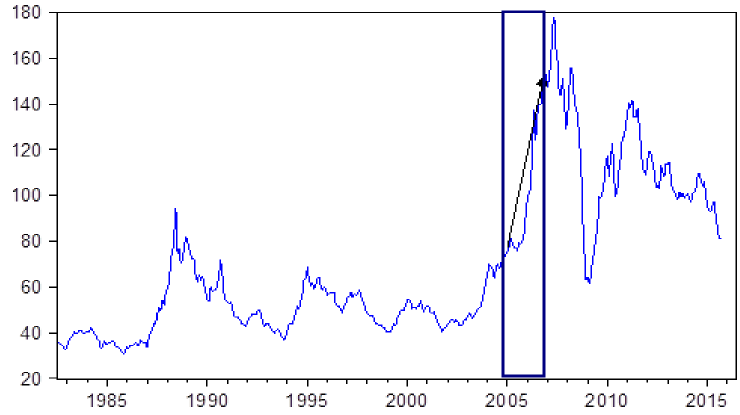
In the two years from 2005 to 2007, Mongolian government revenue and expenditure increased by 125% and 130%, respectively. During 2005-2007, the value of minerals exports doubled from USD 708.5 million to USD 1,408.4 million. The value of total exports increased almost 50% due to this two-fold rise in the value of mineral exports.

Figure 6.1 Copper and coal price, USD/t

Copper ores and concentrates have been the main breadwinning export commodities traditionally, as we emphasized in Chapter 1. However, in our base year 2005, gold was the largest export commodity, comprising 31.2% of total export revenue, with copper ores second, comprising 30.7%. The shares of oil, coal and other mining commodities in total export value were relatively lower, accounting for only 4.8% altogether.

In Figure 6.1 we display the historic price movements of copper and coal from 2005 to 2012. As is evident from Figure 6.1, a spike in the copper price occurred around 2006. This was followed by a spike in the coal price around 2008, although there was a sharp decline in both prices during the global financial crises (GFC). Both prices surged again after the GFC and peaked in 2011. Figure 6.2 below depicts the changes in the Reserve Bank of Australia (RBA)'s index of base metals prices in USD relative to the US GDP deflator. The figure reveals that there was a dramatic increase in the prices of base metals from 2005 to 2007. ORANIMON analysis is concerned with this unprecedented shock.

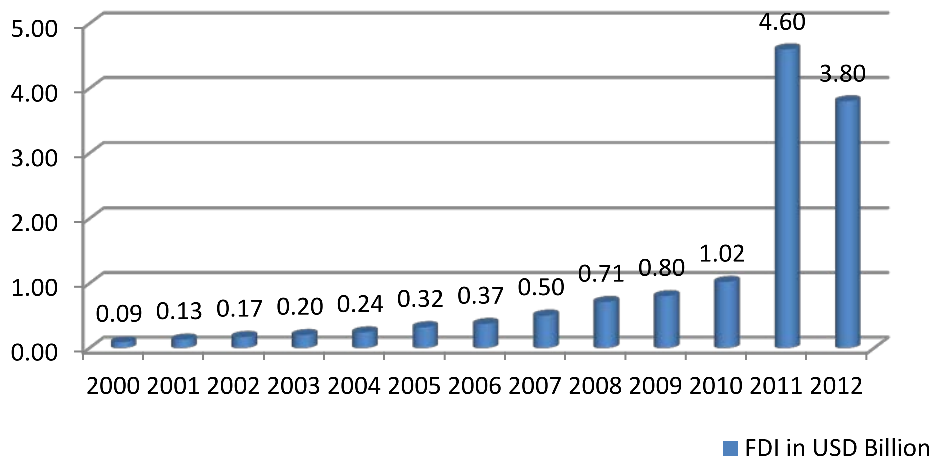
Figure 6.2 Base metals prices



Source: RBA

The higher international price of minerals was associated with foreign capital flows into the mining sector to finance its development. Spending of the sector rose not only because of higher income caused by higher prices, but also from increased capital investment, substantially financed by foreign capital inflow. In the base year of 2005, 66% of the total investment in the mineral sector was financed by foreigners.

Figure 6.3 Foreign Direct Investment (billion USD)



Source: NSO

FDI into the Mongolian mining sector doubled from its value of MNT 126.7 billion in 2005 to MNT 255.7 billion in 2007. However, most of the FDI into mining sector in 2006-2007 was related to exploration and construction activities.

Mining sector development brought an economy-wide lift in investment during 2006-2007. In fact, investment increased across the board and the aggregate investment change was close to 30% in real terms. In addition to mining, the investments in many industries such as Construction, Drinks, Hotels and Cafes and Financial intermediation industry grew by double digit percentages each year (NSO 2012). The ORANIMON analysis is also concerned with this surge in investment.

6.3 Setting up the simulations

6.3.1 Scenarios

In analysing the effects of the mining boom, initially in a comparative static setting, we take up two policy scenarios: SAVE and CONSUME. Higher profits, royalties and other additional taxes due to the mining boom could lead to more tax revenue being paid and this could in turn lead to more government spending and more spending by other companies (on intermediate and investment goods) who may indirectly benefit from the expansion of the mining sectors or may directly benefit from the reduced taxes they pay. Extra benefits received by households could lead to an increase in their consumption. The CONSUME scenario would reflect these spending effects. The scenario SAVE is an abstract scenario of enforced savings where private and public consumption is held constant.

6.3.2 Shocks

We have applied two sets of shocks in two stages to examine the potential effects of a mining boom on Mongolian economy. The shocks are:

(i) a 100% increase in world prices of minerals reflected by shift in the exports demand curve; and

(ii) a 100% increase in investment in the mineral sector; a 30% growth in economy-wide investment; and 30% rise in capital stocks across mineral sectors.

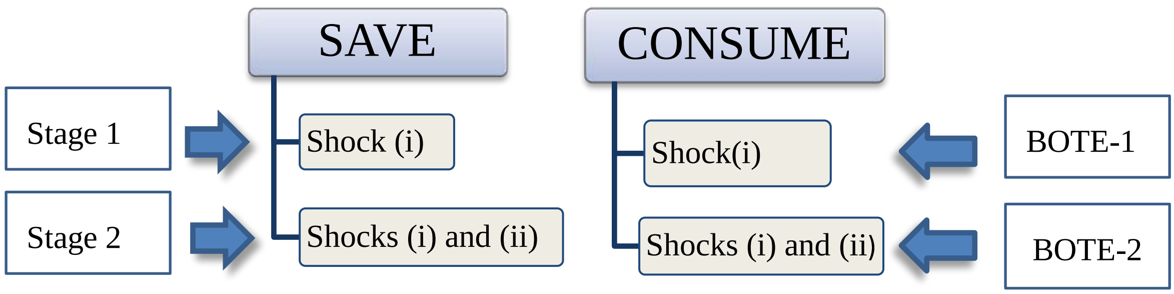
These shocks reflect significant changes in the Mongolian economy between 2005 and 2007. We calculated the composite value weighted increase in the prices of minerals that Mongolia had exported during 2005-2006. This would be reflected by shock (i). The details of the calculation can be found in Appendix 6.1.

The investment in the mining sector doubled during the period. Hence our first shock in (ii) is a 100% increase in investment across mineral industries. As we mentioned earlier, most FDI was for exploration and construction purposes. There was no remittance of foreign dividends. Hence, we can use GDP change as a welfare indicator in this case so that we do not look into GNI at this stage of our research. However, as we move on to MONAGE analysis we focus on GNI and take its change as a main welfare change indicator.

As we mentioned earlier, mining sector development induced an economy wide surge in investment during the period. We reflect this spill over effect in (ii) by increasing the aggregate investment by 30%. Adding a medium term flavour, we allow mining sector capital to increase by 30% due to the rapid growth of the sector. This is equivalent of the Gross Fixed Capital Formation (GFCF) in mining sector in 2006. The third shock in (ii) reflects this change. As we mentioned earlier, most of the FDI was for exploration and construction purposes. With increasing FDI, Mongolia's foreign liability accumulates rapidly. ORANIMON is not equipped with a foreign liability accumulation mechanism but its successor, MONAGE, has such a mechanism.

6.3.3 Simulation stages

Figure 6.4 Sequential simulation set up



We carry out our simulations in two stages sequentially. The first stage is concerned with the effects of mineral price increases and involves shock (i) in two scenarios. The first stage can be considered a short-run analysis. The second stage is concerned with the effects of both mineral price increases and investment surge and involves shocks in (i) and (ii). The second stage can be considered as medium-run. We present stylized analysis of the effects of these shocks on the variables sequentially, comparing two scenarios at the macro level first, and then following up with industry-level analysis. Figure 6.4 describes the simulation set up.

6.4 Macro effects of a Mineral Price Increase

In the first stage of our sequential simulation analysis, we carry out simulations with the shock in (i), the mineral price increase of 100%, in our two scenarios, SAVE and CONSUME. Then we interpret and compare the results in two scenarios, using the BOTE-1 model technique focusing on the differences between results. We shock the value-weighted export price index of mineral commodities (*p4minave*) by 100% in our two contrasting scenarios in stage 1.

6.4.1 Facilitation of the shock

In order to implement the shock in the model, we briefly remind how exports are modelled in ORANIMON and explain how we facilitate additional variables for implementing the shock.

There are two main categories of export goods in ORANIMON. These are:

- Traditional or individual; and
- Non-traditional or collective.

Similar to the Australian case, traditional exports consist mainly of mineral and agricultural products in Mongolia. Metal ores have been a dominant source of export revenue, comprising 63.4% of exports in 2005. In addition to minerals, livestock and some manufactured commodities such as clothing and furs, knitting and leather products, as well as some services like air transport, services to transport, communication are in the traditional exports group. Non-traditional exports consist of commodities for which their shares of exports in total sales are less than 20%. The value share of non-traditional exports was nominal at less than 1% of total exports in 2005. There are 27 non-traditional export goods, including agricultural commodities such as crops, forestry and logs, manufacturing commodities like drinks and other food products, as well as some services, such as technical service. For non-traditional exports, the price variable is an index of the prices of all non-traditional export goods and services.

Since, minerals are in the traditional group we look at the export demand equation for traditional export commodities. Adding the dummy and shifter variables to facilitate the shock into the percentage change in export demand for traditional export commodity c in Chapter 4:

$$\begin{aligned} x4(c) = fgen + f4q(c) + dum\_\min(m) * ff\_minerals - ABS[\gamma(c)] \\ \times \left(p4(c) - phi - f4p(c)\right) \end{aligned} \tag{6.1}$$

where $\gamma(c)$ is the export demand elasticity; p4(c) is the percentage change in price; and $fgen, f4q(c)$, $ff\_minerals$ and $f4p(c)$ are shift variables; and $dum\_\min(m)$ is a dummy variable.

$fgen, f4q(c)$ and $f4p(c)$ are discussed in Chapter 4. We add shifter $ff\_minerals$ and dummy variable $dum\_\min(m)$ in order to accommodate our shock into the model. The dummy variable takes the value of 1 for mineral export commodities and 0 for all other export commodities. Shift variable $ff\_minerals$ is used to shock the export prices of mineral commodities. We also have added another variable *p4minave* which is a value weighted index for the export prices of mineral commodities. In order to reflect the price increase, we swap *p4minave* with shift variable- $ff\_minerals$.

Export elasticities are important for our research purpose since the export elasticity may contribute to the determination of the size of any policy shock-related changes in export volumes and the terms of trade, with flow-on effects to GDP and consumption. We have discussed the elasticities of both ORANIMON and MONAGE models in detail in Chapter 5.

6.4.2 Closure

ORANI style models such as ORANIMON are able to generate both short run and long run simulations. Given a shock *A*, in an assumed macroeconomic economic environment *B*, a variable *C* will differ by *x* per cent in the short run or by *y* per cent in the long run from the value it would have otherwise been without shock, *A* (Dixon et al. 1984).

We need to introduce our assumptions about economic environment, *B* to enable our simulations. This is due to the three important macroeconomic aspects of the effects of shocks to the economy. ORANIMON needs guidance about them. These are:

- The extent to which induced changes in the flexibility of the labour market will be realized as changes in real wages or as changes in employment;
- The extent to which induced changes in national income will be realized as changes in aggregate absorption and/or as changes in balance of trade; and
- The extent to which induced changes in the real exchange rate will be realised as changes in the domestic inflation rate relative to foreign rate or changes in the nominal exchange rate.

In our first scenario in stage one, we have assumed that:

- ✓ Real wages are set exogenously and no change is given reflecting a short run.
- ✓ Changes in national income will be realized by changes in BOT and the aggregate domestic absorption or GNE is fixed.
- ✓ Changes in the real exchange rate will be realized through changes in the domestic inflation rate relative to the foreign rate and not through changes in the nominal exchange rate. Thus, the change in nominal exchange rate is fixed exogenously at zero in our simulation.
- ✓ Economy-wide and industry-specific capital stocks are fixed.

In our second scenario, the difference is that we have assumed the changes in national income will be realized by changes in the BOT, public and private consumption parts of GNE while the investment part of it is fixed.

6.4.3 BOTE-1 analysis

With twin simulations in two scenarios, we aim to separately evaluate the mineral price increase impact on the Mongolian economy. Table 6.1 provides the ORANIMON results from first stage simulations. We explain the ORANIMON macro results in Table 6.1 via a trade-focused BOTE model, in which Mongolia is assumed to produce good *g* domestically and exports it and imports good *v*, consumes *g* and *v* and creates capital from *g* and *v*.

We assume that economy-wide production of good *g* is via a constant-returns-to-scale function of capital and labour inputs and a primary-factor-saving technology shift term. Equation BOTE-1.1 shows their relationship and defines real gross domestic product (GDP) from an aggregate supply side.

$$Y = \frac{1}{A} F(K, L) \qquad \textbf{BOTE-1.1}$$

where Y is total output of good g produced; K is capital input; L is labour input and A is a technology shift term.

Table 6.1 Results from first stage simulations (% change)

Main Macro Indicators	SAVE	CONSUME
1 Real Household Consumption	0	31.42
3 Real Government Expenditure	0	31.42
4 Export Volume	1.6	-13.13
5 Import Volume	1.12	22.28
6 Real GDP Growth	0.33	5.73
7 Aggregate Employment	1.13	14.07
8 Nominal Wage	2.77	38.41
9 GDP Price Index	36.94	71.71
10 CPI	2.77	38.41
11 Export Price Index	71.5	81.44

In base year 2005, the factor payments to capital and labour contribute around 60% and 40%, respectively, of GDP at factor cost in Mongolia when scaling their contributions up, while leaving the contributions of net taxes out. In BOTE-1, we will use these shares, as our BOTE model is a simplified version of the full model.

In addition, we assume the factor payment to labour is determined by the value of its marginal product. The equation BOTE-1.2 illustrates this relationship. From the producers' viewpoint, the factor payment to labour is the cost of hiring a unit of labour. If additional revenue from employing a unit of labour is greater than the additional cost of hiring a unit of labour, producers hire more labour because the additional unit of labour generates profit to them and vice versa. Hence, domestic producers will hire labour until the factor payment to labour equals additional revenue from employing a unit of labour. At this point, the producers have hired the profit-maximising amount of labour. The marginal product of labour (MP_L) is the additional output produced as the labour input is increased by one unit in the economy. In a competitive output market, producers sell additional output at the market price of domestically produced goods-P_g. Therefore, the value of MP_L is equal to the MP_L times the price of domestically produced goods as in equation BOTE-1.2:

$$\mathrm{W} = P_g * \frac{1}{A} * F_L(K/L) \qquad \textbf{BOTE-1.2}$$

where W is a total factor payment to labour; P_g is the price of domestically produced good; A is a technology shift term; and $F_L(K/L)$ is the marginal product of labour (MP_L).

When labour increases, MP_L eventually falls due to the law of diminishing marginal returns. In our case of the short run when capital is fixed in a given production technology, an increase in labour lowers the K/L ratio. Hence, we recognise a positive relationship between MP_L and the K/L ratio.

The next equation, BOTE-1.3, shows the real wage, which is derived from BOTE-1.2 deflated by the consumer price. In the short run, real wages remain unaffected and employment adjusts to clear the labour market. Thus, the nominal wage or the factor payment to labour is indexed to the consumer price so that any deviation in consumer price is offset by a change in nominal wage.

$$RW = \frac{W}{P_c} = \frac{P_g}{P_c} * \frac{1}{A} * F_L(K/L) \qquad \textbf{BOTE-1.3}$$

where W, P_g, $F_L(K/L)$ and A are as previously defined; RW is a consumer real wage; and P_c is a consumption price (consumer price index) including prices of domestically produced good g and imported good v.

The explanation will be provided in following way. First, we will predict and compare the results in two scenarios SAVE and CONSUME. Next we will guess-estimate the direction of the movement in the variables and then calculate the effects in scenarios.

We assume that employment adjusts to clear the labour market in the short run and real wages ($\frac{W}{P_c}$) are fixed. Our first question to answer is how employment adjusts in the given shock.

In both scenarios, technology (A) and capital stock (K) are fixed reflecting a short run. What can we guess regarding the ratio $\frac{P_g}{P_c}$? Our shock is a huge increase in P_g because it includes the export price index. In Mongolia, mineral rent in terms of GDP share was just above 30% in 2005. A 100% increase in the mineral price may induce around a 30% increase in GDP price since GNE is fixed in scenario SAVE. We have held private consumption fixed in SAVE scenario. Therefore, we do not expect a large increase in P_c .

In the CONSUME scenario, both private and government consumption follow nominal GDP. Now the increase in P_g must be higher than the increase in the SAVE scenario. We approximate the share of private and government consumptions in GDP as 60% and 10%, respectively. Hence, we can expect a quite large P_c increase but we expect it to increase less than P_g because P_c includes price of imported good *v*.

Let us check our BOTE estimations from ORANIMON results in Table 6.1. In the SAVE scenario, the change in the price index of domestically produced goods or GDP deflator (good g in BOTE-1) is 36.9% and the change in consumption price is 2.8% resulting in the $\frac{P_g}{P_c}$ ratio (1.37/1.03 = 1.33) rising by about one third. Similarly in the CONSUME scenario, the change in price of good g (71.7%) is larger than the change in price of consumption (38.4%) causing $\frac{P_g}{P_c}$ ratio (1.72/1.38 = 1.25) to increase by a quarter.

As the ratio $\frac{P_g}{P_c}$ increases in both scenarios, MP_L must fall given the fixed real wage assumption in BOTE-1.3. We recognised a positive relationship between MP_L and the K/L ratio earlier. Hence, the K/L ratio must decline to achieve the necessary reduction of MP_L. For the K/L ratio to decline, employment of labour must increase in both scenarios. The mineral sector is relatively capital intensive. We approximate capital, land and labour shares of total factor costs in the sector as 60%, 25% and 15% respectively. Aggregate employment is increased by 1.1% in the SAVE scenario and 14.1% in the CONSUME scenario. With fixed real wages, CONSUME pushes out aggregate demand so that employment must rise relative to SAVE.

Our second question is to determine how GDP is changed and in which scenario the change in GDP is larger.

Let us find the GDP changes from supply side by introducing equation BOTE-1.4.

From the supply side, the percentage change in GDP can be measured from BOTE-1.1 as:

$$y = S_L l + S_K k - a \qquad \textbf{BOTE-1.4}$$

where y is the percentage change in real GDP; a is the percentage change in technology term, A; l is the percentage change in the employment of labour, L; k is the percentage change in aggregate capital, K; S_L and S_K are the shares of returns to labour and capital in GDP.

From our data base, leaving out land and indirect tax shares and scaling up for L and K, S_L and S_K are 0.4 and 0.6 respectively. We assume, in the first stage, that A and K are fixed so that $a = 0$ and $k = 0$. If we calculate y, using the shares and respective changes from this side in two scenarios:

$$y_{SAVE} \approx 0.4 * 1.13\% + 0.6 * 0.0\% = 0.46\%$$

$$y_{CONSUME} \approx 0.4 * 14.7\% + 0.6 * 0.00\% = 5.76\%$$

From the ORANIMON results in Table 6.1, we can see that the increases of real GDP in the SAVE scenario and the CONSUME scenario are 0.33% and 5.73% respectively. The discrepancies in out BOTE calculations are due to the omitted factors, i.e., indirect taxes. Yet it is clear that in both scenarios our BOTE calculations are quite close to the actual outcomes of the CGE model.

Let us introduce another equation to our BOTE system of equations. We define the factor payment to capital as determined by the value of its marginal product (MPK). Similar to BOTE-1.2, we thus write it as:

$$Q = P_g * \frac{1}{A} * F_K(K/L) \qquad \textbf{BOTE-1.5}$$

where Q is a total factor payment to capital; P_g is the price of domestically produced goods; A is a technology shift term; and $F_K(K, L)$ is the marginal product of capital (MP_K). In the short run, capital is fixed so that when labour increases as in our case, the K/L ratio declines. With the fixed capital, additional labour employment will increase MP_K. Hence, MP_K is a decreasing function of the K/L ratio.

The rate of return on capital can be calculated as the factor payment to capital divided by the price (index) of investment goods. Similarly to BOTE-1.3, we define:

$$ROR = \frac{Q}{P_I} = \frac{P_g}{P_I} * A * F_K(K/L) \qquad \textbf{BOTE-1.6}$$

where *ROR* is the rate of return on capital; P_I is the price (index) of investment goods; and *A*, Q, P_g and $F_K(K/L)$ are as previously described.

Our third question is how *ROR* is changed due to shock (i) in the two scenarios.

In the SAVE scenario, we fixed GNE so that we don't expect an increase in P_I. In the CONSUME scenario, we expect an increase in P_I due to an outward movement in aggregate demand, but less than the increase in P_g.

If we return to Table 6.1, the changes in P_g and P_I are 36.94% and 1.94% respectively in the SAVE scenario, resulting in an increase in the $\frac{P_g}{P_I}$ ratio (1.37/1.02 = 1.34). In the CONSUME scenario, the changes in P_g and P_I are 71.71% and 20.86% respectively also resulting an increase in the $\frac{P_g}{P_I}$ ratio (1.72/1.21=1.42). We notice that the increase in this ratio in the SAVE scenario is smaller than the ratio increase in the CONSUME scenario from both BOTE-1 and ORANIMON results.

We have learnt earlier that employment of labour has increased in both scenarios while aggregate capital is fixed; thus, there is a decline in the K/L ratio in each scenario. Due to the inverse relationship of the K/L ratio and MP_K, we anticipate that MP_K has risen in both scenarios. In BOTE-1.6, we know A is constant; both the $\frac{P_g}{P_I}$ ratio and $F_K(K/L)$ increased. Therefore, *ROR* must be increased, requiring Q to increase more than the price of investment goods, P_I.

Let us move on to analyse the expenditure side. Total output or real GDP from an expenditure side is defined by equation BOTE-1.7. Aggregate expenditure consists of four components: private household consumption, investment, government expenditure, and net exports.

$$Y = C + I + G + (X - M) \qquad \textbf{BOTE-1.7}$$

where *C* is household consumption; *I* is investment; *G* is government expenditure; (*X*-*M*) is net exports where *X* is exports and *M* is imports.

Private consumption accounted for just over 60% of Mongolian GDP in 2005. Investment (including changes in stocks) and government expenditure accounted for 30% and 11%, respectively. Mongolia's net export is typically negative and shows a trade deficit. In 2005, the trade deficit equalled -2.6% of real GDP.

The fourth question is to check if we can calculate the change in GDP from the aggregate demand side and to check the results with the calculations from the aggregate supply side.

We can re-write BOTE-1.7 in percentage-change form as:

$$y = S_E e + S_X x - S_M m \qquad \textbf{BOTE-1.8}$$

where *y* is the percentage change in real GDP; *e* is the change in real domestic absorption; *x* is the percentage change in aggregate exports; *m* is the percentage change in aggregate imports; S_E, S_X, and S_M are the shares of domestic absorption, exports and imports in the GDP. S_E, S_X, and S_M are1.027, 0.471 and 0.497, respectively, in our data base. Domestic absorption or gross national expenditure is composed of *C*, *I*, and *G* $(E = C + I + G)$.

We expect imports to increase due to our shock. If we compare the two scenarios for imports, we expect higher imports in the CONSUME scenario than in the SAVE scenario, as imports increase as domestic absorption rises.

Using shares of its components (0.61, 0.11, and 0.28, respectively), we find the changes in E are 0 in the SAVE scenario and 22.7% in the CONSUME scenario.

If we calculate *y* using the shares and respective changes in both scenarios:

$$y_{SAVE} \approx 1.027 * 0.0\% + 0.471 * 1.6\% - (0.497 * 1.12\%) = 0.38\%$$

$$y_{CONSUME} \approx 1.027 * 22.7\% + 0.471 * (-13.13\%) - (0.497 * 22.28\%) = 6.05\%$$

If we compare these BOTE calculations from the aggregate supply side in BOTE-1.4 to the ORANIMON results in Table 6.1 provided at the beginning of the section, the GDP changes in both scenarios are quite close to the ORANIMON results. It may indicate the accuracy of the BOTE calculations, on the one hand, and validate the results of ORANIMON, on the other hand.

Our BOTE model does not contain an equation for GNP. We relate C to GDP via the average propensity to consume (APC) as:

$$C = APC * Y \qquad \textbf{BOTE-1.9}$$

where C, G and Y are private consumption, public consumption, GDP; and APC is the average propensity to consume.

The ratio of private to public consumption spending is defined as following:

$$\frac{C}{G} = \Gamma \qquad \textbf{BOTE-1.10}$$

where *C* and *G* are as previously defined; and *Γ* is the ratio of real public consumption to real private consumption.

In the CONSUME scenario, we endogenize *C* and *G* by exogenizing *APC* and *Γ*. Therefore, *G* follows *C* and *C* follows *Y*. Since *Γ* is constant (exogenous), the percentage changes in *C* and *G* are equal. With constant *APC*, ORANIMON projects that real private and public consumption would be 31.4% higher as can be seen from Table 6.1. But it projects the real GDP change as 5.73%. Why? We will explore this relatively higher increase in consumption by introducing new BOTE equations.

We have assumed that changes in GDP will result in the balance of trade (BOT) changes in the SAVE scenario and in changes in BOT and public (*G*) and private (*C*) consumption parts of the aggregate absorption in the CONSUME scenario. Next, we move on to equation BOTE-1.11 to determine the movement in the BOT. From BOTE-1.4 and 1.8, we see that total output or real GDP increases by close to 0.33% and 5.73% which are the ORANIMON results in the first and second scenarios respectively. If we go back to BOTE-1.8, we can see that the net exports $[0.471 * 1.6\% - (0.497 * 1.12\%) = 0.19\%]$ is increased on par with the real GDP (0.33%) in the SAVE scenario. In this case, the BOT improves to satisfy the identity. In the CONSUME scenario, however, total output increase (5.73%) is much lower than the increase (31.42%) of consumption components (*C* and *G*). This clearly indicates that the BOT must have deteriorated to satisfy the GDP identity.

Hence, we have two contrasting results in our scenarios; one with the BOT improvement and the other one with the BOT deterioration. What is the main reason for this contrasting result?

We need to look at a real appreciation which deteriorates the BOT theoretically. What can represent this term in our system of BOTE equations? To find out, let us pay attention to the terms of the trade (*TOFT*, hereafter):

$$TOFT = \frac{P_X}{P_M} \qquad \textbf{BOTE-1.11}$$

where P_X is price (index) of export goods; P_M is price (index) of import goods; and *TOFT* is the terms of the trade.

TOFT dictates the real purchasing power of domestic output and is one of the key determinants of Mongolia's economic prosperity. For imports, we assume that Mongolia is a price taker and thus treat P_M as exogenous in our simulation. Hence, *TOFT* is defined by prices of export goods which are dependent on the volume of exports (X) and export demand shifters. In an open economy, demand curves for its exports are downward-sloped, showing a negative relationship between prices in foreign currency and export volume, as in Figure 6.5.

Next, we examine how Mongolia's trade condition changes due to the shock.

We are going to check if the $\frac{P_g}{P_c}$ ratio can help determine the BOT deterioration. We know, from both BOTE-1 and ORANIMON results, that P_g increases more than P_c and P_g contains the prices of export goods and P_c contains the prices of import goods. Therefore, the $\frac{P_g}{P_c}$ ratio is a function of *TOFT*. Let us see how they are related by using BOTE-1.12.

We can write the percentage change of the economy wide output price, assuming that the international trade is approximately balanced, as follows:

$$p_g = S_E p_E + S_X(p_X - p_M) \qquad \textbf{BOTE-1.12}$$

where S_E and S_X are the shares of domestic absorption and exports in the GDP: p_g, p_E, p_X and p_M are the percentage changes in prices of GDP, GNE, exports and imports respectively.

Private consumption, C, is the largest category in GNE accounting for more than 60% of GNE. Therefore, we can use p_c as a proxy for p_E.

Then we can re-write BOTE-1.12 as:

$$p_g = S_E p_C + S_X(p_X - p_M) \qquad \textbf{BOTE-1.13}$$

where S_E and S_X are the shares of domestic absorption and exports in the GDP; p_g, p_C, p_X and p_M are the percentage changes in prices of GDP, private consumption, exports and imports, respectively.

As we mentioned earlier, the mineral exports contributed approximately 65% of total exports revenue. Hence, we can calculate the change in p_X to be around 65% in SAVE due to shock (i). We expect the change would be higher in CONSUME as we know from the early BOTE results. Using our BOTE equation defined in BOTE-1.13, we can calculate the percentage changes in economy-wide price (price of domestically produced good g) in two scenarios:

$$p_{g_{SAVE1}} = S_E p_C + S_X(p_X - p_M) = 1.027 * 36.94\% + 0.471 * (71.5\% - 0\%)$$
$$= 36.5\%$$

$$p_{g_{CONSUME1}} = S_E p_C + S_X(p_X - p_M) = 1.027 * 38.41\% + 0.471 * (81.44\% - 0\%)$$
$$= 77.8\%$$

Due to the positive deviation in export price (in other words, *TOFT* improvement), we can see now that the economy-wide price of domestically produced goods has increased more than the consumer price in both scenarios. The results from ORANIMON for changes in the economy wide prices in Table 6.1 are 36.94% and 71.71%, respectively in the SAVE and CONSUME scenarios. We can calculate the terms of the trade in two scenarios as:

$$TOFT_{SAVE1} = p_{X_{SAVE1}} - p_M = 71.5\% .$$

$$TOFT_{CONSUME1} = p_{X_{CONSUME1}} - p_M = 81.44\% .$$

In both scenarios, there are substantial improvements in *TOFT*- export prices increase relative to import prices. This means Mongolia’s trade condition improved so that Mongolia can exchange a given amount of exports for more imports.

As foreshadowed in Chapter 1, the impact of the real appreciation is an adverse effect on many import-competing and non-mining exporting industries.

The real exchange rate is usually defined as the product of the nominal exchange rate, expressed as the number of foreign currency units per home currency unit, and the relative price level, expressed as the ratio of the price level in the home country to the price level in the foreign country. There are only two countries in this definition; the exchange rate used is a bilateral rate.

$$RER = \frac{P_g}{P_m} PHI \qquad \textbf{BOTE-1.14}$$

where P_g and P_m are the prices of domestically produced goods and imports (foreign price); PHI and RER are the nominal and real exchange rates of Mongolian currency, respectively.

If we write BOTE-1.14 in terms of percentage change:

$$rer = p_g - (phi + p_m) \qquad \textbf{BOTE-1. 15}$$

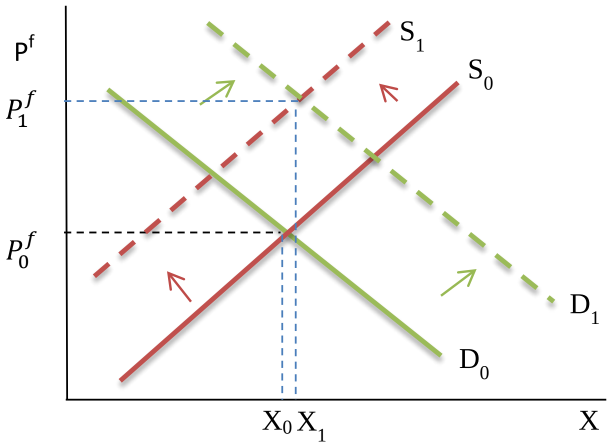
where rer, p_g , phi and $p_m$are the percentage changes in the real exchange rate, the price of domestically produced goods, the nominal exchange rate and the import price (good *v*) respectively. The nominal exchange rate is a *numeraire*, so that phi = 0. As Mongolia is a small open economy with fixed import prices, by inducing a positive deviation in the price of domestically produced goods, we can calculate the real exchange rate in the case of a constant nominal exchange rate that we assumed in the two scenarios as:

$$rer_{SAVE1} = p_{g_{SAVE1}} - p_M = 36.5\%$$

$$rer_{CONSUME1} = p_{g_{CONSUME1}} - p_M = 71.8\%$$

In both scenarios, there are real exchange rate appreciations. However, the subsequent appreciation of the Mongolian real exchange rate in the CONSUME scenario is almost twice as large as that in the SAVE scenario. Policy measures to curb consumption (i.e., saving mechanisms or taxes) could restrict the real appreciation due to a mineral price increase.

Figure 6.5 Movements in Export Supply and Demand in the SAVE Scenario



Let us explain the increases in the price and real volume of exports in the SAVE scenario in a graphical representation. In Figure 6.5, the initial equilibrium price of Mongolian export goods in foreign currency at P_0^f and the initial equilibrium volume of real exports at X_0 are established by the intersection of exports demand curve D_0 and exports supply curve S_0.

Due to our shock (i), the export demand curve shifts rightward, from D_0 to D_1. Due to the real appreciation, the foreign price expressed in domestic currency of export goods has fallen, giving a pull-back impact on Mongolian export supply (an upward shift in the export supply curve from S_1 to S_2). The new equilibrium volume of real exports at X_2 (increased by 1.6% from X_0) and the new equilibrium price in foreign currency at P_1^f (increased by 71.5% from P_0^f) are established by the intersection of shifted export demand curve D_1 and shifted export supply curve S_1.

Table 6.2 shows the BOTE-1 equations in levels and percentage change forms. We have used the equations in levels form to develop expectations about the directional change in variables. The equations in percentage change form have enabled us to carry out calculations. Table 6.2, Figure 6.6 and Figure 6.7 summarize the relationships in the BOTE -1 analysis.

Table 6.2 BOTE-1 equations in levels and percentage change forms

$Y = \frac{1}{A} F(K, L)$	$y = a + S_L l + S_K k$
$P_g = P_g(W, Q)$	$p_g = a + S_L w + S_K q$
$\frac{W}{P_c} = \frac{P_g}{P_c} * \frac{1}{A} * F_L(K / L)$ $\frac{Q}{P_I} = \frac{P_g}{P_I} * A * F_K(K / L)$	$l - k = -\delta(w - q)$
$Y = C + I + G + (X - M)$	$y = S_E e + S_X x - S_M m$
$\frac{C}{G} = \Gamma$	$c = g + f5$
$TofT = \frac{P_X}{P_M}$	$toft = p_X - p_M$
$RER = \frac{P_g}{P_m} PHI$	$rer = p_g - (phi + p_m)$
$X = X(1/RER, 1/Y_W)$	$x = -\epsilon(p_g - phi)$
$M = M(Y, RER)$	$m = y - \theta * rer$

Figure 6.6 Short run relationships in ORANIMON (SAVE)

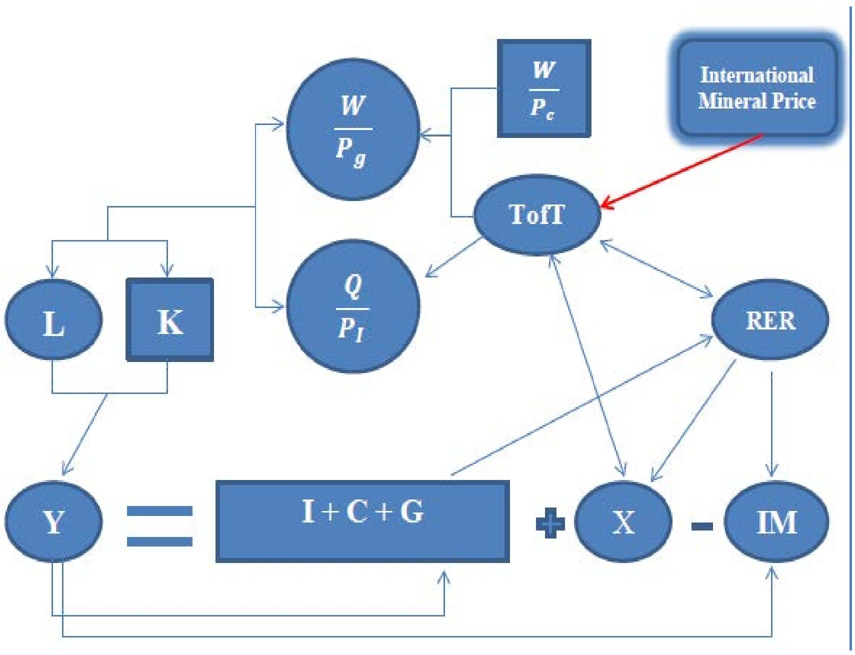
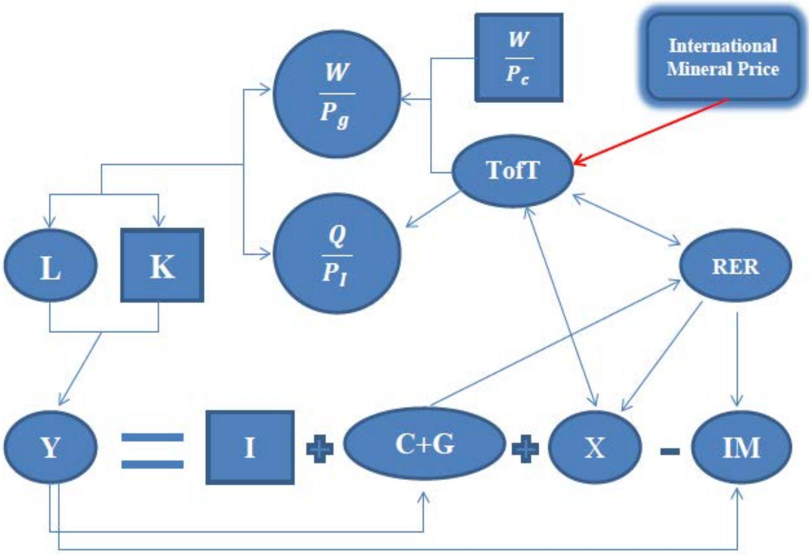


Figure 6.7 Short run relationships in ORANIMON (CONSUME)



6.5 Macro effects of a Mineral Price Increase and an Investment Tide

In the second stage of our sequential simulation analysis, we carry out both sets of shocks (i), a mineral price increase of 100%, and (ii), a 100% increase in investment in the mineral sector, a 30% growth in economy-wide investment, and a 30% rise in capital stocks across mineral sectors in our two scenarios, SAVE and CONSUME. We interpret the results in two scenarios using the BOTE-2 technique, focusing on the discrepancies between BOTE-2 and ORANIMON results.

We concentrated on export demands in ORANIMON in the previous section. We now turn our attention to investment demand in order to apply our shocks in set (ii). The underlying theory of investment demand is discussed in Chapter 4. Hence, we focus on the mechanism that implements the shocks in ORANIMON. It is assumed that investment goods consist of domestically produced and imported commodities. We divide industries into two groups: exogenous investment industries and endogenous industries. In ORANIMON, there are nine exogenous investment industries whose investments follow aggregate investment. The other industries are endogenous investment industries whose investment decisions are linked to their profits.

6.5.1 Closure

In stage two for the SAVE scenario, we assume:

- ✓ Real wages are set exogenously via indexing money wages to CPI.
- ✓ Changes in national income will be realized by changes in the BOT. Private and public consumption parts of the aggregate domestic absorption or GNE is fixed. The investment part of GNE is partly endogenous. This means that aggregate real investment is set exogenously and shocked by historical change (hence, real investments of the industries, which follow aggregate investment) and mineral sector investment are exogenously shocked by historical change. Yet the real investments of other sectors are endogenously determined, given the change in aggregate investment.
- ✓ Changes in the real exchange rate will be realized through changes in the domestic inflation rate relative to the foreign rate and not through changes in the nominal exchange rate. Thus, the change in the nominal exchange rate is fixed exogenously at zero in our simulation.

- ✓ Economy-wide and industry specific capital stocks are exogenous and the capital stock for mineral sector is shocked.

In the CONSUME scenario, we have assumed the changes in national income will be realized by changes in the BOT, and public and private consumption parts of GNE, as well as the change in investment which is partly endogenous.

6.5.2 BOTE-2 analysis

We use BOTE-2 equations to describe the principal mechanisms behind the simulation results starting at the top and working down. First, we check what happens to GDP and then show what happen to other important variables. The ORANIMON simulation results of the two scenarios in stage 2 are shown in Table 6.3.

Table 6.3 Results from second stage simulations (% change)

Main Macro Indicators	**SAVE**	**CONSUME**
Real GDP Growth	8.2	14.9
Aggregate Capital Stock	9.5	7.1
Aggregate Employment	11.1	29.7
Real Investment	30	30
Real Household Consumption	0	41.9
Real Government Expenditure	0	41.9
Export Volume	13.5	-4.8
Import Volume	14.7	48.28
Real Wage	**0**	**0**
Nominal Wage	4.7	57.5
GDP Price Index	41.7	94.1
CPI	4.8	57.5
Export Price Index	74.0	85.7
Imports Price Index	0	0
Nominal Household Consumption	4.7	122.5
Nominal GDP Growth	53.2	122.5
GNE Price Index	5.8	94.9

From Table 6.3, we can see that GDP is increased under both scenarios and the increase in CONSUME is higher than the change in SAVE.

The decomposition of GDP changes for both scenarios is given in Table 6.4. We observe that there is a significant difference between the results in the two scenarios in terms of shock (i) and a relatively smaller difference in terms of shocks in (ii) from column subtotals in Table 6.4. The further decomposition of (ii) affirms the finding. The difference is due to the induced impacts of the increases in private and public consumption through producers to investors in CONSUME.

Table 6.4 GDP change in second stage ORANIMON simulations (%)

Scenarios	**Change in GDP**	Subtotals		Further decomposition of investment		
		Mineral price increase	Investment increase	Mineral investment increase	Mineral capital increase	Aggregate investment increase
SAVE	**8.16**	0.41	7.75	0.83	5.69	1.23
CONSUME	**14.94**	6.31	8.63	1.15	5.82	1.67

Because SAVE is an extreme scenario to restrict consumption in the short and medium runs, the CONSUME scenario produces greater GDP changes than SAVE in the short and medium run. Since we have explored the difference between the results in terms of the mineral price increase in BOTE-1 analysis, and there is a relatively smaller difference in terms of shocks in (ii), our focus is now shifted to overall or combined results of (i) and (ii) in the two scenarios, rather than separately analyzing the results from (ii). Investigating combined effects is necessary, because a mineral price surge is most likely to bring on an inflow of investment in Mongolia.

Table 6.5 Contributions to GDP change (%)

Scenarios	**Change in GDP**	**Contributions of**		
		Labour	Capital	Indirect taxes
SAVE	**8.16**	3.55	4.31	0.87
CONSUME	**14.94**	9.52	3.32	3.08

Table 6.5 shows the contributions of labour, capital and indirect taxes to the change in GDP. The notable difference is the contribution of capital, which is higher in SAVE than in CONSUME. Conversely, the contributions of labour and indirect taxes are 2.7 and 3.5 times larger in CONSUME than in SAVE. We will address these differences with the help of BOTE-2 calculations.

In BOTE-2, we assume that real GDP is determined by inputs of primary factors and technology via a Hicks neutral CRS function in BOTE-2.1. In BOTE-2.1, *Y* is real GDP, *K* is capital input, *L* is labour input, and *A* is a technology shift term. The set of shock in

(ii) includes the increase in mineral sector capital. How does the aggregate capital stock in BOTE-2.1 change as a result of capital increase in mining industries?

Table 6.6 BOTE-2 Equations

$Y = \frac{1}{A} * \; F(K, L)$	**BOTE-2.1**
$y = S_L l + S_K k - a$	**BOTE-2.2**
$\frac{W}{P_{VA}} = \frac{1}{A} * F_L(K/L)$	**BOTE-2.3**
$\frac{W}{P_{VA}} = \frac{W}{P_C} \frac{P_C}{P_{GNE}} \frac{P_{GNE}}{P_{GDP}} \frac{P_{GDP}}{P_{VA}}$	**BOTE-2.4**
$(w - p_{va}) = (w - p_C) + (p_C - \; p_{gne}) + (p_{gne} - p_{gdp}) + (p_{gdp} - p_{va})$	**BOTE-2.5**
$l - k = -\frac{\sigma}{S_K}(p_C - p_{VA})$	**BOTE-2.6**
$BOT = Y - C - I - G = Y - GNE$	**BOTE-2.7**
$bot_{SAVE} = \frac{1}{S_{BOT}} [y_{SAVE} - \; S_{C+G} c - S_I i]$	**BOTE-2.8**
$RER = \frac{P_E}{P_M} \; PHI$	**BOTE-2.9**
$rer = p_{EXP} - (phi + p_m)$	**BOTE-2.10**

In 2005, the share of mineral sector capital in the aggregate capital was 24%. We can calculate the change in aggregate capital stock simply as:

$$\Delta \mathrm{K} \; = \; \mathrm{S_K(Mine)} \mathrm{x} \, \Delta \mathrm{K(Mine)} = \; 0.24 \mathrm{x} 30\% \; = \; 7.2\%$$

where S_K(Mine) is the share of mineral sector capital and ΔK(Mine) is the change in mineral sector capital.

If we look at the ORANIMON results, the aggregate capital is increased by 9.5% in SAVE and 7.1% in CONSUME. The result for CONSUME is close to what we have expected. With the same shock, however, the increase in aggregate capital is different in the two scenarios. The underlying reason is that the change in aggregate capital is itself a rental weighted sum of the changes in real industry-specific capitals. In SAVE, the rental prices of capital in mineral industries are higher than those in CONSUME scenario due to our shocks. Shock (i) induced a massive increase in rental prices of capital while the increase in mineral capital in (ii) puts downward pressure on the hike in rental prices of capital in mineral industries. Hence, the contribution of capital is higher in SAVE than in CONSUME, as we have seen from Table 6.5.

In BOTE-2.2, y is the percentage change in real GDP, a is the percentage change in technology term, l is the percentage change in the employment of labour, k is the percentage change in aggregate capital, and S_L and S_K are the shares of returns to labour and capital in the GDP. Using BOTE-2.2, recalling the shares of capital and labour in the base year as 0.6 and 0.4 respectively, we can calculate the changes in the employment of labour in scenarios as:

$$l_{SAVE} = \frac{1}{S_L}(y - S_K k) = \frac{1}{0.4}(8.2\% - 0.4 * 9.5\%) = 11.0\%$$

$$l_{CONSUME} = \frac{1}{S_L}(y - S_K k) = \frac{1}{0.4}(14.9\% - 0.4 * 7.2\%) = 30.5\%$$

If we look at the ORANIMON results from Table 6.7, the changes in aggregate labour in SAVE and CONSUME are 11.1% and 29.7% confirming our BOTE-2 calculations.

Table 6.7 Aggregate employment change in second stage ORANIMON simulations

	Employment change	Subtotals		Further decomposition of investment tide		
		Mineral price increase	Investment growth	Mineral investment increase	Mineral capital increase	Aggregate investment increase
SAVE	**11.11**	1.41	9.7	2.66	3.67	3.36
CONSUME	**29.72**	15.73	14	3.45	6.17	4.37

From the BOTE-2 calculations and the ORANIMON results, we know there is an increase in employment in both scenarios. In accordance with the short run assumptions, GDP moves by less than employment in both scenarios. Now, let us try to reason why the employment goes up.

To answer, we move on to the next BOTE-2 equation which defines the producer real wage in BOTE-2.3 where A and $F_L(K/L)$ are as previously defined; W is a total factor payment to labour; and P_{VA} is the price of value added. Earlier, we have found the change in capital stock. If we find how the producer real wage is changed due to the shocks, we can then define how the employment would be altered, using BOTE-2.3. Let us define the producer real wage as the product of price ratios as in BOTE-2.4. In

BOTE-2.4 W is a total factor payment to labour, P_{VA} is the price of value added, P_c is the consumption price (CPI), P_{GNE} is the price of GNE, and P_{GDP} is the price of GDP.

The ratio $\frac{W}{P_{VA}}$ is a producer real wages; $\frac{W}{P_C}$ is a consumer real wages; $\frac{P_C}{P_{GNE}}$ shows the relative price ratio of consumption and GNE; $\frac{P_{GNE}}{P_{GDP}}$ is an inverse function of the terms of trade (since P_{GNE} includes imports and excludes exports, whereas P_{GDP} includes exports and excludes imports); and the $\frac{P_{GDP}}{P_{VA}}$ ratio change indicates indirect taxes change.

Equation BOTE-2.4, $\frac{W}{P_{VA}} = \frac{W}{P_C}\frac{P_C}{P_{GNE}}\frac{P_{GNE}}{P_{GDP}}\frac{P_{GDP}}{P_{VA}}$, shows the cross relationship of the relative prices. We start with the SAVE scenario to learn the directional change in $\frac{W}{P_{VA}}$. Our shock (i) effects through $\frac{P_{GNE}}{P_{GDP}}$. Since P_{GDP} includes price of export goods, and the major components of GNE are tied up in SAVE, we expect this ratio to go down reflecting terms of trade improvement, even though P_{GNE} would increase due to shocks (ii).

We have assumed that the consumer real wage is fixed. In other words, W is indexed with P_C. Hence, $\frac{W}{P_C}$ remains effectively unchanged. With fixed private and government consumptions in SAVE, we expect the $\frac{P_C}{P_{GNE}}$ ratio might go down because P_{GNE} includes investment price that would go up due to the shocks (ii). We do not apply any shocks regarding tax changes so that we would expect $\frac{P_{GDP}}{P_{VA}}$ ratio to be unchanged. We have discovered that two of the four price ratios would decrease, while the other two would stay at the same level. Therefore, we can conclude that the producer real wage $\frac{W}{P_{VA}}$ must have gone down in SAVE.

Let us examine the results from the second stage ORANIMON simulations in Table 6.3. As we expected, there is a steep decline in the $\frac{P_{GNE}}{P_{GDP}}$ ratio, indicating a huge upswing in the terms of trade $\left(\frac{105.8}{141.7} = 0.75 < 1\right)$ since it is an inverse function of *TOFT*. Table 6.3 also reveals that there is a slight decline in $\frac{P_C}{P_{GNE}}$ indicating the rise in P_{GNE} is slightly larger than that in P_C $\left(\frac{104.8}{105.8} = 0.99 < 1\right)$. Our prediction for the ratio $\frac{P_{GDP}}{P_{VA}}$, however, is not correct. ORANIMON results show that there has been marked decrease in this ratio, as the increase in P_{VA} is greater than that of P_{GDP} $\left(\frac{141.7}{147.2} = 0.96 < 1\right)$. As it is the short run condition, $\frac{W}{P_C}$ ratio has not changed $\left(\frac{104.8}{104.8} = 1\right)$. As a result, we find the $\frac{W}{P_{VA}}$ ratio in BOTE-2.3 is declined, since three ratios out of four have fallen while the other one is fixed.

Let us find the reduction in $\frac{W}{P_{VA}}$ via BOTE-2.5, a percentage change form of BOTE-2.4. In BOTE-2.5, lowercase symbols represent percentage changes in the variables defined previously and denoted by the corresponding uppercase symbols. Using BOTE-2.5 we can find the percentage change in producer real wage for SAVE as:

$$(w - p_{va})_{SAVE} = (4.8\% - 4.8\%) + (4.8\% - 5.8\%) + (5.8\% - 41.7\%) + (41.7\% - 47.2\%) = -31.4\%$$

Likewise, we can compute the percentage change in producer real wage for CONSUME as:

$$(w - p_{va})_{CONSUME} = -46.1\%$$

Now we are able to learn the direction of the change in labour via BOTE-2.3. We know *A* is fixed and $\frac{W}{P_{VA}}$ has gone down substantially. Hence *MPL* must fall drastically to sustain the equality. We recognised a positive relationship between *MPL* and the *K/L* ratio earlier. Hence the K/L ratio must decline to achieve the necessary reduction of MPL. Thus labour needs to increase by a larger per cent than capital. In order to calculate this positive change, we introduce and use our next equation, BOTE-2.6 $l - k = -\frac{\sigma}{S_K}(p_C - p_{VA})$. In BOTE-2.6, l and k are the percentage changes in the employment of labour and capital, w and q are the percentage changes in factor payments to labour and capital respectively, and σ is the elasticity of substitution between *L* and *K*.

From our database, we can find the primary factor value weighted elasticity of substitution between L and K is 0.5 ($\sigma = 0.5$). We calculated $S_K = 0.6$ in BOTE-1 analysis, leaving out land and indirect tax shares and scaling up for labour and capital. We calculated $k = 7.2\%$ earlier for CONSUME and we know k is higher in SAVE at 9.5%.

We can now calculate the change in the employment of labour as:

$l_{SAVE} = 9.5\% - \frac{0.5}{0.6}(-31.4\%) \approx 16.6\%$

$l_{CONSUME} = 7.2\% - \frac{0.5}{0.6}(-46.1\%) \approx 31.2\%$

Our BOTE-2 calculations, however, are higher than ORANIMON results (11.1% in SAVE and 29.7% in CONSUME). The difference is due to the change in the other component of producer price: land price. The ORANIMON decomposition results in Table 6.7 aligns with BOTE-2 regarding $\frac{W}{P_{VA}}$.

The BOT is defined by BOTE-2.7. Aggregate expenditure consists of four components: private household consumption, investment, government expenditure, and net exports. The set of shocks in (ii) includes a 30% increase in the real aggregate investment for each scenario. Hence the BOT must deteriorate in both scenarios. When we constrain private and public consumption, we expect relatively weaker deterioration in SAVE than in CONSUME. In CONSUME, we expect private consumption, as well as public consumption, to increase, due to our shocks, since they are proportional to income. We then anticipate even worse deterioration in CONSUME. In addition, domestic private saving in the CONSUME scenario must be lower than that in the SAVE scenario. We note that investment is equal to total, not just domestic, saving. Total saving includes net borrowing from foreigners or foreign saving. Foreign saving, in turn, can be seen from the GDP identity to be equal to the balance of trade deficit. The real aggregate investment is also the value-weighted average of real changes in industry-specific investments. Thus the cost of a unit of capital or investment price plays an important role. It is worth remembering that we are considering a medium run, in which we allow mineral sector capital to move up exogenously and yet the BOT is determined endogenously, unlike a typical long-run closure, where the BOT is exogenous. In reality, most investment (thus capital) is financed by foreigners or from foreign saving in Mongolia. As we mentioned earlier, ORANIMON does not link trade flows and debt stocks. To track the existence and accumulation of foreign liability is one of the reasons to develop MONAGE, a dynamic successor to ORANIMON.

Private and public consumption contributed 72% of Mongolian GDP in 2005, while investment accounted for 28%. Mongolia’s trade balance showed a relatively small trade deficit at close to 2%, which was equivalent to the share of stocks. The BOT share was 97%, consisting of the export share of 47% and the import share of 50%.

We can convert the BOTE-2.7 equation to percentage-change form as in BOTE-2.8. In BOTE-2.8, y is the percentage change in real GDP; e is the change in real domestic absorption; x is the percentage change in aggregate exports; m is the percentage change in aggregate imports; *bot* is the percentage change in BOT; S_{C+G}, S_I , S_X, S_M, S_E and S_{BOT} are the shares of domestic consumption, investment, exports, imports, absorption and the BOT in the GDP respectively. Then we can calculate the change in BOT in the two scenarios as:

$$bot_{SAVE} = \frac{1}{S_{BOT}}[y_{SAVE} - S_{C+G}c - S_I i] = \frac{1}{0.97}[8.2\% - 0.72 * 0\% - 0.28 * 30\%] \approx 0.2\%$$

$$bot_{CONSUME} = \frac{1}{0.97}[14.9\% - 0.72 * 41.9\% - 0.28 * 30\%] \approx -24.4\%$$

We can see from the calculations that there is a massive deterioration in CONSUME confirming our expectation. Table 6.8 shows the decomposition of the BOT change in the two scenarios. BOTE-2 results are slightly different than the ORANIMON results due to other factors. However, BOTE-2 results are still relevant and closer to the model outcomes. As we expected, the aggregate investment increase had a large crowding-out effect in both scenarios. As we found and explained in the BOTE-1 analysis, the major difference in terms of BOT deterioration is due to the mineral price increase when the real appreciation is subdued with SAVE.

Table 6.8 BOT change in second stage ORANIMON simulations

	BOT change	Subtotals		Further decomposition of investment		
		Mineral price increase	Investment growth	Mineral investment increase	Mineral capital increase	Aggregate investment increase
SAVE	**0.87**	0.41	0.46	0.83	5.69	-6.06
CONSUME	**-19.17**	-14.77	-4.41	-0.08	2.04	-6.36

We know that the BOT deterioration requires real appreciation. BOTE-2.9 defines the real exchange rate, in which P_{GDP} and P_M are the prices of export goods and imports (foreign price), *PHI* and *RER* are the nominal and real exchange rates of the Mongolian currency, respectively. If we write BOTE-2.9 in terms of percentage change, we will get BOTE-2.10 where rer, p_{GDP} , phi and p_M are the percentage changes in the real exchange rate, the domestic price, the nominal exchange rate and the import price, respectively.

Table 6.9 TOFT change in second stage ORANIMON simulations (%)

	TOFT change	Subtotals		Further decomposition of investment		
		Mineral price increase	Investment growth	Mineral investment increase	Mineral capital increase	Aggregate investment increase
SAVE	**73.97**	73.53	0.45	-0.69	0.13	1.01
CONSUME	**85.7**	84.32	1.38	-0.39	0.71	1.07

We can calculate *TOFT* as we did in BOTE-1. In 2005, the share of mineral exports in total exports was 67%. Hence, we calculate the increase in Mongolian export price as:

$$p_X = \mathrm{S_X(Mine)x\,p4minave} = 0.67\text{x}100\% = 67\%$$

where $\mathrm{S_X}$(Mine) is the share of mineral exports in total exports and p4minave is the change in the mineral price.

In the same way as for other important variables, we can see from Table 6.9 that *TOFT* changes in the two scenarios resulted from the mineral price increase.

Based on the change in Mongolia's export prices and using export share in 2005, we can calculate the change in p_{GDP} as:

$$p_{GDP(SAVE)} = \mathrm{S_E}\text{x}\,p_X = 0.47\text{x}73.\% \approx 34.7\%$$

$$p_{GDP(CONSUME)} = 0.47\text{x}85.7\% \approx 40.2\%$$

RER changes from the second stage ORANIMON simulations are shown in Table 6.10. In both scenarios, the real exchange rates substantially appreciated. For both scenarios, the appreciation is largely due to the mineral price increase if we look at their decomposition. As we expected, there is a relatively larger overall appreciation in CONSUME than in SAVE.

The effects of appreciation in *RER* can really be seen at industry level. As we have discussed in Chapter 1, the real appreciation brings about a loss of competitiveness in manufacturing and trade exposed sectors.

ORANIMON produces detailed effects for the two scenarios, enabling us to analyze the different aspects and implications of the mining boom. The next section analyses the impacts of the mining boom at industry level, employing different methods.

Table 6.10 RER change in second stage ORANIMON simulations

	RER change	Subtotals		Further decomposition of investment tide		
		Mineral price increase	Investment tide	Mineral investment increase	Mineral capital increase	Aggregate investment increase
SAVE	**29.71**	27.49	2.23	-2.47	0.4	4.29
CONSUME	**49.21**	40.94	8.26	-2.12	4.03	6.35

6.6 Industry Effects of the Resources Boom

This section is concerned with the implications of the mining boom at industry level. We track winners in subsection 6.6.1 and losers in subsection 6.6.2 by looking at the different decompositions. These descriptive analyses are followed up by non-parametric tests in subsection 6.6.4 and then the linear regression analysis in subsection 6.6.5 relating the simulated changes in industry outputs to various characteristics of the industries.

Table 6.11 Effects on sectoral outputs results in stages 1 and 2 (%)

Aggregate Sector	**Stage 1**		**Stage 2**	
	SAVE	**CONSUME**	SAVE	CONSUME
Agriculture	-0.26	2.42	-0.48	3.18
Mining and Quarrying	2.87	2.17	19.99	18.72
Manufacturing	-2.94	-14.75	-2.88	-16.72
Services	-0.73	8.93	5.18	17.91

The effects on aggregate sector outputs of shock (i) in stage one and of shocks (ii) in stage two are presented in Table 6.11 above. It is evident from Table 6.11 that the manufacturing sector is the main loser because its output decreases in both stages for both scenarios. This de-industrialization impact is consistent with the Dutch disease hypothesis. The services sector is a major winner, since its output increases in stage two for both scenarios and in stage 1 for CONSUME, in addition to the booming sector. The agriculture sector is relatively mildly affected with mixed results for both scenarios. A comparison of the two sets of results for the two scenarios reveals that there is a notable difference in terms of negative impacts on the industry sector, which is relatively mild in SAVE and quite harsh in CONSUME. This indicates that consumption restrictions and saving measures could help restrain the negative impacts of the mining boom. As we progress, we focus on the stage two results for the CONSUME scenario, to avoid repetitive detail, and report the major differences in terms of industry performance between SAVE and CONSUME. Before we start tracking winners and losers, let us define a few important indicators of trade analysis.

In order to estimate the sensitivity of industry outputs, we define the following variables:

(a) import share;

(b) import sensitivity;

(c) export sensitivity; and

(d) trade sensitivity.

The import share is calculated as:

$IMSH(c) = VOIMP(c)/[(1 - EXPSHR(c)) * MAKE\_I(c) + V0IMP(c)]$;

where $IMSH(c)$ is an import share for commodity c; $VOIMP(c)$ is a total basic-value import of commodity c, $EXPSHR(c)$ is the export share of commodity c; and $MAKE\_I(c)$ is the total production of commodity c summed over industries. Mongolia is a net importer of fuel products. Hence, the import share of fuels products is equal to 1. Some services like the services to finance (‘SvcToFinance’) have no imports, so that the import share for ‘SvcToFinance’ is equal to 0. The import shares for other industries are between these two extremes.

The import sensitivity, a product of non-export share, a share of imports in domestic sale, and the Armington elasticity of a commodity in intermediate use, defines the sensitivity of an output of commodity c to imports. We use following formula to calculate (b):

$IMSE(c) = [1 - EXPSHR(c)] * IMPSH(c) * \delta 1(c)$

where $EXPSHR(c)$ is as previously defined, $IMPSH(c)$ is the share of imports in domestic sale of commodity *c*, and $\delta 1(c)$ is the Armington elasticity of substitution between domestically produced and imported commodity *c*.

The higher the value of import sensitivity, the more sensitive the output of a commodity to imports. Of 55 ORANIMON commodities, the commodity with the highest import sensitivity is 'ElectEquip'.

The export sensitivity (hereafter, *EXPS*), a product of export share and export elasticity of a commodity (γ), indicates how sensitive an output of a commodity is to exports. We also use this measure for our systematic sensitivity analysis. The 'Livestock' commodity has the highest export sensitivity in ORANIMON commodities.

The trade sensitivity (hereafter, *TRDS*), the sum of import sensitivity and export sensitivity, defines the overall sensitiveness of an output to trade of a commodity. 'ElectEquip' stands out again as the commodity with the highest trade sensitivity.

6.6.1 Tracking winners in CONSUME

Due to the mining boom, we expect that the non-traded sectors or sectors that have a large share of their sales into households, investment and government would benefit most. Due to fixed real wages, we expect labor-intensive industries might be better off. Since we have both supply and demand side shocks, however, the repercussion effects at industry level can differ and contrast, so that how the combined effects play out will determine the performance of the industries.

Figure 6.8 Change in Activity level (%)-Winners

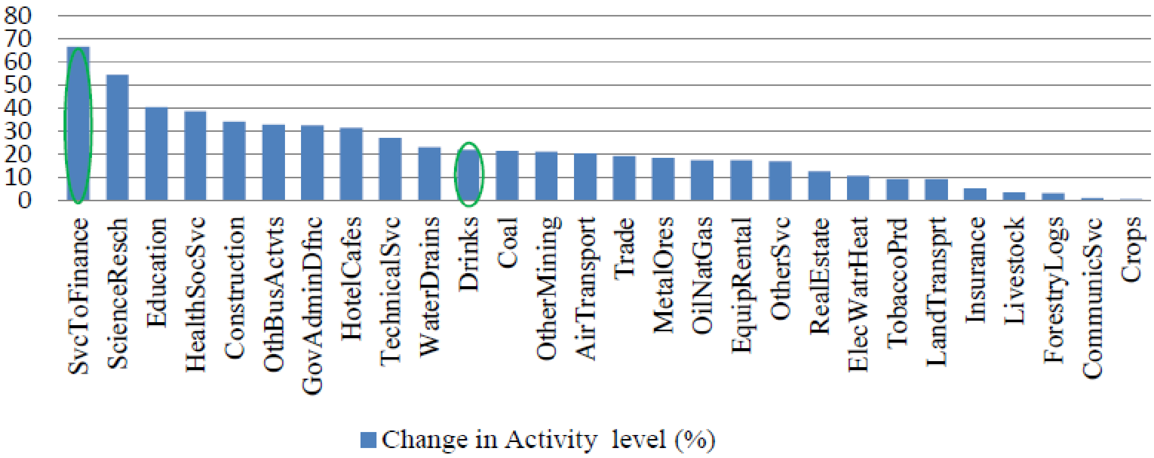


Figure 6.8 shows the changes in activity level across industries which have positive variations. The results are ranked, the industry which gains the most in terms of its output level appearing first in the figure. The top five winning industries are 'SvcToFinance' and 'ScienceResch', followed by 'Education', 'HealthSocSvc' and

‘Construction’. As can be seen from the table above, the top ten industries are non-traded service industries. The eleventh-ranked industry,‘Drinks’, an import-competing manufacturing industry, is also a big winner. Our explanations focus on the leading winners, ‘SvcToFinance’ and ‘Drinks’, to avoid repetition, as they can represent the winners.

Table 6.12 Decomposition of output change (%)

Industries	**Output change**	Subtotals		Further decomposition of investment		
		Mineral price increase	Investment growth	Mineral investment increase	Mineral capital increase	Aggregate investment increase
SvcToFinance	**66.8**	**49.4**	**17.4**	**1.7**	**10.7**	**5.1**
ScienceResch	54.6	40.8	13.8	1.9	7.5	4.4
Education	40.6	31.7	8.9	2.1	5.6	1.2
HealthSocSvc	38.7	30.3	8.4	2.0	5.3	1.1
Construction	34.3	-0.6	34.9	13.9	0.6	20.4
OthBusActvts	33.0	10.7	22.3	8.1	2.6	11.5
GovAdminDfnc	32.7	25.7	7.0	2.1	4.6	0.3
HotelCafes	31.3	23.0	8.3	2.6	5.0	0.8
TechnicalSvc	27.2	19.6	7.6	1.3	3.6	2.7
WaterDrains	23.1	17.2	5.9	1.9	2.7	1.3
Drinks	**22.1**	**17.5**	**4.7**	**0.5**	**2.8**	**1.4**

Table 6.12 contains the decomposition of the percentage effects of the mining boom on the output for the top 11 industries. From Table 6.12 in the subtotals column, we can see that the most winners gain greatly from the mineral price increase. ‘Construction’ and ‘Other business activities’ gain significantly from the investment growth.

The leading winner, 'SvcToFinance', a small labour-intensive service industry, produces non-tradable goods and sells 48% of its output for intermediate consumption and 52% of its output to households. 'Drinks', a capital-intensive manufacturing industry, is in the group of non-traditional exporting industries and the export share of its output is nominal at 0.3%. The industry sells 13% and 84% of its output as an intermediate input to other industries and to households, respectively. Around 2.7% of its output is accounted for in stocks. The import share of the commodity was 23% in base year 2005. It is worth noting that major user industries of the commodities and services produced by the winning sectors also benefited from the shocks. Table 6.13 breaks down the changes in outputs of the winning industries in CONSUME into the results from the effects of the local market, the domestic share change and exports. The Fan decomposition, named after Fan Ming-Tai of the Academy of Social Sciences, Beijing, who suggested this decomposition while visiting the COPS, aims to show the relative magnitude of three contributions to output change: the local market, domestic share and exports.

Table 6.13 Fan decomposition of top winners (%)

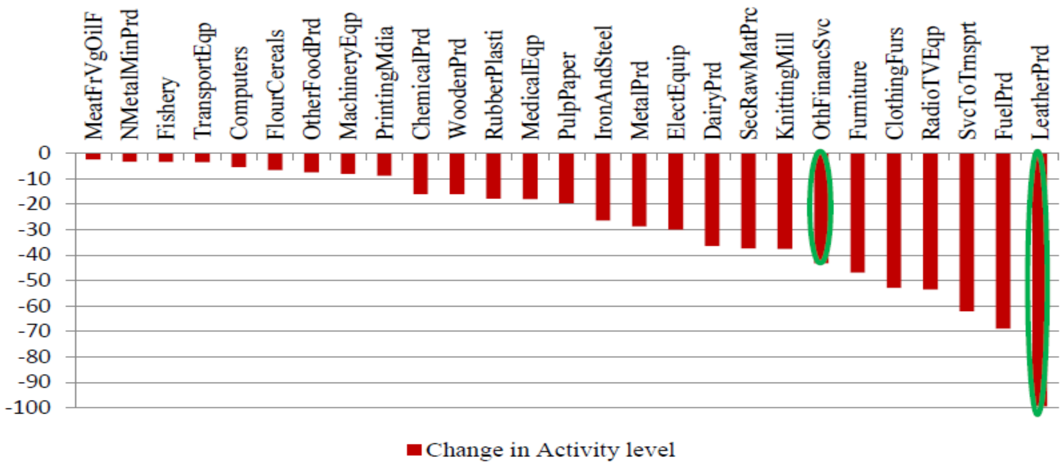
Industries	Local Market	Domestic Share Change	Export	Total
SvcToFinance	**66.1**	**0**	**0**	**66.1**
ScienceResch	53.7	0	0	53.7
Education	44.7	-4.6	0	40.1
HealthSocSvc	46.4	-8.6	0	37.8
TechnicalSvc	35	0	0	35
GovAdminDfnc	35.3	-1.5	-1.2	32.6
Construction	33.6	-1.2	-0.2	32.2
OthBusActvts	34	-1.5	-0.5	32
HotelCafes	30.6	0	0	30.6
WaterDrains	23.6	-0.6	-0.1	23
Coal	9.1	-0.1	12.3	21.4
OtherMining	4.7	-2.7	18.8	20.8
AirTransport	63.7	-18.7	-24.5	20.5
Drinks	**27.9**	**-8**	**-0.2**	**19.7**
Trade	18.9	0	0	18.9

Let us look at the change in domestic production of 'Drinks'. The change is due to three causes: the local market effect, which shows an increase in local usage of 'Drinks', whether domestically-produced or imported; the export effect, which shows the change in exports of ‘Drinks’; and the domestic share effect, which results from a shift in local usage of ‘Drinks’, from imported to domestically-produced. As it is in our case of ‘Drinks’, very often these three effects will work in different directions: for example, an increase in domestic demand may increase the domestic price and facilitate import penetration. ‘Drinks’ has a huge increase in terms of local market effect. However, the increase from the local market effect is offset by the effect of domestic share change. There is also a small loss associated with a decrease in export supply.

Since ‘SvcToFinance’ is a non-traded good (no exports or imports), the local market effect is not offset by the changes in domestic share or in exports, as in Drinks.

Table 6.13 reveals general characteristics of the big winners: non-exporting or having minimal shares of exports, not import-competing or the import competition threat is relatively lower, and hence mostly domestically used. In addition, the margin industries are all better off due to the mining boom because transport margins are high in the winners.

Figure 6.9 Change in Activity level (%)- Losers



6.6.2 Tracking losers in CONSUME

We show the results of the industries which have negatives changes in their outputs in Figure 6.9. As a result of the mining boom, we expect that the industries which produce traded goods would suffer most. The simulated negative impacts of the mining boom, in fact, were very severe for those industries.

Some industries like ‘LeatherPrd’ were almost wiped out. Of 27 industries which found negative changes in their outputs, 25 were manufacturing industries. There was one industry from agriculture and one from services. While most losers were manufacturing industries, there was one service industry, 'OthFinanSvc'. Hence we chose 'LeatherPrd' and 'OthFinanSvc' as focus industries and commodities.

In terms of sales structure, the 'LeatherPrd' industry exported 95% of its output in 2005. About 2% of its output was sold to intermediate consumption, while around 1% was bought by households. This industry is import-competing and the share of imports in total supply of 'LeatherPrd' was massive at 76%. 'LeatherPrd' is a downstream industry that has potential to generate value-added income, as the Mongolian economy is an agrarian economy with a large volume of livestock. The industry was one of the better-developed manufacturing industries during the communist era. 'OthFinanSvc' is an industry with the highest import share at 82% import share in domestic supply of the service. 'OthFinanSvc' sells 75% of its output for intermediate consumption. However, the major users of this service are other service industries who are better off. Both industries are labour–intensive, with the labour share in total primary factor cost at around 85% each.

Table 6.14 Fan decomposition of biggest losers (%)

Industries	**Local Market**	**Domestic Share Change**	**Export**	**Total**
LeatherPrd	**1.1**	**-2.6**	**-83.8**	**-85.3**
FuelPrd	2.2	-2.2	-69.2	-69.2
RadioTVEqp	13.3	-63	-3.9	-53.7
SvcToTrnsprt	6.7	-0.5	-58.7	-52.5
ClothingFurs	8.1	-4.7	-55	-51.6
OthFinanSvc	**17.3**	**-49.3**	**-11.3**	**-43.4**
Furniture	24.3	-49.9	-12.2	-37.8
KnittingMill	-2.5	2.7	-37.3	-37
DairyPrd	18.2	-44.1	-9.9	-35.8
SecRawMatPrc	0.1	-0.1	-30.6	-30.6
ElectEquip	**22.3**	**-50.6**	**-1.4**	**-29.8**

Table 6.14 contains the Fan decomposition results of the biggest losers. The loss in terms of export is the main reasons for the biggest loser, 'LeatherProd'. The major part

of the losses of our focus industries ‘OthFinanSvc’ and ‘ElectEquip’, however, are due to the reduction in domestic share. Consistent with the Dutch disease hypothesis, the industries which produce traded goods suffer most from the mining boom. At this stage, we cannot draw a conclusion on labour intensity as a positive factor. In order to summarize the relationship of industry characteristics to the ORANIMON industry level results, we will later employ statistical methods. We note that the above results in sections 6.6.1 and 6.6.2 are under the CONSUME scenario.

6.6.3 Winners and Losers in the SAVE scenario

Figure 6.10 Winners and losers in SAVE

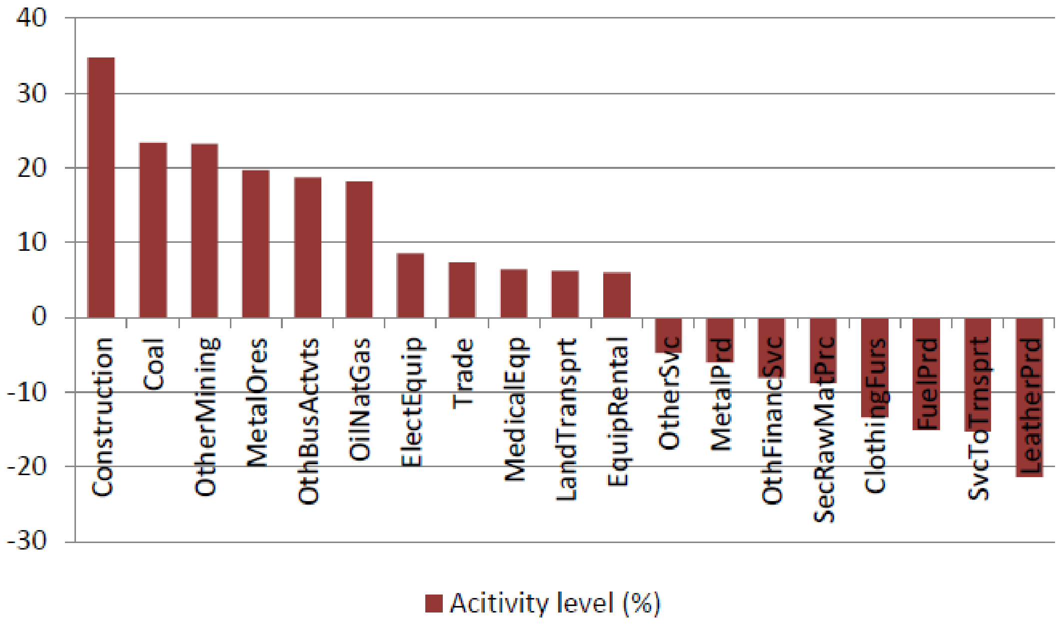


Figure 6.10 presents the activity level changes of industries who are top winners and the worst losers in the SAVE scenario. The decomposition of output change, sales and cost structures of the industries show that the top winners benefit most from the investment surge. Most of the worst losers are the same industries as the losers in CONSUME due to collapses in their exports. However, the output contraction of losers in SAVE is not as bad as in CONSUME if we compare the results in Figure 6.9 and Figure 6.10. For example, ‘LeatherPrd’ is the biggest loser in both scenarios. While it is almost wiped out in CONSUME, the fall in its activity level is 21.3% in SAVE. In the next subsection, we analyze the results across the two scenarios.

6.1.2 Cross-scenario investigation

From the aggregate results in Table 6.11, we have already seen that the overall negative impacts on the manufacturing sector of the mining boom are far worse in the

CONSUME scenario. In order to examine contrasting industry results, we cross-tabulate the winners and losers in CONSUME and SAVE in Table 6.15.

Table 6.15 Cross tabulation of winners and losers in two scenarios

		SAVE		Total
		Loser	Winner	
CONSUME	Loser	20	7	**27**
	Winner	13	11	**24**
Total		**33**	**18**	**51**

We exclude four mining industries, so that the number of industries is 51. From the table, we can see that there are seven industries which are winners in SAVE but losers in CONSUME. These seven industries all turn out to be important downstream manufacturing industries.

Table 6.16 Industries winners in SAVE but losers in CONSUME

Industries	SAVE	CONSUME
ElectEquip	8.6	-29.86
MedicalEqp	6.44	-18.02
PulpPaper	4.49	-19.52
RubberPlasti	3.76	-17.81
IronAndSteel	2.8	-26.47
NMetalMinPrd	1.94	-3.31
Computers	1.86	-5.35

Hence, we will further investigate them. Table 6.16 contains the output changes of those industries in two scenarios. The case of the seventh-ranked major winner in the SAVE scenario, 'ElectEquip', attracts our attention, because it is one of the worst suffering industries in CONSUME. We explore this industry as a representative of the group of industries winners in SAVE but losers in CONSUME.

We expect that 'ElectEquip' does not sell much to households and government, as it suffers in CONSUME. Upon examining the sales structure of the industry, we find that the industry sells most of its output for intermediate and investment uses. 'ElectEquip' is one of the import-competing commodities with the highest import share.

Further decomposition reveals that it sells almost 30% of its output to ‘Construction’, about 10% to ‘LandTransport’ and another 10 percent to ‘CommunicSvc’ industry. In SAVE, the ‘Construction’ (ranked at 1) and ‘LandTransport’ (ranked at 10) industries are major winners.

Table 6.17 Fan decomposition (%) - ‘ElectEquip’ industry

Scenarios	Local Market	Domestic Share Change	Export	Total
SAVE	24.5	-16.4	-0.4	7.7
CONSUME	22.3	-50.6	-1.4	-29.8

Table 6.17 presents Fan decomposition of the industry in SAVE and CONSUME. In terms of local market and export effects, the results are not very different. However, there is a substantial difference in terms of domestic share change effect.

The simulation results indicate that the policy measurements of restricting domestic consumption and/or establishing saving mechanism could not only help in the long run to stabilize but also to counteract and lessen the de-industrialization effect of the mining boom in the short and medium term.

6.6.4 Non-parametric tests

Non-parametric tests do not depend on assumptions about the parameters of the parent population and generally assume data are only measured at the nominal or ordinal level. We carried out a series of Pearson Chi-square and Fisher’s exact tests to evaluate the relationship between various industry characteristics and the associated industry-level results, using SPSS. These tests are used to check whether a statistically significant relationship exists between two categorical variables. We have already classified the industries into two groups: winners and losers. To carry out tests, we assign a value of 1 to the winners and 0 to the losers. As we have discussed in section 6.4.1, ORANIMON commodities are classified into traditional (individual) and non-traditional (collective) groups. Hence, we can use this classification for export orientation in non-parametric test. Likewise, we can assign binary values to various characteristics of the industries. These dual characteristics include tradable or non-tradable, import-competing or non-competing, labour-intensive or not labour-intensive, and capital-intensive or not capital-intensive. The detailed description for each of the 55 ORANIMON industries and commodities is provided in Appendix 6.4. In our non-parametric tests, we exclude four mining industries, as they are subject to our shocks and our primary interest is in the effects on the other industries.

Table 6.18 Non-parametric test results

Null hypothesis	Pearson Chi-square test values		Fisher's exact test p value	**Decision**
	$\chi 2$	p		
No association between **industry labour intensity** and **industry results**	1.114	.291	.391	Do not reject H_0
No association between **industry capital intensity** and **industry results**	.004	.949	1.0	Do not reject H_0
No association between **import competitiveness** and **industry result**	29.76	.000	.000	Reject H_0
No association between **export orientation** and **industry results**	5.269	.022	.031	Reject H_0

Table 6.18 contains the summary of the test results. The cross-tabulations and the detailed test outputs can be found in Appendix 7.4.

An association between import competitiveness and industry result is found, $\chi 2$ (1, N = 55) = 30.611, p = 0.000. Examination of the cell frequencies showed that 87.5% (21 out of 24) of the winners are non-import competing industries while the percentage of losers in import competing categories is 89% (24 out of 27). Fisher's exact test result also confirms the finding (p=0.000). Given such a relatively low p value (0.000), we conclude that import competitiveness plays a crucial role for industry output changes due to the mining boom.

Pearson $\chi 2$ (p=.003) and Fisher's exact (p=.005) test results reveal that there is a dependency between export orientation and industry results. Examination of the cell frequencies showed that about 75% (18 out of 24) of the winners are industries which produce collective export goods while 67% (18 out of 27) of the losers are industries which produces individual export goods.

The test results indicate that there is no significant relationship between other characteristics (labour intensity and capital intensity) and industry performance.

In terms of different elasticities, we can also classify the commodities into elastic or inelastic. But in case of various elasticities, and the trade measures that we have defined earlier, we use parametric tests and analyse through a regression method in our systematic sensitivity analysis.

6.6.5 Regression analysis

The application of regression analysis to test explanations of results is one of the multiple validating procedures (Dixon & Rimmer 2013, p. 1272).

To test the validity of our descriptive analysis and to further explore the relationship between the trade measures and industry performance, we estimate the compact and extended regression equations of the forms by using EVIEWS[6]:

$$z_c = b_0 + b_1 TRDS_c \tag{6.2}$$

where z_c and $TRDS_c$ are the change in output and the trade sensitivity of each commodity c; and b_0 and $b_1$are regression coefficients.

$$z_c = c_0 + c_1 IMSE_c + c_2 EXSE_c \tag{6.3}$$

where z_c, $IMSE_c$ and $EXSE_c$ are as previously defined; and c_0, c_1 and c_2 are regression coefficients.

In ORANIMON, the number of industries is equal to the number of commodities. Some industries produce more than one commodity. Because our multiproduct industries produce only a negligible quantity of other products in addition to its main product, we assume $z_c = z_i$ for simplicity. ‘Livestock’ industry is multi-product industry, i.e., and one of its product mix, ‘Leather product’ commodity, accounts for less than 0.7% in the industry’s total output.

The LS outcome of first regression is:

$$z_c = 22.65 - 15.81 TRDS_c, \qquad R^2 = 0.68 \tag{6.4}$$

[6] EVIEWS stands for Econometric Views. It is a statistical package for Windows.

In (6.4) all regression coefficients are statistically significant at the 1% level and overall model is itself significant at the 1% level (F stat = 102.45, p<0.01).

The estimated equation shows there is significant negative relationship between the trade sensitivity and the changes in outputs of commodities or the industry activity levels due to the mining boom. Equation (6.4) indicates that 68% of the variation in the changes of activity level can be attributed to variations in *TRDS*. This shows, in turn, overwhelming implications for a nation's trade from mining booms.

The outcome of the second regression is:

$$z_c = 16.2 - 3.3IMSE_i - 17.1EXSE_i, \quad R^2 = 0.62 \qquad \textbf{(6.5)}$$

All regression coefficients are statistically significant at the 1% level and overall regression equation is itself significant at the 1% level (F stat = 39.48, p<0.01).

The estimated equation confirms that both import and export sensitivities are negatively related to the changes in outputs of commodities. In terms of estimated coefficients in (6.5), export sensitivity has a larger effect on the outcome for industries.

Consistent with the non-parametric test results, adding the shares of labour and capital to the regressions cannot improve the explanatory power of the regressions and each of them has no significance (p>0.35).

As we have seen in previous subsections, we can determine the impacts and their underlying reasons related to the structure and characteristics of each ORANIMON industry in greater detail. The regression results, in addition, help summarize industry results at the economy-wide level.

6.7 Systematic sensitivity analysis

Systematic sensitivity analysis (SSA) can evaluate and measure the extent to which parameter choice influences modelled outcomes (Arndt & Pearson 1998; Wittwer 2000).

The first reason to carry out SSA is due to the results from our statistical tests and regression analysis. We know that each *IMSE* contains an intermediate Armington elasticity, whilst each *EXSE* includes export elasticity. Further regressions and tests reveal that these elasticities have statistically significant effects on the variations of output changes across industries ($p < 0.05$). However, all other elasticities have been found to have no significant statistical relationship to the changes in outputs. Hence, the parameters to be evaluated through SSA are intermediate Armington elasticities and export elasticities.

The second reason to do SSA is that we use imposed estimates rather than estimated elasticities in ORANIMON analysis. Therefore, SSA is essential in order to check the robustness of the ORANIMON results. We have carried out three versions of SSA: varying Armington elasticities (SSA1), varying export elasticities (SSA2) and varying both Armington and export elasticities (SSA3).

We vary two elasticities uniformly from their base values by plus and minus 75%. We choose to vary these elasticities individually or one by one so that ORANIMON is solved 112 times each for SSA1 and SSA2 and 222 times for SSA3. The SSA calculations provide the mean and standard deviation (SD) for each endogenous variable. In order to compare the sensitivities across variables and industries or commodities, moreover, we have calculated the coefficient of variation (CV) for each of them.

Table 6.19 summarises the SSA results for the main macro variables. The CONSUME column shows the ORANIMON results from the second stage simulation in the CONSUME scenario. SSA1 columns show the estimated mean, standard deviation from the SSA analysis and the calculated coefficient of variance for each main macro variables. If we look at the results, the standard deviations across variables are very small and so are the coefficients of variation.

The SSA1 results clearly indicate that the ORANIMON results are robust as far as the intermediate Armington elasticities are concerned. SSA2 and SSA3 columns in Table 6.19 provide the results from varying export elasticities and varying both Armington and export elasticities, respectively.

All of the standard deviations except for export volume are extremely low. For those variables which have the CV values of 0.05 or less, we can be sure that the ORANIMON simulated results are robust results. The CV for export volume (0.18 in SSA2 and 0.25 in SSA3) indicates that the results for export volume is quite sensitive compared to others. However, the rule of thumb in SSA says that, if the mean is significantly greater than the standard deviation, we can conclude the model result is a robust one (Arndt & Pearson 1998).

Table 6.19 SSA results for main macro variables

Main Macro Indicators	CONSUME	SSA1			SSA2			SSA3		
		Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Real Household Consumption	41.9	41.9	0.2	0.00	41.9	0.5	0.01	41.9	0.6	0.01
Real Government Expenditure	41.9	41.9	0.2	0.00	41.9	0.5	0.01	41.9	0.6	0.01
Export Volume	-4.8	-4.8	0.2	0.04	-4.5	0.8	0.18	-4.4	1.1	0.25
Import Volume	48.3	48.3	0.4	0.01	48.8	1.1	0.02	48.9	1.3	0.03
Real GDP Growth	14.9	14.9	0.1	0.01	14.9	0.3	0.02	14.9	0.4	0.03
Aggregate Employment	29.7	29.7	0.4	0.01	29.7	1	0.03	29.7	1.1	0.04
Nominal Wage	57.5	57.6	0.6	0.01	58.2	2.1	0.04	58.4	2.8	0.05
Aggregate Capital Stock	7.1	7.1	0	0.00	7.1	0.1	0.01	7.1	0.1	0.01
GDP Price Index	94.1	94.2	0.6	0.01	94.9	2.4	0.03	95.2	3	0.03
CPI	57.5	57.6	0.6	0.01	58.2	2.1	0.04	58.4	2.8	0.05
Export Price Index	85.7	85.7	0.1	0.00	85.9	0.4	0.00	85.9	0.4	0.00
Nominal Household Consumption	122.5	122.6	0.9	0.01	123.4	2.5	0.02	123.7	3.4	0.03
Nominal GDP Growth	122.5	122.6	0.9	0.01	123.4	2.5	0.02	123.7	3.4	0.03

With the CV value of 0.18, for instance, we can calculate that the threshold related to the standard deviation is 2.77SD. If the normal distribution is assumed, then we can be 99.44% confident that the ORANIMON simulated export volume will be a robust result.

Table 6.20 contains SSA results for aggregate sectoral results. All three SSA results confirm that the ORANIMON sectoral output results are highly robust, given such low values of SD and CV.

It can be seen from the SSA2 results in Table 6.20 that CV values for ‘Agriculture’ and ‘Industry’ sectors are small but higher than for the other two sectors. Hence, we have analysed industry outcomes of SSA and have provided the results in Appendix 7.6. Disaggregated SSA2 results indicate that the output change of 'Crops' industry, one of the collective export commodity producing industries, is quite sensitive compared to the others.

Parameter choices within ORANIMON over a reasonably wide range for intermediate Armington and export elasticities do not affect the impacts on simulated changes in the macroeconomic and sectoral variables.

Table 6.20 SSA results for aggregate sectoral results

Aggregate sectoral output	CONSUME	SSA1			SSA2			SSA3		
		Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Agriculture	3.2	3.2	0.1	0.03	3.2	0.2	0.06	3.2	0.3	0.09
Mining and Quarrying	18.7	18.7	0	0.00	18.7	0.1	0.01	18.7	0.1	0.01
Industry	-16.7	-16.5	0.6	0.04	-16.5	1.2	0.07	-16.4	1.5	0.09
Services	17.9	17.9	0.3	0.02	17.9	0.6	0.03	17.9	0.7	0.04

6.8 Summary

We carried out the two scenario-two step sequential simulations using ORANIMON, the first COPS-style CGE model of the Mongolian economy, to assess the impacts of the mining boom. In general, there are three main aims for the ORANIMON application. The first is to validate the modeling. We employed different types of validation techniques, such as BOTE calculations and statistical methods. Two simple BOTE models were used to analyse the simulated effects on the Mongolian macro economy from the mining boom and to check the plausibility of the model results. We find that the BOTE calculations are quite close to the actual outcomes of the CGE model, supporting the ORANIMON results. The non-parametric tests, which had not been used in CGE modelling, are utilized to summarize industry results at the economy-wide level, and to explore the relationship between various industry characteristics and industry performance. The additional tests and regression analysis are further used to examine the relationship between various industry characteristics and industry performance and to check the sensitivity of the parameters. Taking account of the results from the statistical methods, we have carried out three SSA to check the robustness of the ORANIMON results. When analysing SSA outcomes, we have added CV, a newly used measure in a CGE SSA, and have attempted to employ a probabilistic approach for validation. The SSA results assure us that the ORANIMON results are robust to the changes in choice of export and Armington elasticities.

The second aim is to evaluate the impact of the mining boom. The mining boom results in a massive increase in Mongolia's *TOFT* which, in turn, increased the real purchasing power of domestic output. The boom stimulated the employment of labor and the overall performance of the economy. The balance of trade, the overall price level of the economy and main macroeconomic variables are greatly affected by the boom. Furthermore, we have analysed the effects at industry level through decomposition and statistical methods. The manufacturing sector is a main loser, as its output is decreased at both stages for both scenarios. This de-industrialization impact is consistent with the Dutch disease hypothesis. The services sector was a major winner, as its output increased sizably. The agriculture sector is relatively mildly affected, with mixed results in the two scenarios. ORANIMON determines the effects and decomposes those into the contributions of the factors related to the structures and characteristics of each ORANIMON industry in greater detail. We have used statistical methods, in addition, to summarize industry results at an economy-wide level. Of different characteristics of industries and commodities, import competitiveness and export orientation are significantly associated with industry performance, according to non-parametric test results. We have defined trade sensitivity measures that are regressed to changes in outputs of industries. These trade sensitivity measures have been found to explain the variations in the performance of the industries, significantly leading to the investigation of two parameters: intermediate Armington and export elasticities. Parameter choices within ORANIMON over a reasonably wide range do not affect the simulated changes in the macro and industry level variables.

The third aim is to assess and propose the policy measure against the negative effects of the mining boom. Due to the shocks, the real exchange rate substantially appreciated, pressuring trade-sensitive industries. ORANIMON produces the detailed effects for the two scenarios, enabling us to analyze the different aspects and implications of the mining boom. The results from step-by-step simulations and the decomposition of the macroeconomic variables indicate that the changes induced by the mineral price increase are significantly different, while the changes brought by the investment surge are quite similar across scenarios. The simulated results reveal that there is a notable difference in terms of negative impacts on the manufacturing sector, which is relatively mild in SAVE and quite harsh in CONSUME. The simulation results indicate that the policy measurements of restricting domestic consumption and/or establishing saving could not only help in the long run to stabilize but also to counteract and lessen the de-industrialization effect of the mining boom in the short and medium term. This finding has an important implication for Mongolian economic policy. Volatility in developing countries arises from external shocks, as we have simulated through ORANIMON in the case of Mongolia. Unfortunately, the fiscal policies of Mongolia had been pro-cyclical: expansionary rather than countercyclical during the recent mining boom. This type of economic policy often exacerbates volatility and creates larger cycles of fluctuation; in turn, economies become more exposed to external factors. In addition, government revenue in a mineral economy unavoidably fluctuates due to frequent volatility in commodity prices. As a result, budgeting and planning become more problematic and require frequent adjustments that may cause trouble in private investment. There are countercyclical policy methods, such as a Sovereign Wealth Fund (SWF), a method often advanced to counter many of the potential negative consequences of natural resource extraction in developing countries. The results from the ORANIMON sequential simulations with two scenarios may help to understand the reasons and may provide confidence in utilizing methods like a SWF for reducing negative structural change effects of the mining boom.

ORANIMON applications identify differences between two alternative states of the Mongolian economy at some past point in time: one state in which the mining boom occurred and the other in which the boom did not occur. We have not made any attempt to identify how the economy might have evolved from 2005 under any particular set of assumptions. Because of its comparative static nature, we are not able to run year-on-year simulations that may explain recent episodes of the mining boom in Mongolia. ORANIMON is not equipped with dynamic links between investment flows and capital stocks, and between trade flows and stock of foreign debt. In order to study the adjustment path and structural change during the recent mining boom, we have developed a recursive dynamic CGE model called MONAGE. The next two chapters are concerned with the applications of MONAGE.

Chapter 7. Historical and Decomposition simulations

7.1 Preamble

The COPS-style approach to fitting history is the technique of historical simulation. Historical simulations have become popular for the last decade with MONASH style modellers. Its origins, however, can be traced back to Dixon and McDonald (1993). In general, there are three main purposes to doing historical simulations. The first is to update a CGE database to a recent year. The second is to estimate changes in structural variables. The third is to assess the plausibility of model estimations as a form of validation.

In the previous chapter, we analysed the short- and medium-run impacts of a mineral price increase and investment growth on the Mongolian economy. In order to examine the long-run impacts, we use historical and decomposition simulations for determining and quantifying the underlying sources of structural change and their contributions to economic growth in Mongolia. These simulations are concerned with the growth of the Mongolian economy from 2005 to 2012 with reference to the recent mining boom.

The role of the historical simulation is to 'fill the gaps' by inferring values for the unobservable variables that are consistent with what is already known about the Mongolian economy. Hence, the historical simulation involves forcing MONAGE to track economic history by exogenising and shocking observable variables, and allowing the model to determine implied paths for naturally exogenous but unobservable variables, such as industry technologies, household preferences, required rates of return on capital, and positions of export-demand curves and import supply curves. The changes in these variables are, in fact, the sources of structural change in Mongolia.

We quantify several aspects of technical change in Mongolian industries for the period 2005 to 2012, including: intermediate-input-saving technical change; primary-factor-saving technical change; and import-domestic bias in technical change. It also quantifies the movement in export-demand curves and import supply curves. These quantifications are done in accordance with the economic theory underpinning the MONAGE model.

Then we apply the decomposition simulation in illustrative analyses of growth in the Mongolian economy between 2005 and 2012 and of growth in the winner and loser industries that we find through short- and medium-run simulations in Chapter 6.

7.2 Decomposition and Historical Closures

We have discussed closures in general for COPS-style models in Chapter 2 and four types of closures in Chapter 4, Section 4.3. Decomposition and historical simulations and related closures refer to the past. A decomposition simulation essentially explains economic history by identifying the key drivers behind the actual outcomes, e.g., how significant was a change in technology relative to a change in government policy in explaining why a commodity's output moved strongly in a particular way. In a historical simulation, we impose observed changes in economic variables over the period 2005 to 2012 as exogenous shocks. These economic variables include employment and wages, investment and capital stocks, value added prices, balance of payment components, consumption composition and consumer prices. Most of these are normally endogenous in a standard or decomposition closure of the model. Imposing these normally endogenous variables as exogenous requires, on the other hand, that variables describing the structure of the economy be endogenous. The structural variables include primary factor productivity, household taste change, shifts in foreign demand curves, changes in industry rate of returns, propensities to consume/invest, shifts in source preference, and shifts in export supply curves.

Let us define MONAGE again by:

$$F(X) = 0 \tag{7.1}$$

where F is the m-vector of differentiable functions of n variables, X. In MONAGE, the number of equations is less than the number of variables so that n-m number of variables is needed to be determined exogenously.

The equations of F define the theoretical structure of MONAGE, as we have described in Chapter 3 and 4. An initial solution to (2.2) is provided for the year of 2005, as we explored in Chapter 5.

It is convenient to define historical closure along with decomposition closure, as in Dixon and Rimmer (2002), by dividing the variables of the model into four sets, since an historical closure is typically developed by incrementally moving away from a decomposition closure. Let us denote exogenous and endogenous variables in our historical closure by $\overline{\boldsymbol{H}}$ and $\boldsymbol{H}$ respectively. Similarly, let us denote exogenous and endogenous variables in our decomposition closure by $\overline{\boldsymbol{D}}$ and $\boldsymbol{D}$ respectively. In our convention, the bar notation expresses an exogeniety.

Furthermore, we can define four divided sets of the variables $X(\overline{\boldsymbol{H}}\overline{\boldsymbol{D}})$, $X(\overline{\boldsymbol{H}}\boldsymbol{D})$, $X(\boldsymbol{H}\overline{\boldsymbol{D}})$ and $X(\boldsymbol{H}\boldsymbol{D})$, where $X(\overline{\boldsymbol{H}}\overline{\boldsymbol{D}})$ is comprised of those variables that are exogenous under both historical and decomposition closures, $X(\overline{\boldsymbol{H}}\boldsymbol{D})$ is comprised of those variables that are exogenous under historical closure but endogenous under decomposition closure, $X(\boldsymbol{H}\overline{\boldsymbol{D}})$ is comprised of those variables that are endogenous under historical closure but exogenous under decomposition closure, and $X(\boldsymbol{H}\boldsymbol{D})$ is comprised of those variables that are endogenous under both historical and decomposition closures.

The sets $X(\overline{\boldsymbol{H}}\boldsymbol{D})$ and $X(\boldsymbol{H}\overline{\boldsymbol{D}})$ are related to each other and contain the same number of corresponding elements. Most importantly, there exists an economic relationship between the individual elements of each set. The economic relationship, in turn, helps facilitate our historical and decomposition simulations. In our historical simulation, we allow the elements of $X(\boldsymbol{H}\overline{\boldsymbol{D}})$ to be determined endogenously and the corresponding elements of $X(\overline{\boldsymbol{H}}\boldsymbol{D})$ to be determined exogenously. Conversely, in our decomposition simulation, we allow the elements of $X(\overline{\boldsymbol{H}}\boldsymbol{D})$ to be determined endogenously and the corresponding elements of $X(\boldsymbol{H}\overline{\boldsymbol{D}})$ to be determined exogenously equal to their values obtained through the historical simulation. Table 7.1 provides some examples of the partitioning of variables in the historical and decomposition closures.

Table 7.1 Variables in the Historical and Decomposition Closures

Selected components of $X(\overline{\boldsymbol{H}}\boldsymbol{D})$	Corresponding components of $X(\boldsymbol{H}\overline{\boldsymbol{D}})$
Private consumption by commodity	Shifts in household preferences
Total intermediate usage by commodity	Intermediate-input-saving technical change
Employment of labour and capital inputs by industries	Primary-factor-saving technical change and capital/labour bias
Imports by commodity	Shifts in import/domestic preferences
Producer prices by industry	Rates of return on capital or markups on costs
Export volumes and FOB prices	Shifts in foreign demand and domestic supply functions

Macro variables	Shifts in macro functions
Selected components of $X(\overline{\boldsymbol{H}}\overline{\boldsymbol{D}})$	
Population Number of households CIF prices of imports in foreign currency Tax and tariff rates Interest rates Land use by industry	
Selected components of $X(\boldsymbol{HD})$	
Demands for margin services Prices of inputs by industry for current production and capital creation	

Source: Adapted from Dixon and Rimmer (2002)

Upon the partition of four sets, we can carry out the historical simulation to obtain a solution of:

$$X(H) = G^{\overline{H}}(X(\overline{H})) \tag{7.2}$$

where $X(H) = X(\boldsymbol{H}\overline{\boldsymbol{D}}) \cup X(\boldsymbol{HD})$; $X(\overline{H}) = X(\overline{\boldsymbol{H}}\overline{\boldsymbol{D}}) \cup X(\overline{\boldsymbol{H}}\boldsymbol{D})$; and $G^{\overline{H}}$ is a m-vector of differentiable functions used to calculate the values for $X(H)$ by assigning their historically observed values to the variables in $X(\overline{H})$.

By observing and assigning $X(\overline{\boldsymbol{H}})$ for 2005 and 2012, along with the movements of the variables in $X(\overline{\boldsymbol{H}}\overline{\boldsymbol{D}})$, we can estimate percentage changes of the variables in $X(\boldsymbol{H})$ for the period using equation (7.2).

Next, we can carry out the decomposition simulation to get a solution of the form:

$$X(D) = G^{\overline{D}}(X(\overline{D})) \tag{7.3}$$

where $X(D) = X(\overline{\boldsymbol{H}}\boldsymbol{D}) \cup X(\boldsymbol{HD})$; $X(\overline{D}) = X(\overline{\boldsymbol{H}}\overline{\boldsymbol{D}}) \cup X(\boldsymbol{H}\overline{\boldsymbol{D}})$; and $G^{\overline{D}}$ is an m-vector of differentiable functions used to calculate the values for $X(D)$ by assigning their historically observed values to the variables in $X(\overline{D})$.

Following the linearisation method discussed in Chapter 2, we can write (7.6) in percentage change form as:

$$x(D) = B \cdot x(\bar{D}) \tag{7.4}$$

where $x(D)$ and $x(\bar{D})$ are vectors of percentage changes in the variables in $X(D)$ and $X(\bar{D})$; and B is an *m* by *n-m* matrix in which the *ij*-th element is the elasticity of the *i*-th component of $X(D)$ with respect to the *j*-th component of $X(\bar{D})$, that is:

$$B_{ij} = \frac{\partial G_i^{\bar{D}}(X(\bar{D}))}{\partial X_j(\bar{D})} \cdot \frac{X_j(\bar{D})}{X_i(D)} \tag{7.5}$$

After carrying out the historical simulation, the percentage changes in all variables of $X(\bar{D})$ or the vector $x(\bar{D})$ are known. Therefore, we can use (7.4) to compute the percentage changes in all variables of $X(D)$ or the vector $x(D)$ over the period 2005 to 2012. This enables a decomposition of the percentage changes in the variables in $X(D)$ over the period 2005 to 2012 into the parts attributable to movements in the variables of $X(\bar{D})$. With the completion of the historical simulation, each of the variables in $X(\bar{D})$, i.e., technology variables, preference variables, international variables (e.g. shifts in export demand curves) and policy variables, can be considered as independently determined and as having their own attributed effects on the variables of $X(D)$, i.e., outputs, incomes, employment, consumption, exports, imports and investment.

7.2.1 BOTE-3 model

Table 7.2 BOTE-3 model and its historical and decomposition closures

B. Decomposition closure	**A. Historical closure**	
$Y = \frac{1}{\bar{A}} F(K, \bar{L})$	$Y = \frac{1}{A} F(\bar{K}, \bar{L})$	**BOTE-3.1**
$Y = C + I + G + X - M$	$Y = \bar{C} + \bar{I} + \bar{G} + \bar{X} - \bar{M}$	**BOTE-3.2**
$\frac{C}{G} = \bar{\Gamma}$	$\frac{\bar{C}}{\bar{G}} = \Gamma$	**BOTE-3.3**
$TofT = \frac{P_x}{\bar{P}_m}$	$TofT = \frac{\bar{P}_x}{\bar{P}_m}$	**BOTE-3.4**
$RW = F(K/\bar{L}, \bar{A}, TofT, \bar{\Omega})$	$\overline{RW} = F(\bar{K}/\bar{L}, A, TofT, \Omega)$	**BOTE-3.5**
$K/\bar{L} = F(\overline{RoR}, \bar{A}, \bar{T}_K, TofT, \bar{\Omega})$	$\bar{K}/\bar{L} = F(\overline{RoR}, A, \bar{T}_K, TofT, \Omega)$	**BOTE-3.6**
$X = F(P_x, RER, \bar{\Lambda})$	$\bar{X} = F(\bar{P}_X, RER, \Lambda)$	**BOTE-3.7**
$M = F(Y, TofT, \bar{T}, RER, \bar{\Upsilon})$	$\bar{M} = F(Y, TofT, \bar{T}_m, RER, \Upsilon)$	**BOTE-3.8**
$\bar{\Psi} = I/K$	$\Psi = \bar{I}/\bar{K}$	**BOTE-3.9**

$GNP = Y \cdot F(TofT) - NFL \cdot \bar{R}$	$GNP = Y \cdot F(TofT) - NFL \cdot \bar{R}$	**BOTE-3.10**
$C + G = \overline{APC} \cdot GNP$	$\bar{C} + \bar{G} = APC \cdot GNP$	**BOTE-3.11**
$NFL = F(K, \overline{APC}, GNP)$	$NFL = F(\bar{K}, APC, GNP)$	**BOTE-3.12**

Notes: Barred denotes exogenous. Remaining variables are endogenous. F expresses a function. *Source*: Modified from Giesecke and Tran (2009).

We explain the historical closure and its relationship to the decomposition closure via a trade-focused BOTE-3 model in which Mongolia produces good g domestically and exports it and imports good *v*, consumes g and *v* and creates capital from g and v. Table 7.2 introduces equations of BOTE-3 model and its decomposition and historical closures.

7.2.2 Developing the MONAGE decomposition closure

The decomposition closure, as we have defined earlier, is a standard, one-period long-run closure in which all naturally exogenous variables are exogenous. We partition the variables in MONAGE into eight groups to organize the presentation of the decomposition closure.

(a) Technology, import/domestic preferences and consumer tastes

In the decomposition closure, changes in technology, import/domestic preferences and consumer tastes are exogenous. The equation BOTE-3.1 is the economy-wide production function, which relates real GDP to inputs of labour and capital, and to a technology shift term (A). The equation BOTE-3.8 provides the function for real imports (M) of GDP (Y), the terms of trade ($TofT$), the real exchange rate (RER) and ϒ- a cost-neutral shift term in technologies and preferences in favour of foreign commodity *v* against domestic commodity g. A and Υ are examples of the variables in first group and are in the set $X(\boldsymbol{H\bar{D}})$. The only technology and preference variables that are not included in the list of exogenous variables in the decomposition closure are derived from other technology and preference variables or have their own explanatory (theoretical) equations. For instance, variable *a2csi* in equation 4.36, a source-specific commodity-saving technical change variable in industry, is determined by other twin technical variables: *a2csi_dom* and *a3csi_imp*. These two variables convert twists into source-specific commodity-saving technical changes, *a2csi*.

(b) Employment and wages

Hence it is long-run closure, aggregate employment and relative wages across industries that are exogenized in the decomposition closure. To accommodate the exogenous determination of aggregate employment, the overall real wage rate needs to be endogenous. The consumer real wage (RW) is defined as a function of the capital labour ratio (K/L), all-factor-augmenting technical change (A), $TofT$ and the cost-neutral labour/capital preference twist Ω in BOTE-3.5. Here, L, A and Ω are in the list of exogenous variables. A and Ω belong to $X(\boldsymbol{H}\overline{\boldsymbol{D}})$ while L is an example of the elements in $X(\overline{\boldsymbol{H}}\overline{\boldsymbol{D}})$.

(c) Capital, investment and rates of return

In decomposition simulations, year-to-year movements in investment and capital stocks are not concerned. Reflecting the long-run, typical decomposition, simulations generate results for capital available for use in industries in year t (say, 2012), mainly on the basis of exogenously specified movements in rates of return. BOTE-3.6 defines rates of return (RoR) as a function of the capital labour ratio (K/L), all-factor-augmenting technical change (A), the terms of trade ($TofT$) and the cost-neutral labour/capital preference twist (Ω). We can see that RoR is also exogenous along with L, A and Ω in this equation and belongs to $X(\overline{\boldsymbol{H}}\overline{\boldsymbol{D}})$.

(d) Public and private consumption

In decomposition simulations, aggregate private and public consumption are typically linked to GNP through APC. BOTE-3.11 links consumption ($C+G$) to GNP via a given average propensity to consume (APC). The familiar equation for the ratio of private to public consumption spending (Γ) is given as BOTE-3.3. Both APC and Γ are exogenous in the decomposition closure. Changes in the ratio of private and public consumption to GNP can be introduced by shocks to APC, whereas changes in the ratio of public consumption to private consumption can be introduced by shocks to Γ. Both APC and Γ belong to $X(\boldsymbol{H}\overline{\boldsymbol{D}})$.

(e) Export demand and import prices

As we treat Mongolia as a small importing nation, the CIF foreign-currency prices of imports are exogenous in the decomposition closure. BOTE-3.4 defines the terms of trade ($TofT$), which shows the real purchasing power of domestic outputs as a ratio of export and import prices. Here, P_v is exogenous and the movement in $TofT$ is explained by changes in P_g. As we have discussed in Chapter 3, we adopt downward-sloping foreign-demand curves for Mongolian exports. The positions of these demand curves are exogenized in the decomposition closure. BOTE-3.7 defines real exports as a function of export price(P_X), RER and Λ – a shift in foreign demands. Thus, Λ is included in the exogenous list and belongs to $X(\boldsymbol{H\bar{D}})$.

(f) Tax rates and transfer payments

In the decomposition closure, tax rates, rates of various benefit payments and rates of other transfer payments to the households are included in the exogenous list. The equations BOTE-3.6 and BOTE-3.8 contain tax variables T_K and T_m. These are exogenous both in the decomposition and historical closures belonging to $X(\boldsymbol{\bar{H}\bar{D}})$.

We note, however, that there are some tax variables, which are functions of the other tax variables, in MONAGE. Let us illustrate a general case. Sales tax revenue on any commodity flow or production tax revenue on the basic value of an industry's output can be written as:

$$T = P \cdot Q \cdot (\Pi - 1) \tag{7.6}$$

where T is the tax revenue; P is the basic price of the relevant commodity or industry output; Q is the quantity flow; and Π is the power (one plus the rate) of the tax applicable to the basic flow of the particular flow.

The percentage change form of (7.6) can be written as:

$$100 \cdot \Delta T = T \cdot (p + q) + (T + BV) \cdot \pi \tag{7.7}$$

where ΔT is the change in tax revenue; BV is the basic value of the flow (that is, $BV = P \cdot Q$); and p, q and π are percentage changes in the variables represented by the corresponding upper case symbols.

If we express is the product of two shift variables, Π_G and Π_{PH}:

$$\Pi = \Pi_G \cdot \Pi_{PH} \tag{7.8}$$

where Π_G and Π_{PH} are the power of genuine taxes and the power of phantom taxes.

Genuine taxes are those collected by the government and phantom taxes are a device for reconciling incompatible data items in prices and costs.

If we express each of Π_G and Π_{PH} as a product of other shift variables, $\Pi_{G,1}, \ldots, \Pi_{G,n}$ and $\Pi_{\mathrm{PH,1}}, \ldots, \Pi_{\mathrm{PH,m}}$, and then the define the percentage change form of (7.8) as:

$$\pi = \sum_{j=1}^{n} \pi_{G,j} + \sum_{j=1}^{m} \pi_{PH,j} \tag{7.9}$$

The various phantom tax power shift variables are used in our historical simulation. In the decomposition closure, all these tax power shift variables are exogenous imposing fixed tax rates.

(g) Foreign assets and liabilities and the balance of payment

In decomposition simulations, net foreign liabilities at the start of the year t (say, 2012) are determined mainly by growth between $t - \tau$ and t (e.g. 2005 and 2012) in GNP, the average propensity to consume, the exchange rate and the aggregate capital stock. BOTE-3.12 shows this relationship in which APC is exogenously determined.

(h) Numeraire

The absolute price level is tied down by exogenization of either the exchange rate or a macro price index (i.e., *CPI*), as MONAGE does not explain the absolute price level. In MONAGE, we have used the CPI as the *numeraire*.

In the decomposition closure, each BOTE-3 equation can be associated with determination of a specific endogenous variable. Between 2005 and 2012, the foreign currency prices of Mongolia's commodity exports were almost tripled, resulting in a significant increase in the terms of trade, *TofT*. Let us look at the impact of *TofT* improvement in BOTE-3. For a given increase in *TofT*, BOTE-3.6 determines *K*. This fixes *Y* from the supply side via BOTE-3.1. With *K* determined, *I* is fixed and determined by BOTE-3.9. With a given *TofT* and *K* determined, BOTE-3.5 allows us to find RW. With *Y* determined, much of *GNP* can be determined via BOTE-3.10. With *GNP* determined, *C* and *G* are determined by BOTE-3.3 and BOTE-3.11. Since *K* determined, so too are savings and investment *I*, allowing BOTE-3.12 to determine *NFL*. BOTE-3.8 determines *M* leaving BOTE-3.2 to determine *X*.

7.2.3 Developing the MONAGE historical closure

The historical simulation is best described as a stepwise development from the decomposition closure. At each step, a variable describing an observable feature of economic history is moved to the exogenous variable list via endogenous determination of a relevant variable describing economic structure (Dixon & Rimmer 2002). In our historical simulation, we deduce changes in these variables between two points in time, 2005 and 2012, as a result of movements in outputs, factor inputs and real wages over the same period. In other words, changes in technology variables are endogenously determined by exogenously set movements in employment, capital and real wage rates. Under the decomposition closure, most variables describing economic history are endogenous. Hence their values cannot be imposed on the model. A new closure (the historical closure) must be developed in which variables describing economic history are exogenous.

BOTE-3.2 shows the familiar GDP identity in constant price terms defined from the demand side. In the MONAGE historical simulation from 2005 to 2012, movements in *C*, *I*, *G*, *X* and *M* are set exogenously at their observed values. This meant that Y, while formally endogenous, is effectively tied down. Here, *C* is swapped with *APC*; *G* is swapped with Γ; I is swapped with Ψ; X is swapped with Λ. Now, structural variables *APC*, Γ, Ψ, and Λ are endogenous.

With movements in L and K also set exogenously using observed data and Y is determined through BOTE-3.1, the model is able to compute the change in *A*. In the context of an historical simulation this effectively ensures that GDP (*Y*) from the income side will 'hit the target' as determined by GDP (*Y*) from the expenditure side. As will be seen later, conceptually similar calculations take place at the industry level to determine all-factor-augmenting technical change for the period of 2005 to 2012.

In terms of BOTE-3.3, Γ, swapped with G, is now endogenous in the historical closure. With the observed values of *C* and *G*, the model is able to compute the change in Γ. The terms of trade ($TofT$) is endogenous in both closures and therefore belongs to $X(\boldsymbol{HD})$, while P_M is exogenous in both closures and hence belongs to $X(\overline{\boldsymbol{H}}\overline{\boldsymbol{D}})$. $TofT$ is fixed and determined via BOTE-3.4 in the historical simulation, as both P_X and P_M are set exogenously at their observed values. BOTE-3.5 defines a consumer real wage (RW). We have seen the variant of this equation in BOTE-1 and BOTE-2 analyses and have derived the relationship of $TofT$ to RW. Armed with results for *A* and $TofT$, along with data reflecting changes in RW, L and *K*, the historical simulation endogenously computes the movement in Ω.

The relationship between BOTE-3.5 and BOTE-3.6, which defines the rates of return (RoR) as a function of the capital labour ratio (K/L), all-factor-augmenting technical change (A), $TofT$ and the cost-neutral labour/capital preference twist Ω are implied by the factor-price frontier. The factor-price frontier relates the marginal product of labour to the marginal product of capital, for which the latter determines the rate of return. Exogenization of real wages in BOTE-3.6 means that the marginal product of labour is tied down in the historical simulation. As a result, rates of return on capital (RoR) must have the flexibility to adjust to the exogenous wage rate values. Thus the model is able to determine RoR in BOTE-3.6, since we have results for A, $TofT$, Ω, along with data reflecting changes L and K.

Commodity exports in MONAGE are inversely related to foreign currency prices via constant elasticity demand functions. This is summarized by the BOTE-3.7 equation that relates the foreign currency export price(P_X) as a function of X and Λ – a shift in foreign demand. With the observed values of X and P_X, we are now able to compute the change in Λ. As we have seen in Chapter 6, the movement in Λ is crucial for determining the impact of a mining boom. With the calculated values of Y, $TofT$ and exogenously given value of T_m, as well as the observed value of M, the model is able to solve the change in Υ in equation BOTE-3.8.

In historical simulations, the changes in each industry's capital stock and investment between the base and final years are exogenous, reflecting statistical observations. Hence we can estimate the long-run industry-specific investment/capital ratios through historical simulations. We have seen that these ratios reflect the investor confidence in Chapter 4. Similar to other structural variables, Ψ is exogenous in the decomposition closure but endogenous in the historical one. It is determined by BOTE-3.9, as we have the observed values for I and K.

BOTE-3.10 defines that *GNP* is equal to the gross domestic product (Y) adjusted for the terms of trade via $F_2(TofT)$ and net foreign income flows ($NFL \cdot R$), where NFL is real net foreign liabilities and R is the interest rate. It can be seen from Table 7.2 that *GNP* is an element of the $X(\boldsymbol{HD})$ set and R is an element of $X(\overline{\boldsymbol{H}}\overline{\boldsymbol{D}})$. BOTE-3.11 links consumption $(C + G)$ to GNP via a given consumption propensity (APC). APC, swapped with *C*, is endogenous in the historical closure. MONAGE relates the change in *NFL* to the accumulated saving/investment imbalance over the simulation period, as represented in BOTE-3.12.

In the last three BOTE-3 equations we have three endogenous variables undetermined: *GNP*, APC and NFL. We can calculate the change in *GNP* through substituting *NFL* in BOTE-3.10 by BOTE-3.12 and *APC* in BOTE-3.12 by *(C+G)/GNP* from BOTE-3.11. With the result for *GNP*, we are able to solve for *APC* in BOTE-3.12 and then *NFL* in BOTE-3.13.

To summarise, the historical simulation imposes historical values for *C*, *G*, *I*, *M*, *X*, P_X, P_M, P_G, *L* and *K*, leaving the model to calculate the movements in variables describing economic structure, namely, A, Γ, APC, Υ, Ψ and Λ in BOTE-3.

7.3 Historical simulation results

In MONAGE, the starting point of the historical and decomposition simulation analyses is an initial solution of 2005. As we have seen in Chapter 5, this solution consists of the CGE database describing the links between all economic agents in 2005 and of a set of commodity and factor prices for that year. This detailed representation of the Mongolian economy can be regarded as a model solution in that it satisfies all the economic theory described in Chapters 3 and 4. From this initial solution, the economy undergoes changes over time to 2012. Starting with the decomposition closure, the historical simulation is carried out in ten stages. In stages 2 to 10, we cumulatively exogenize the naturally endogenous variables for which we have observed data. At each stage, we make sure to have a valid closure for MONAGE.

The step-by-step approach is adopted for four reasons. First, the approach enables us to identify the economic relationships between the elements of $X(\boldsymbol{H}\overline{\boldsymbol{D}})$ and $X(\overline{\boldsymbol{H}}\boldsymbol{D})$. In turn, it bridges the historical and decomposition simulations facilitating the interpretation of the results from one to another. The step-by-step introduction of changes from the decomposition closure to the historical closure through swaps between the appropriate pairs of exogenous and endogenous variables assists in forming a valid closure based on economic relationships in our model. Second, the approach allows a natural progression for showing the particular partition of history, i.e., a mining boom in our case, adopted in the decomposition simulation. Unlike our previous analyses with ORANIMON, the MONAGE historical and decomposition simulation application has numerous shocks at macro and industry levels, reflecting the changes in every aspect of the Mongolian economy during the period from 2005 to 2012. To evaluate the impact of the mining boom, we thus need to carefully analyze the interplay and combined effects of those shocks. The historical closure can be complicated and unusual, as Dixon and Rimmer (2002) explain. A third reason to employ the step-by-step approach is therefore to ease the development of this complicated closure and the facilitation of the plausibility and trouble-shooting analyses. Fourth, the step-by-step approach allows the size of $X(\bar{\boldsymbol{H}}\boldsymbol{D})$ to be potentially much larger, allowing the use of a large amount of observable data, than it would be if the approach had not been adopted (Giesecke 2004).

The historical simulation may also require different steps due to the availability of the observable data, the magnitude of shocks and the nature of the economy under investigation. Reconciling the difference in dimensions of the databases, we have aggregated 2005 and 2012 databases into 44 industries and 52 commodities. Two-point databases are in values and in current prices of respective years. When we do not have observed volume or real data, we use the data on movements of prices along with values from our databases. As discussed in next section, we utilize different techniques to accommodate value data from our databases, along with other various extraneous data.

The Mongolian economy had undergone a massive change for the period 2005 to 2012. Table 7.3 shows the changes in selected macro indicators that occurred between 2005 and 2012. These changes will be applied as shocks in different stages and the related explanations regarding the variable will be given in the following sections. The steps are designed carefully due to the sizes of the shocks, since most of the shocks are over 100% or very large, to avoid computational problems. The model variables are defined differently from the typical COPS-style model variables. For instance, the nominal exchange rate in our simulation is the MNT amount for buying one unit of USD. Instead of real depreciation, we use real appreciation in order to avoid negative percentage change over 100%. The shocks in steps are administered cumulatively. In other words, the shocks applied in previous stage or stages are included in next stages.

7.3.1 Stage One: Naturally exogenous observable variables

The variables shocked at this stage are:

- ✓ population;
- ✓ population under 18;
- ✓ the number of households;

✓ the consumer price index (the *numeraire*); and

✓ the homotopy variable, *U*.

These variables are exogenous in both the historical and decomposition closures. As we have defined earlier, these variables belong to $X(\boldsymbol{HD})$. Hence no change is required in the decomposition closure for this stage. Stage 1 itself consists of series of step-wise simulations.

Table 7.3 Changes in selected macro indicators, between 2005 and 2012

Indicators	**2005**	**2012**	**Change**
Population, end-year (millions)	2.551	2.868	12.4
Number of households (thousands)	611.03	768.26	25.7
Real GDP, at constant 2005 prices			
(in billions of MNT)	3,041.4	5,529.3	81.8
(in millions of USD and in constant exchange rates)	2,523.6	4,587.9	81.8
GDP, at current purchaser prices (in billions of MNT)	3,041.4	16,688.4	448.7
GNI, at constant 2005 prices (in billions of MNT)	2,979.1	4,992.7	67.6
Export value index (2005 = 100%)	100.0	406.8	306.8
Export volume index (2005 = 100%)	100.0	198.2	98.2
Import value index (2005 = 100%)	100.0	569.5	469.5
Import volume index (2005 = 100%)	100.0	372.4	272.4
Real investment, at constant 2005 prices (billions of MNT)	849.7	3,310.9	356.9
Real household consumption, at	1,678.1	3,953.83	135.6
Real public consumption, at constant 2005 prices (billions of MNT)	369.19	628.27	70.2
Land area for cereals and crops (in thousand hectares, applies to only	159.4	305.6	91.7
Employment of labour (thousands of persons)	1,009.9	1,103.6	9.3
FDI stock, net (in millions of current USD)	4,947.3	14,850.6	
Net Foreign Liabilities, end of year (in millions of current USD)	2,047.1	14,219.4	
Net Foreign Liabilities (in percent of GDP)	81.1	115.7	42.6
CPI, end-year	100	223.2	123.2
GDP deflator	100	303.5	203.5
Exchange rate (MNT/USD period average)	1,205.2	1,359.2	12.8

The population increased by 12.43% with the annual average growth rate of 1.77% and the population under 18 grew by 15.5% for the period 2005 to 2012. The resources boom increased government revenues and encouraged political parties to create a large social welfare conditional cash transfer program known as the Child Money Programme (CMP), which began in 2005. CMP started as a targeted transfer in January 2005 and turned into a universal transfer in July 2006.

The median age was 22.5 in 2010, according to the 2010 Population and Housing Census of Mongolia (NSO, 2011). This indicates that the Mongolian population is relatively young. The number of households in Mongolia grew by a quarter between 2005 and 2012. In addition, the new family money programme, another welfare policy adopted by the government between 2008 and 2010, had an impact on the growth in the number of households. The programme provided a lump-sum amount of MNT 300,000-500,000 to newly-wed couples. The shock to the number of households is a preparatory move to ensure that the LES operates correctly when we introduce additional shocks.

Inflation in Mongolia has been volatile and high, resembling a roller coaster ride with sharp rises and steep drops during the period. The consumer price increased by 123.2% from 2005 to 2012.

When the homotopy variable is shocked (moved from 0 to 1), it ensures that the value of NFL in 2012 reflects the momentum effect. In the absence of any other changes to the economy, except the investment that is required to cover the depreciation of capital stock, the momentum effect arises due to the accumulated net interest and dividends on 2005 stock of NFL and the increments to NFL that would have occurred had GNP and capital stock remained at their 2005 levels. Hence the shock to the homotopy variable ensures that the 2012 value for NFL reflects accumulated interest and dividends on the initial stock of NFL and the changes resulting from the path of investment and savings implied by the changes in GNP and the capital stock between 2005 and 2012.

Table 7.4 reports the results of the step-wise introduction of historical shocks at each stage in the development of the historical closure, where the blue-colored cells indicate the values of variables which are shocked at a certain stage and the green cells show the observed or estimated values of respective variables are final and cannot be changed in

Table 7.4 Historical simulation results (%)

	Selected macro variables	Observed Change	Cumulative percentage changes (in stages)										Estimated change
			1	2	3	4	5	6	7	8	9	10	
Real quantity variables	Real GDP	81.8	0.5	7.4	10.6	48.2	57.6	105.0	102.4	85.2	82.4	81.8	
	Real GNI	67.6	3.2	8.3	14.3	54.2	71.7	158.8	108.5	91.1	77.1	67.6	
	Real private consumption (C)	135.6	3.2	8.3	14.3	135.6	135.6	135.6	135.6	135.6	135.6	135.6	
	Real public consumption (C)	70.2	3.2	8.3	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	
	Real investment	289.2	0.5	3.8	9.6	48.0	289.2	289.2	289.2	289.2	289.2	289.2	
	Real exports	98.2	-1.9	7.3	-7.0	-34.5	-81.5	98.2	98.2	98.2	98.2	98.2	
	Real imports	272.4	2.2	6.8	11.4	83.0	155.1	231.2	236.1	272.4	272.4	272.4	
	Aggregate capital	91.2	0.4	3.8	9.6	47.3	61.6	144.2	91.2	91.2	91.2	91.2	
	Aggregate employment	14.3	0.0	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3	
Price variables	Real wage	344.4	1.0	-12.5	6.6	64.5	101.0	170.2	183.3	150.6	344.4	344.4	
	Real appreciation	50.8	1.4	-4.0	5.3	25.6	57.2	161.5	113.5	114.1	63.3	50.8	
	Terms of trade	31.5	0.4	-2.1	1.2	7.6	18.7	104.5	19.5	25.3	28.5	31.5	
	GDP deflator	203.5	123.4	121.8	124.4	128.9	136.3	165.7	126.1	126.9	203.5	203.5	
	CPI	123.2	123.2	123.2	123.2	123.2	123.2	123.2	123.2	123.2	123.2	123.2	
	Nominal exchange rate	12.8	122.0	125.8	119.1	103.3	79.1	12.8	12.8	12.8	12.8	12.8	
Structural	APC of GNP		0	0	0	81.4	63.9	-23.2	27.1	-44.5	-43.5	-38.5	-38.5
	Contribution of technical change		0	0	0	0	0	1.2	13.0	4.7	11.8	7.4	7.4
	Aggregate exports demand curve		0	0	0	0	0	589.3	651.5	638.5	467.9	463.7	463.7
	Ave. Primary-factor-saving		0	0	0	0	0	-1.4	-15.0	-5.4	-14.7	-5.5	-5.5
	The ratio of C and G		0	0	-55.9	65.4	65.4	65.4	65.4	65.4	65.4	65.4	65.4
Ratio of net NFL to GDP			-70	-60	-60	70	30	-70	-90	-50	39	43	43

Notes: Blue cells indicate the values of newly introduced shocks of corresponding variables in respective stages.

Green cells indicate the final observed or estimated values of the variables.

Yellow cells indicate the in-process or preliminary estimated values of the corresponding structural variables.

the successive steps. The values highlighted in yellow indicate preliminary estimations for respective structural variables.

The results in column ‘Stage 1’ show that, in the absence of changes in employment and technology, capital growth would have been slow and domestic savings would have been sufficient to finance ‘restricted’ investment, which only covers the depreciation of capital stock, and the net interest payment for 2005 stock of NFL. This leads to a fall in the ratio of NFL to GDP, causing higher change in real GNP (3.2%) than in real GDP (0.5%).

We have defined the link between consumption and GNP through a constant APC in the decomposition closure via BOTE-3.11. With the increase in GNP, MONAGE projects that real private and public consumption would be 3.2% higher and real investment would grow slightly by 0.5%. Hence, the projected increase in GNE (6.4%) is higher than that of GDP. Therefore we expect a worsening of the balance of trade. Real imports would grow 2.2% while real exports decline by 1.9%. The underlying reason for exports falling is the real appreciation of 1.4%. BOTE-3 suggests that capital stock should be unchanged at this step, hence there are no changes in technology, employment and rates of return. MONAGE is a multi-sectoral model, whereas BOTE-3 is a single sector model. MONAGE allows for the possibility that changes in the composition of aggregate variable may in turn affect the aggregate variables like *K* in BOTE-3.

We can see that the consumer price is highlighted in blue, indicating that it is a shocked variable in the first stage. The effects of the shocks in Stage 1 are of no particular interest in terms of explaining economic history. This serves as an introductory check-up step.

7.3.2 Stage 2: Aggregate Employment and Land Use

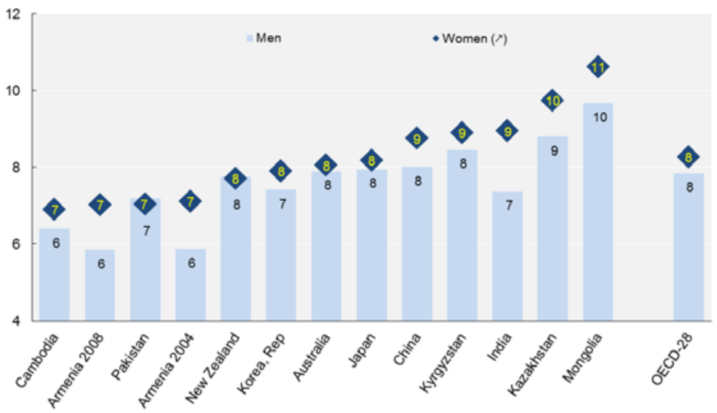
The variables shocked additionally at this stage are:

- ✓ aggregate employment hours; and
- ✓ land use.

During the period, employment in terms of the number of persons increased by 9.3%. Mongolia has limited resources of labour and Mongolia’s labour-force participation is low compared with that of other small transition countries (Batchuluun & Dalkhjav 2014).

According to the Organisation for Economic Cooperation and Development (2012), Mongolians work the longest in Asia and the Pacific region. Men and women work on average 581 minutes (almost 10 hours) and 637 minutes (almost 11 hours) per day, respectively. The aggregate employment hours grew by 14.3% for the period.

Figure 7.1 Working hours in selected countries



Source: OECD (2012)

The land use in the Crops industry increased by 91.3%, due to the Third Crops rehabilitation campaign, implemented by the government during the period. Mongolia is a relatively new country in terms of producing crops. During the communist period, the first campaign to grow crops on a large scale on Mongolian land took place between 1959 and 1965, with the main goal to supply flour domestically. The second campaign was conducted in the 1970s to diversify and increase the production of agriculture. With the collapse of the communism, however, a large part of the land was abandoned. The third campaign was designed to rehabilitate those abandoned lands and is considered one of the few government policies that have had positive effects.

No swap is required for labour and land, since they are exogenous in the decomposition closure in terms of our BOTE-3.

The 'Stage 2' column in Table 7.4 shows the effects in MONAGE of the shocks from 'Stage 1', plus the 2005/2012 shocks to the aggregate employment and land use. In this stage, the main effects come from the change in aggregate labour. Hence the rate of return is fixed and there is no technological change, there will be no change in the capital labour ratio as in BOTE-3.6. Hence, we would expect capital stock to increase at the same percentage as aggregate labour. However, MONAGE projects that capital stock will grow at a lower rate of 3.4% from Stage 1. In BOTE-3.6, $K/\bar{L} = F(\overline{RoR}, \bar{A}, \bar{T}_K, TofT, \bar{\Omega})$, the capital labour ratio, is also dependent on the terms of trade. The terms of trade deteriorated by 2.5% from the previous stage, causing the labour-capital ratio to fall. Thus the capital stock increase is less than that of labour.

7.3.3 Stage 3: Public consumption

The variables shocked additionally at this stage are:

✓ The real public consumption spending by a commodity.

Table 7.3 shows that aggregate real public consumption grew by 70.2% over the period. Public consumption is the smallest expenditure component of GDP in Mongolia. The share of public consumption in GDP was 11.3% in 2005 and 13.3% in 2012. The changes in real public consumption by commodities between the two periods were quite different across the commodities, being 'GovAdminDfnc' at 84.6% and 'HealthSocSvc' at 24.6%.

Let us re-examine the equation for real public consumption by commodity in MONAGE to explain the development of historical closure in this stage. Real public consumption for each composite commodity c is:

$$x5c(c) = f5c(c) + f5gen \qquad (7.10)$$

where $x5c(c)$ is the percentage change between 2005 and 2012 in public consumption of composite commodity c; and $f5c(c)$ and $f5gen$ are vector and scalar shift variables.

MONAGE defines the percentage change in the ratio of real private to real public consumption $f5tot3$ as:

$$f5tot3 = x3tot - x5tot \qquad (7.11)$$

where $x3tot$ and $x5tot$ are the percentage changes between 2005 and 2012 in real private and real public consumption.

As we can see from BOTE-3.3, $f5tot3$ in (7.10) is a percentage change in Γ.

In (7.10), $f5c(c)$s allow for shifts in the commodity composition of public consumption, whereas $f5gen$ allows for overall changes in the level of public consumption. In the decomposition closure, the commodity composition of public consumption is exogenous and the overall quantity of public consumption is endogenous and linked to the overall quantity of private consumption. Therefore, $f5(c)$s and $f5tot3$ are exogenous and $x5tot$ and $f5gen$ are endogenous. As we have seen in the previous stage, the change in real private consumption determined by the change in real GNP is equal to the change in real public consumption. In the 'Stage 2' column, the increase in public consumption is the same as the increase in private consumption, at 8.3%.

In the historical closure, we need to exogenize $x5c(c)$ to introduce the shocks with historically observed values between 2005 and 2012. This requires endogenization of $f5c(c)$. With the changes in the composition of public consumption known, aggregate public consumption cannot be linked to private consumption anymore. Thus we need to dismantle the link by endogenizing $f5tot3$. In turn, this requires the exogenization of $f5gen$.

In terms of BOTE-3, *G* is swapped with *Γ* exogenizing *G* and endogenizing *Γ*. Hence, the link between *C* and *G* is now freed. For MONAGE, following swaps are required:

i. $x5c(c)$ in (7.10) with $f5c(c)$in (7.10);

ii. $f5gen$ in (7.10) with $f5tot3$ in (7.11).

The 'Stage 3' column in Table 7.4 shows the effects in MONAGE of the shocks from 'Stage 1', plus the 2005/2012 shocks to the composition of public consumption. The number highlighted in green (70.2%) indicates that this is the value of corresponding macro variable of the shocked variables (composition of public consumption) in the second stage. With aggregate employment and the technology fixed, MONAGE projects a 10.6% increase in real GDP due to the shocks introduced in this stage. The impacts of the shocks can be compared to the effects of a massive fiscal expansionary policy to boost aggregate demand and the level of economic activity.

First estimation of the structural variable appears in yellow in the 'Stage 3' column. The values highlighted yellow indicate preliminary results for the structural variable. This is the initial estimation of $f5tot3$ determined by (7.11) and we expect its value would change in next stage. Hence $x3tot$ increases only 6.0% at this stage from the previous stage when we apply a massive increase in $x5tot$. As a result, MONAGE generates a negative value of 55.9% for $f5tot3$.

In the supply side of the economy, capital is increased by 5.8% from the previous stage. In Chapter 6, we have approximated the share of capital in GDP as 60% in 2005. If we calculate the economic growth that would result from the rise in capital, it would be 3.48% (5.8%x0.6), which is close to the growth of 3.2% (10.6%-7.4%) in GDP from Stage 3, generated by MONAGE.

7.3.4 Stage 4: Private consumption

The variables shocked at this stage are:

- ✓ Aggregate real private consumption spending (C);
- ✓ The values of household consumption for 52 MONAGE commodities;
- ✓ The prices of 12 commodity groups, where each of 52 MONAGE commodities belongs to a commodity group.

Between 2005 and 2012, the aggregate real household consumption (C) grew by 135.6%. Private consumption is the largest expenditure component in Mongolia. The share of private consumption in GDP was 61.3% in 2005. The share, however, went down to 52.7% in 2012 by 8.5 percentage points due to a sharp increase in investment.

Let us look at the equations in MONAGE explaining household demand by commodity. We have shown the optimization problem faced by a representative household in Chapter 3. The household demand for each composite commodity c takes the form:

$$x3\_s(c) - q = \varepsilon(c) \cdot (w3tot - q) + \sum_k \eta(c,k) \cdot p3\_s(k) + [a3com(c) - ave\_a3com] \tag{7.12}$$

where $x3\_s(c)$ is the percentage change between 2005 and 2012 in private consumption of a composite commodity c; q is the percentage change in the number of households (shocked in the first stage); $\varepsilon(c)$is the expenditure elasticity of demand by households for composite commodity c; $w3tot$ is the percentage change in aggregate value of private expenditure; $\eta(c,k)$is the elasticity of demand for commodity c with respect to changes in the price of commodity k; $p3\_s(k)$ is the percentage change in the price of commodity k; $a3com(c)$ is a commodity-c specific preference variable; and ave_a3com is a budget-share-weighted average of the $a3com(c)$s.

The percentage change in aggregate value of expenditure by households- $w3tot$ is equal to:

$$w3tot = x3tot + p3tot \qquad (7.13)$$

where $x3tot$ is the aggregate volume or real change in household consumption and $p3tot$ is the change in CPI (shocked in the previous stage).

Equation (7.13) represents the budget constraint for households. We can relate $w3tot$ to gnp as:

$$w3tot = gnp + apc\_gnp \qquad (7.14)$$

where gnp is the percentage change in nominal GNP and apc_gnp is the percentage change in the average propensity to consume out of GNP.

The budget-share-weighted average of the commodity specific preference variables- ave_a3com is:

$$ave\_a3com = \sum_k S3(k) \cdot a3com(k) \qquad (7.15)$$

where $S3(k)$ is the share of commodity k in household expenditure.

If $a3com(k)$ is greater than ave_a3com, then the rate of growth of consumption per household of commodity k is one percentage point higher than would be expected on the basis of changes in total expenditure per household and changes in prices. The inclusion of an RHS of (7.12) ensures the budget constraint.

In (7.12), q plays an important role, because private consumption in MONAGE is represented by an average household. We shocked q with the historically observed growth rate in the first stage to ensure this.

$x3\_s(c)$, $p3\_s(k)$ and ave_a3com are endogenous in the decomposition closure but exogenous in the historical closure. Hence, they belong to the set $X(\overline{\boldsymbol{H}}\boldsymbol{D})$. On the other hand, $a3com(k)$ and apc_gnp are exogenous in the decomposition closure but endogenous in the historical closure. Thus these are the elements of the set $X(\boldsymbol{H}\overline{\boldsymbol{D}})$.

Through historical simulation, $a3com(k)$ and apc_gnp are typically estimated using observed movements in $x3\_s(c)$. In our case, however, we do not have the observed values of $x3\_s(c)$. As we have twin CGE databases, the changes in the values of 52 MONAGE commodities between 2005 and 2012 are readily available. In order to find the volume changes, we use the movements in the prices of 12 commodity groups obtained from the NSO. The additional equations that are used to facilitate the data on value and prices are included in Appendix 7**.**

In developing historical closure for the stage, we swap *C* with *APC i*n terms of our BOTE-3, as in $\bar{C} + \bar{G} = APC \cdot GNP$. For MONAGE, a few swaps, associated with the inclusion of the above-mentioned equations, are required and shown in Appendix 8.

The 'Stage 4' column in Table 7.4 describes the effects in MONAGE of the shocks from 'Stage 1' to 'Stage 3', plus the 2005/2012 shocks to the aggregate private consumption, the values of all 52 commodities, and the prices for 12 commodity groups.

In the structural variables section in the 'Stage 3' column, we now have an initial estimation of apc_gnp highlighted in yellow and the finalized estimation of $f5tot3$ highlighted in green. Because the increase in real private consumption (135.6%) is higher than the increase in real public consumption (70.2%) between 2005 and 2012, the historical simulation generated a positive value of 65.4% for $f5tot3$. This value is now a final estimation. The estimation of apc_gnp, however, is not final one, as the real GNP would be changed in the next stages.

Since the increase in GNE is higher than that of GDP, we expect that the balance of trade must move to deficit. Real imports substantially increased from the previous stage, indicating that higher import intensiveness in private consumption contributed much of the trade deficit. There is a further but relatively mild contraction of exports, which in turn requires a real appreciation of the exchange rate. The contraction in export volumes, in addition, accounts for the improvement in the terms of trade. With aggregate employment fixed, MONAGE projects that the real wage will markedly increase by 63.2% from the previous stage. In terms of BOTE-3, these two changes impact on the expansion of the capital stock. With falling national savings and increasing capital stock, NFL rises sharply from its value in Stage 3, because the direct effect on the trade balance of the improvement in TOFT (14.9%) is outweighed by the decline in the quantity of exports (-27.5%) to the quantity of imports (71.6%).

7.3.5 Stage 5: Real investment

The shocked variables in this stage are:

✓ Investment volumes by sectors.

Out of the expenditure components of GDP, real investment grew largest, by around 289.6%, between 2005 and 2012. The contribution of investment to GDP, as a result, increased from around 30% in 2005 to around 45% in 2012, that is, by 15 percentage points.

Let us look at the equations defining movements in investment/capital ratios. These are:

$$x2tot(i) = x1cap(i) + r\_ik(i) + u\_rik \tag{7.16}$$

and

$$x2tot\_i = \sum_i S2(i) \cdot x2tot(i) \tag{7.17}$$

where $x2tot(i)$ is the percentage change between two years in investment in each industry i; $x1cap(i)$ is the percentage change in each industry i's start-of-year capital stock; $r\_ik(i)$ is the percentage change in the ratio of investment to the quantity of capital used in each industry i; $x2tot\_i$ is the percentage change in aggregate volume of real investment; and $S2(i)$ is each industry i's share in aggregate investment. u_rik is the economy-wide ratio of investment to the quantity of capital equivalent of Ψ in BOTE-3.

In the decomposition closure, $x2tot(i)$ is endogenous and is determined by (7.16). Thus it is an element of the set $X(\overline{\boldsymbol{H}}\boldsymbol{D})$. $x1cap(i)$ is also endogenous and is determined mainly by assumptions concerning rates of return. On the other hand, $R\_IK(i)$ is exogenous in the decomposition simulation, belonging to the set $X(\boldsymbol{H}\overline{\boldsymbol{D}})$.

We have real investment data for 41 sectors, given in Appendix 9. To employ sectoral investment information, we used the methods described in Chapter 4, adding the following equations:

$$x2tot\_s(s) = S2(s) \cdot x2tot(i) \tag{7.18}$$

$$r\_ik(i) = f\_r\_ik(i) + r\_ik\_s(s) \tag{7.19}$$

where $x2tot\_s(s)$ and $r\_ik\_s(s)$ are the percentage changes in sectoral investment and the others are as previously defined.

Equation (7.18) shows that each sectoral investment is a share-weighted sum of industry-specific real investment belonging to the sector. During the period, the investment into the mining sector increased most, owing in large part to the Ouy Tolgoi mine development.

In developing historical closure for the stage, we swap *I* with Ψ in terms of our BOTE-3 as in $\Psi = \bar{I}/\bar{K}$.

For MONAGE, however, following swap is required:

$x2tot\_s(i)$ in (7.18) with $r\_ik\_s(i)$ in (7.20).

The 'Stage 5' column in Table 7.4 shows the effects in MONAGE of the shocks from 'Stage 1' to 'Stage 4', plus the 2005/2012 shocks to the real sectoral investments. In the structural variables section in the 'Stage 5' column, we have the updated estimation of apc_gnp which is still in yellow, indicating the value of it will change in the next stages. There is a massive increase in imports, indicating that Mongolia is a net importer of major investment commodities such as machinery and vehicles. The improvement in the terms of trade pushes capital stock and real wages up, in turn increasing the growth in GDP.

7.3.6 Stage 6: Real exports

The variables shocked at this stage are:

- ✓ Aggregate export volume (*X*);
- ✓ Export volumes of major export commodities;
- ✓ Nominal exchange rate (*PHI*).

Table 7.3 reveals that there was a substantial increase in the export value index compared with that of the export volume index, showing a sharp growth in exports prices between 2005 and 2012. As Table 7.3 shows, minerals made up over 70% in

2005 and 89% in 2012 of Mongolia's total export earnings. Thus the economy had been highly reliant on world commodity prices during the period. A distant next major contributor to exports is the textiles and textile articles commodity, comprising 17.3% of total exports in 2005. The share of textiles and textile articles in exports, however, went down significantly to 5.3% in 2012. NSO publishes volume and price indexes for main export and import commodities. We have cross-checked the changes with GTAP 9, UNCTAD and trademap.org databases and have prepared yearly data on aggregated value-weighted changes in volumes of export and import commodities in MONAGE. The nominal exchange rate depreciated by 12.8% for the period 2005 to 2012.

Let us look again at the export demand equation we discussed in Chapters 3 and 6.

$$x4(c) = fgen + f4q(c) - ABS[\gamma(c)] \times \left(p4(c) - phi - f4p(c)\right) \qquad (7.20)$$

where $\gamma(c)$ is the export demand elasticity; $x4(c)$ and p4(c) are the percentage changes between two years in export volume and export price of commodity c, respectively; and $fgen, f4q(c)$ and $f4p(c)$ are shift variables.

The percentage change in the aggregate real export is:

$$x4tot \ = \sum\nolimits_{c} S4(c) \cdot x4(c) \qquad (7.21)$$

where $w4tot$, $x4tot$ and $p4tot$ are the percentage changes in aggregate value, quantity and price of exports.

For our historical simulation, we ascribe the observed movement in export volume of each individual commodity. In developing historical closure for the stage, we swap ***X*** with Λ in terms of our BOTE-3. For MONAGE, however, following swaps are required.

(i) $x4tot$ in (7.21) with $fgen$ in (7.20);

(ii) $x4(c)$ in (7.20) with $f4p(c)$ in (7.20); and

(iii) phi with $a1primgen$.

$a1primgen$ is all-industry all-factor augmenting technical change in MONAGE.

The 'Stage 6' column in Table 7.4 shows the effects in MONAGE of the shocks from 'Stage 1' to 'Stage 5', plus the 2005/2012 shocks to aggregate exports and its composition. As in previous stages, the number highlighted in blue indicates that this is the value of corresponding shocked macro variable in the fifth stage.

In the structural variables section in the 'Stage 6' column, we now have an initial estimation of the shift in the aggregate export demand curve (589.3%). Hence, we have endogenized $a1primgen$ in this stage, the initial estimations of two other structural change variables, the contribution of technical change to GDP and the average primary-factor-saving technical change, highlighted in yellow, appears in Table 7.4, along with the updated estimation of apc_gnp still in yellow.

The average primary-factor saving technical change is the value-weighted average of primary factor saving technical variables, $a1prim(i)$, plus $a1primgen$. The initial estimation of the technology variable shows slight improvement in technology (-1.4%), resulting in a positive contribution to GDP (1.2%). There is a massive improvement in the terms of trade, pushing capital stock up, in turn increasing the growth in GDP.

7.3.7 Stage 7: Sectoral employment and capital

The variables shocked at this stage are:

- ✓ Sector-specific capital stock (K_s);
- ✓ Sectoral employment for 18 industries; and
- ✓ Real interest rate.

The agriculture sector employs the largest share of labour, accounting for 38% in 2005 and 30% in 2012, respectively, in total employment. The number of employees (hence, the number of hours worked) in the transportation and transportation support services sector rose most by 112.5% between 2005 and 2012, while the number of employees in agriculture fell by almost 16%.

The simplified version of the industry-specific labour demand equation in MONAGE is:

$$\begin{aligned} x1lab\_o(i) &= z(i) + a1(i) + a1prim(i) + a1primgen \\ &\quad - \sigma 1PRIM(i)[p1lab\_o(i) - p1prim(i)] \\ &\quad + SK(i)twistlk(i) \end{aligned} \tag{7.22}$$

where $x1lab\_o(i)$ is the percentage change in labour input to each industry i; $z(i)$ is the percentage change in the overall level of output in each industry i; $a1(i)$ is a variable allowing for all-input-using changes in each industry i's technology; $a1prim(i)$ is a variable allowing for primary-factor-using changes in each industry i's technology; $a1primgen$ is a variable allowing for all-industry all-factor augmenting technical change; $p1lab\_o(i)$ is the percentage change in the wage rate paid in each industry i; $p1prim(i)$ is the percentage change in the overall price of primary factors to industry i defined in Chapter 3 via equation 3.17; $SK(i)$ is the share of capital in each industry i; and $twistlk(i)$ is a variable allowing for cost-neutral twists in industry i's technology either favouring labour (positive) or favouring capital (negative).

For MONAGE we swap $a1prim(i)$ and $x1lab\_o(i)$. There are other equations to facilitate sectoral employment information, which we considered in Chapter 4.

The aggregate capital stock almost doubled in 2012 from its level in 2005. The variable that is closely related to capital stock is the real interest rate. The real interest rate was quite high at 8.72% in 2005. It fell significantly to 5.45%, by 37.5%, resulting in substantial reduction in the cost of capital to industries. The simplified version of the industry-specific capital demand equation in MONAGE is:

$$\begin{aligned} x1cap(i) = z(i) + a1(i) + a1prim(i) + a1primgen \\ - \sigma 1PRIM(i)[p1lcap(i) - p1prim(i)] \\ + SL(i)twistlk(i) \end{aligned} \tag{7.23}$$

where $x1cap(i)$ and $p1lcap(i)$ are the percentages changes in the quantity and price of capital input to industry i; $SL(i)$ is the share of labour in each industry i; and the others are as previously defined in (7.22).

In developing historical closure for the stage, we swap K with Ω in BOTE-3.6, $\frac{K}{L} = F(\overline{RoR}, \bar{A}, \bar{T}_K, TofT, \bar{\Omega})$. For MONAGE, we endogenize $a1prim(i)$ and $twistlk(i)$ in equations (7.23) and (7.25).

The 'Stage 7' column in Table 7.4 shows the effects in MONAGE of the shocks from 'Stage 1' to 'Stage 6', plus the 2005/2012 shocks in 'Stage 7'. The updated estimation of apc_gnp and $fgen$ are still in yellow, showing that these results are not the final estimates.

7.3.8 Stage 8: Real imports

The variables shocked at this stage are:

- ✓ Aggregate import volume;
- ✓ Import volumes of ‘net import’ commodities;
- ✓ Import volumes of ‘twist import’ commodities; and
- ✓ The power of tariff.

Table 7.3 reveals that there was a huge increase of 272.4% in the import volume from 2005 to 2012. The main import commodities were ‘MachineryEqp’ and ‘CokeFuelPrd’ during the period. ‘CokeFuelPrd’ comprised around 20.5% in 2005 and around 19% in 2012 of the aggregate imports, as Mongolia is a net importer of refined petroleum. The share of ‘MachineryEqp’ commodity was 14.5% in 2005 and increased to 29.5% in 2012, overtaking ‘CokeFuelPrd’, and became the largest import commodity in 2012, due largely to investment growth. The import volumes of ‘CokeFuelPrd’ and ‘MachineryEqp’ rose by 140% and 223%, respectively, during the period. The weighted average import tariff was 4.2% in 2005. The rate was raised to 4.94% in 2012, resulting in a 0.71% increase in the power of tariff.

Let us look at the equations defining import demand of each commodity c in MONAGE. We defined in Chapter 3 that both ORANIMON and MONAGE use the Armington specification of import/domestic choice. In Chapter 4, we defined the MONAGE equation of a source-specific demand for investment commodity c through equation 4.36. We can simplify and strip down the equation, leaving out the technical change variables in order to show the specification of import/domestic choice as the percentage change in the ratio of import to domestic usage of commodity c, by:

$$\begin{aligned} x2(c,imp,i) - x2(c,dom,i) \\ &= -\sigma2(c)[p2(c,imp,i) - p2(c,dom,i)] \\ &+ twist\_src(c) \end{aligned} \quad (7.24)$$

where $x2(c,\text{imp},i)$ and $x2(c,dom,i)$ are percentage changes in the demand for imported and domestically produced good c by investor i; $p2(c,imp,i)$ and $p2(c,dom,i)$ are the percentage changes in the prices to investor i of imported and domestically produced commodity c; $\sigma2(c)$ is investor’s elasticity of substitution between imported and domestically produced good c; and $twist\_src(c)$ is a cost-neutral change in technologies in favour of imported commodity c against domestic commodity c.

As we discussed in Chapter 4, cost neutrality is imposed by including $twist\_src(c)$ in demands of intermediate, investment, household and government users for both imported and domestic commodities in such a way that it allows for the replacement of domestic commodity c with imported commodity c of equal cost to the investor. We have defined $twist\_src(c)$ via equations (4.39) and (4.41) and have determined $twist\_eff(c)$ through equation (4.40).

A noteworthy feature of equations (4.40) and (4.41) is that they help facilitate historical simulation where we have observations of movements in import volumes. Endogenising $ftwist\_src(c)$ while setting $twist\_c$ and $ftwist\_eff(c)$ exogenously at zero, we can determine the value of each $ftwist\_src(c)$ which can be interpreted as import/domestic twist for each commodity c arising from changes in technology and preferences. In developing historical closure for the stage, we swap M with ϒ in terms of our BOTE-3. The swaps required for MONAGE are shown in Appendix 8.1. Mongolia is a net importer of machinery, vehicles and fuel. We classify those commodities as net import commodities. For those commodities, we cannot adopt the twist theory. For those commodities, we endogenise $ftwist\_eff(c)$ while setting $twist\_src(c)$ exogenous. There are several other major import commodities for which we can apply the twist theory. We call those commodities 'twist import' commodities. For those commodities, we endogenise $ftwist\_src(c)$ and exogenise $ftwist\_eff(c)$.

The 'Stage 8' column in Table 7.4 shows the effects in MONAGE of the shocks from 'Stage 1' to 'Stage 7', plus the 2005/2012 shocks to the aggregate real import and the aggregate observed import volumes of Mongolian major import commodities.

7.3.9 Stage 9: Outputs, value added prices and nominal wages

The variables shocked at this stage are:

- ✓ Outputs of commodities;
- ✓ Prices of value added; and
- ✓ Nominal wages.

Table 7.5 shows the changes in the outputs for the period 2005 to 2012. It can be seen from the Table that the most of the services sectors grew sharply during the period. The output of the mining sector, however, grew at relatively lower speed, indicating the investment phase of the major projects. In this stage, MONAGE is set up to absorb data on movements in outputs of 38 aggregate commodities. These 38 aggregate commodities cover most of the 52 MONAGE commodities where these data are for individual commodities, but in a few cases the data are for an aggregate of three to four MONAGE commodities.

Table 7.5 Sectoral outputs (millions MNT, in 2005 prices) and changes in real outputs (%)

Economic sectors	2005	2012	Growth	Annual growth
Agriculture	602,136.3	801,269.2	33.1	4.7
Mining	642,089.0	861,511.4	34.2	4.9
Manufacturing	175,155.9	295,225.0	68.5	9.8
Electricity and gas	75,928.2	111,667.2	47.1	6.7
Water supply, drainage	13,768.9	20,388.4	48.1	6.9
Construction	81,408.4	102,604.2	26.0	3.7
Trade	227,478.2	591,110.6	159.9	22.8
Transport, storage	256,726.4	605,013.9	135.7	19.4
Hotels & cafes	19,341.7	60,167.0	211.1	30.2
Communications	96,261.1	226,794.4	135.6	19.4
Financial intermediation & insurance	112,278.8	249,875.0	122.5	17.5
Real estate, renting & other business activities	160,522.7	217,574.6	35.5	5.1
Research & development	18,024.5	50,763.4	181.6	25.9
Other public supporting services	34,071.1	80,097.5	135.1	19.3
Public administration and defence	66,923.1	72,982.2	9.1	1.3
Education	86,528.6	102,230.4	18.1	2.6
Health and Social services	37,516.9	50,946.0	35.8	5.1
Cultural services	7,744.5	12,933.8	67.0	9.6
Other services	15,763.7	24,238.5	53.8	7.7

Let us look at the simplified output equations of MONAGE to clarify the facilitation of the shocks.

The stripped-down version of output equations in MONAGE is:

$$x1(c,i) = z(i) + a1(i) + ac(i) \tag{7.25}$$

where $x1(c,i)$ is the percentage of in the input of good c to industry i; $ac(i)$ is a variable allowing for commodity c, using technical change in all industries; and the others are as defined in the previous stage. And:

$$q1(c,i) = z(i) + \sigma1OUT(i)[p0com(c) - p1tot(i)] + a0(c,i) - a0\_ave(i) \tag{7.26}$$

where $q1(c,i)$ is the percentage change in the output of commodity c by industry i; $\sigma1OUT(i)$ is the elasticity of transformation in industry i between the production of different commodities; $p0com(i)$ is the percentage change in the basic price of commodity c; $p1tot(i)$ is the percentage change in the average price of industry i's output mix; $a0(c,i)$ is a variable allowing for commodity-c-output-augmenting technical change in each industry i; and $a0\_ave(i)$ is the average amount of commodity-output-augmenting technical change in each industry i.

Equation (7.26) is an extended version of equation (3.39) in Chapter 3. The technology variables in (7.25) and (7.26) are exogenous in the decomposition closure, except $a0\_ave(i)$. It is defined by:

$$a0\_ave(i) = \sum_i R(c,i) \cdot a0(c,i) \tag{7.27}$$

where $R(c,i)$ is the share of industry i's revenue accounted for by commodity c.

With $a0(c,i)$ are exogenous, (7.27) requires $a0\_ave(i)$ to be endogenous in the decomposition closure. In order to accommodate the shocks described above, and to estimate the changes in technological variables in equations (7.25)-(7.27), we endogenize $a0(c,i)$ in (7.26) and $ac(i)$ in (7.25). The endogenization of $a0(c,i)$ and $ac(i)$ requires the exogenization of $a0\_ave(i)$ and $a1(i)$ respectively.

At this stage we also introduce the shocks to the prices of value added and nominal wages (wage bills). The movements in these variables tie down rental prices on capital and industry rates of return. First, we exogenise the prices of value added for 18 sectors and endogenise the shifters in sectoral rate of return. Adjustments in rates of return allow sectoral value-added prices to hit their target by causing adjustments in rental prices of capital. Second, we also exogenise the real wage rate while endogenising the wedge between the data on sectoral value added prices and the endogenously determined industry value-added prices. Third, we damp the movements in rental prices of capital through the adjustment required to absorb the data on value-added prices spread to the prices of other cost tickets. Effectively, we can now assume that the movements in the real wage rate in all industries are the same, since they are tied down by the data on nominal wages in this stage and employment in one of the preceding stages.

The ‘Stage 9’ column in Table 7.4 shows the effects in MONAGE of the shocks from ‘Stage 1’ to ‘Stage 7’, plus the 2005/2012 shocks in this stage. Our data on value-added prices and nominal wages generates a reduction in rates of return across mining industries. As a result, there is a less outward movement in the aggregate export demand curve.

7.3.10 Stage 10: Foreign prices and other macro shocks

The variables shocked at this stage are:

- ✓ Export prices;
- ✓ Import prices;
- ✓ Foreign currency aggregate export value;
- ✓ Foreign currency aggregate import volume.
- ✓ NFL; and
- ✓ Value Added Tax (VAT).

In Stage 10, we introduce information on the export and import prices along with the USD value of exports and imports. The increase in export prices of the commodities produced by MONAGE mineral industries requires the treatment that unties unit production costs and industry output prices, as MONAGE relates domestic currency export prices to costs and export taxes via zero-pure profit in exporting. Thus, for these industries, we use the phantom export taxes that we have defined in Section 7.2.2 to allow ‘mark ups’ and to define the unit costs independently of export prices. As we have seen in Chapter 6, the prices of Mongolian mineral commodities increased substantially during the period of 2005 and 2012. The mineral industries with relatively easier technology, such as the ‘Coal’ industry, responded relatively quickly to produce more. In 2012, Mongolia overtook Australia to become the largest coal exporter to China when the Australian coal industry was subdued by the flooding in Queensland. From 2005 to 2012, the quantity of coal exports (solely to China) increased by 826.5%. Appendix 12 contains the information related to mineral commodity exports.

We also absorb information on import prices for most of the import commodities, including ‘net’ and ‘twist’ import commodities. In addition, we make a uniform adjustment to all foreign-currency export prices and import prices to ensure that the change in USD values of exports and imports implied by the MONAGE historical simulation is consistent with the data.

Since the early years of the transition, Mongolia has relied on external concessional borrowing from the international organizations and donor countries. Concessional loans have low interest rates and very long maturities, implying low exposure to changes in interest rates and exchange rates. As the economy has progressed and moved to upper middle income status, the access to concessional loans has become limited. Mongolia started borrowing increasingly at market terms around 2012. The public sector’s external borrowing rose 31% in 2012 after the government’s USD 1.5 billion ‘Chinggis’ bond sales (named after Genghis Khan). Getting commercial type of debt increases Mongolia’s risk level, especially when the government’s repayment ability is affected by commodity price volatility.

Mongolia adopted a Value Added Tax (VAT) in 1998, effective from the 1 July of that year, on the recommendation of the WB and IMF. Mongolian VAT law was first developed on a New Zealand model with a registration threshold of MNT 15 million and rates of 0 and 10%. The VAT rate was raised to 13% in 1998 and to 15% in 2000. In the base year of 2005, the VAT rate was 15%, then reduced to 10% by the revised law of 29 June 2006. The VAT contributed around 21.6% and 26% of the budget revenues in 2005 and 2012, respectively.

The ‘Stage 10’ column in Table 7.4 shows the effects in MONAGE of the shocks from ‘Stage 1’ to ‘Stage 9’, plus the 2005/2012 shocks in this stage. There is a small change in the terms of trade and real appreciation. Since GDP is fixed from both the supply and demand sides, there is only a slight change in GDP due to the shock. The increase in net foreign liabilities leads to a higher interest payment, resulting in a decline in GNP.

7.5.1 Summary of historical simulation results

In our historical simulation, we incorporated the observed changes in the Mongolian economy into MONAGE from 2005 to 2012. The estimation results at macro level indicate:

- ✓ A large outward movement in the export demand;
- ✓ A significant change in the average propensity to consume;
- ✓ A massive change in the capital labour ratio;
- ✓ A small primary-factor saving technical change growth; and
- ✓ A slight overall technical change resulting in a small GDP contribution.

7.4 Decomposition simulation results

Having completed the historical simulation estimating the changes in technology and taste variables, we can now carry out the decomposition simulation. We will adopt the decomposition closure in which technology, taste and international trade position variables are exogenous. By setting these variables at their values estimated from the historical simulation, we are able to obtain historically observed results for output, employment and other endogenous variables in the decomposition simulation. Hence the technology, taste and international trade position variables are exogenous in the decomposition simulation, we can assess and decompose the effects of changes in these structural variables.

In Table 7.6, we show decomposition outcomes for macro variables between 2005 and 2012. We note that there are slight differences in changes of a few variables between estimates from historical and decomposition simulations. The reason is that, in a multi-step simulation (100 in our case), the total contribution of a group of shocks (say, shocks in column 1) is calculated as the total contribution to the percentage changes in the endogenous variables away from their initial values. In each step, all shocks to exogenous variables are applied and then the endogenous variables are updated. As these shocks have different effects on different variables, updated final estimates may be slightly different from the results obtained in the historical simulation.

The outstanding feature of the period was rapid growth in real investment and import volume relative to GDP. Both Table 7.4 and Table 7.6 reveal that real investment and import volume increased by 289.2% and 272.4%, while the increase in real GDP was 81.8%. We group the results from the changes in naturally exogenous variables, including those that determine the structure of the economy, into six groups. The momentum column in Table 7.6 shows what would have happened to the Mongolian economy if there had been no changes in other exogenous variables in the five adjacent columns. The explanation of the momentum effect is similar to that of the historical simulation we have described earlier. The momentum has a larger effect on GNP and private and public consumption than on GDP. As we have discussed, the underlying reason is that investment expenditures over the period would have covered depreciation due to a very small change in capital.

Table 7.6 Decomposition results (% from 2005 to 2012)

Selected macro variables	1 Momentum	2 Shifts in international trade position	3 Growth in employment and the number of households	4 Technical change	5 Changes in household tastes and import domestic preference	6 Macro and other factors	7 Total
Real GDP	0.5	45.3	9.8	7.4	3.3	13.0	82.3
Real GNP	3.2	36.6	4.8	-1.9	3.2	21.9	67.8
Real public consumption	3.2	36.5	4.9	-1.6	4.9	22.7	70.6
Real household consumption	3.2	36.5	4.9	-1.6	13.1	80.7	136.8
Real investment	0.5	79.7	6.2	15.5	3.1	190.4	289.2
Real exports	-1.9	41.3	9.4	38.8	9.4	5.3	102.3
Real imports	2.2	77.3	4.4	27.7	44.4	116.4	272.4
Capital stock	0.4	79.2	6.3	14.1	3.5	-5.7	90.8
Aggregate labour	0.0	0.0	14.3	0.0	0.0	0	14.3
Real wage	1.0	180.0	-13.6	14.7	20.1	150.6	352.8
Real appreciation	1.9	86.8	-22.6	-11.7	-6.7	15.6	63.3
TOFT	1.4	73.7	-2.5	-4.2	-3.6	-33.0	31.8
GDP price	0.6	77.1	-1.6	0.6	2.9	125.6	205.2
Consumer price	0.0	0.0	0.0	0.0	0.0	123.2	123.2

Thus Mongolia's saving would have exceeded investment expenditure, therefore allowing an increase in GNP and public and private consumption. The increase in private and public consumption outweighs the increase in GDP, so that imports increase and exports decline. The contraction of exports causes improvement in the terms of trade (TOFT) as Mongolia faces downward sloping foreign demand curves.

A TOFT improvement increases the GDP deflator relative to domestic expenditure prices such as investment price. In Chapter 6, we have shown that the GDP deflator includes the prices of exports but excludes the prices of imports.

If we re-look at BOTE-1.6 below,

$$ROR = \frac{Q}{P_I} = \frac{P_g}{P_I} * A * F_K(K/L)$$

with L, A and ROR fixed, an increase $\frac{P_g}{P_I}$ in generates a decrease in the marginal product of capital $F_K(K/L)$. In turn, a decrease in the marginal product of capital requires an increase in K (0.4%). The real wage rate rises (1.0%), reflecting an increase in the K/L ratio and in $\frac{P_g}{P_c}$ and the subsequent increase in the marginal product of labour $F_L(K/L)$ in BOTE-1.5, below.

$$RW = \frac{W}{P_c} = \frac{P_g}{P_c} * \frac{1}{A} * \ F_L(K/L)$$

The second column of Table 7.6 shows the additional effects of changes over the period in Mongolia's international trading conditions, considering both import and export markets. The historically estimated shifts in export demand curves, together with the observed changes in import prices, are in this group of factors. The shifts in international trade position were the main contributor to the economic growth, accounting for just over half of the growth in real GDP. The changes in the international trade position improved TOFT by 73.7%. BOTE-3.6 in the decomposition closure, $K/\bar{L} = F(\overline{RoR}, \bar{A}, \bar{T}_K, TofT, \bar{\Omega})$, shows that an increase in TOFT results in an increase in K due to BOTE-1.6. As K increases, the real wage will increase according to BOTE-3.5, $RW = F(K/\bar{L}, \bar{A}, TofT, \bar{\Omega})$. The underlying reason can be explained by BOTE-1.3. Investment also rises as in BOTE-3.9, $\bar{\Psi} = \frac{I}{K}$. Without any change in preferences, the improvement in TOFT creates greater increase in Mongolian imports than in exports. These results are consistent with the Dutch disease literature we reviewed in Chapter 1.

Column 3 in Table 7.6 shows the effects of growth in employment and in the number of households. With constant returns to scale (BOTE-3.1), the fixed rates of return (BOTE-3.6) and fixed investment capital ratio (BOTE-3.9), we would expect that the increase of 14.3% in employment creates the same level of growth in capital, investment and GDP with no change in the real wage. However, MONAGE generates more exports, with an associated decline in the terms of trade (-2.5%). The reduction in TOFT restricts the increases in capital, investment and GDP. With a reduction in the capital labour ratio, both the marginal product of labour and real wages decline. The TOFT reduction also limits the growth in public and private consumption. In addition, the growth in capital causes an increase in net foreign liability, restricting growth in consumption and GNP. There is a sharp increase in exports, facilitated by a substantial real devaluation.

Column 4 in Table 7.6 provides the contribution of technical changes. Overall, the technical changes contribute 7.4% to economic growth. The shocks included in this group are changes in sector-specific primary factor productivity, sector-specific input *c* saving technology in current production and capital formation, sector-specific all-input using technology and sector-specific labour-capital twist. Table 7.7 shows the changes in the average of technical change terms in current production for four aggregate sectors.

Table 7.7 Average of technical change (%), production

	Average of technical change
Agriculture	13.6
Mining	-32.6
Manufacturing	3.8
Services	-1.4

The worst performer in terms of technical change is the Agriculture sector. However, our finding may reflect more favourable weather in 2005 than in 2012, as Mongolia had one of the worst ‘dzud’ disasters in the 2009-2010 winter, losing approximately 20% of livestock or 8.5 million head. The livestock sector is in any case highly reliant on the pasture land, susceptible to weather shocks and lacks productivity improvement and technological change.

With fixed employment and fixed rates of return on capital, technical improvements (decrease in A) increase GDP directly through BOTE-3.1, $Y = \frac{1}{A} F(K, \bar{L})$, and indirectly through BOTE- 3.6, $K/\bar{L} = F(\overline{RoR}, \bar{A}, \bar{T}_K, TofT, \bar{\Omega})$. The real wage increases, as in BOTE-3.5, $RW = F(K/\bar{L}, \bar{A}, TofT, \bar{\Omega})$, due to BOTE-1.2, where an increase in the capital labour ratio requires both the marginal product of labour and the real wage to rise. The technical change pushed exports up more than imports, causing a decline in the terms of trade. The underlying reason is that the mining sector, which is the main exporter, experienced a large increase in technical efficiency. But it is worth noting that changes in the real cost of production mainly arise from changes in the quantity of unmeasured inputs, most notably natural resource inputs. This may affect the productive capacity of the sector, but can be distinct from the sector's productivity performance.

Column 5 in Table 7.6 shows the contribution of the effects of changes in consumer preferences and the changes in import/domestic preferences. Over the period, household purchases of motor vehicles dramatically increased. Mongolia imported 5,280 cars in 2005. The number of cars imported increased to 46,409 in 2012. This increase (878.9%) is more than can be explained by changes in household income, the number of households and consumer prices. Mongolia does not produce cars domestically. Hence, imports increase due to the preference shift to cars. For those 'net' import commodities, like cars and machineries, we cannot use the 'twist' idea so that we combine them into the preference change. There are strong consumer taste shifts to commodities such as 'Drinks' and 'DairyPrd' and services such as 'SvcToTransport'.

Figure 7.2 News in the Australian Financial Review

Mongolia is a re-run of WA miners' thirst for alcohol

Ulan Bator The beverage industry is booming along with the resources sector.

Simon Evans

Yak milk is low down on the list of **Trevor O'Hoy**'s favourite beverages.

But the former chief executive of Foster's Group has been clenching his teeth and swallowing it anyway as part of his role as a director of Mongolia's largest alcoholic beverages company, APU Group, which is growing fast in parallel with the rapid opening up of the country's resources sector.

APU makes the leading beer and vodka brands in Mongolia and the growth in the mining industry, with its renowned thirst for alcoholic beverages, is helping to drive a rapid internationalisation of the sector in the Central Asian country.

"It is a re-run of Western Australia because of the mining boom," O'Hoy tells *The Australian Financial Review*.

APU, with a history dating back to 1924, is listed on the fledgling stock exchange in Mongolia, where O'Hoy spent a week carrying out due diligence early in 2012 prior to agreeing to join as a director.

This was where the yak's milk and other local delicacies came onto the scene, when O'Hoy thought it important to immerse himself in the local culture. Yak's milk wasn't a personal favourite. "I can't say I've acquired a taste for it," he says. "It's on a par with kava [the Fijian drink made from the roots of the plant of the same name]."

O'Hoy came to be on the board of APU after giving a lecture to a group of MBA students in Melbourne at La Trobe University. In the audience was a young executive from APU who had been sent to Australia on a fast-tracking program.

A few months passed and then Mr O'Hoy was contacted by APU who were seeking more expertise on the international beverage industry and how best to progress. "I'd never been to Mongolia and I was a bit inquisitive," he says.

He says the hotel lobbies in Ulan Bator, the Mongolian capital, are full of mining engineers and resource-related professionals and there is a real air of vibrancy, although the community infrastructure such as the road systems are still in their infancy in some areas.

O'Hoy does a substantial proportion of his work with APU via video-conferencing because of the sh
in getting to Mongolia, v
about three days of tra
bourne. "It is hard to get t

But the APU middle
are extremely enthusias
ing growth and consci
home-grown company
serious competition fron
beverage giants. "The m
ment are like a big, big sp
very enthusiastic and v
knowledge," he says.

O'Hoy says APU sales
between 30-35 per cent
the company is laying th
for a potential listing on t
Stock Exchange in the r
"To me there is an awful

One of the areas of foc

Continued p22

Former Foster's chief Trevor O'Hoy is now in charge of Mongolian liquor firm.

Source: The Australian Financial Review *July 23*, 2013

Mongolians' taste changes had been reported in the Australian media. Figure 7.2 is an excerpt from the news in the Australian Financial Review regarding the top beverages company, APU, in Mongolia. Recalling 'Drinks' was one of the top performers in the short run and medium run simulations in Chapter 6, let us compare the sales composition 'Drinks' commodity in 2005 and 2012.

Table 7.8 Sales decomposition of 'Drinks' in 2005 and 2012

Destination	**Sales composition (%)**	
	2005	2012
Intermediate	12.6	12.7
Investment	0	0
Household consumption	84.1	79.4
Exports	0.3	0.1
Government consumption	0	0
Stocks (future consumption)	3.1	7.8
Total	100	100

From Table 7.8, it can be seen that there was little compositional change in domestically produced 'Drinks'. The sales value of the commodity increased by 16.5 fold as a result of substantial increase in its price and volume. One of items in 'Drinks', beer sales volume, for instance, grew by 714.4% for the period 2005 to 2012, showing the magnitude of the change.

The estimated twist changes were mostly in favour of imports. Mongolian producers and consumers became able to import a variety of intermediate, investment and final consumption commodities from many different countries. In particular, with the surge in investment and the demand pressures when the domestic economy is growing rapidly, there is a tendency for demand shift to occur towards import commodities. This occurred in Mongolia, bringing a huge change towards imported commodities in the composition of overall and industry-level import and domestic mixes.

There are some twist changes to domestically produced commodities. In Chapter 7, we found that 'LeatherPrd' is the biggest loser in both scenarios in the short and medium run. In the long run, the industry is still one of the worst performers. However, there was a favourable taste shift to domestically produced 'LeatherPrd', coupled with a strong import to domestic preference shift, helping the industry to survive.

Table 7.9 Sales decomposition of ‘LeatherPrd’in 2005 and 2012

Destination	Sales composition (%)	
	2005	2012
Intermediate	2.1	28.5
Investment	0	0
Household consumption	0.8	40.4
Exports	95.4	25.2
Government consumption	0	0
Stocks (future consumption)	1.8	6
Total	100	100

Table 7.9 shows the sales composition of ‘LeatherPrd’ commodity in 2005 and 2012. The commodity was mainly exported in 2005. Due to the structural changes, there was a substantial increase in domestic use; a massive share increase of 39.6 percentage points in household consumption and 26.4 percentage points in intermediate consumption.

Table 7.10 Domestic and imported sales composition of ‘LeatherPrd’

Sales		Intermediate	Household
2005	Domestic	50	5.7
	Imported	50	94.3
2012	Domestic	88.1	55.6
	Imported	11.9	44.4

The main reason for ‘LeatherPrd’ industry to become the biggest loser was its trade exposure. Table 7.10 provides the domestic and imported shares of ‘LeatherPrd’ commodity for intermediate use and household consumption. It can be seen that there was a substantial shift toward the domestically produced ‘LeatherPrd’ in both intermediate and household uses. Underlying reason is the positive change in consumer taste and twist to domestically produced ‘LeatherPrd’, perhaps due to a quality improvement and a variety increase.

Table 7.11 Main items in ‘LeatherPrd’

Main items in ‘LeatherPrd’	2005	2012	Change (%)
Leather footwear (thousand pairs)	3.00	18.30	510.0
Leather coat (thousand pieces)	3.60	13.90	286.1
Leather jacket, shirt (thousand pieces)	4.20	8.30	97.6

Source: NSO

Table 7.11 shows the changes in sales volumes of main items in 'LeatherPrd'. There was not major technological improvement in the industry, yet the outputs of main items in 'LeatherPrd' composite commodity increased. It is one of the down-stream industries related to Mongolian livestock sector, in which there is a comparative advantage. Thus, there is a room for the industry to grow sustainably if the policy measures to improve productivity and technology are implemented.

With labour, the rate of return and technology fixed, we would expect little change for capital, investment and thus for GDP. Since the terms of trade decreased, we might expect decreases in capital and investment. However, we find that there is an increase in capital, indicating a structural change favouring capital intensive industries like mining sector.

Column 6 in Table 7.6 shows the effects of macro and other factors. The main shocks in this group are macro ratios, such as the average propensity to consume and the wedge between public and private consumption. The changes in sectoral investment and capital ratios are also included in this group. For the mining and services sectors, the investment and capital ratio are substantially higher in 2012 than in 2005, resulting in a very strong positive change in the real investment. The average propensity to consume in 2012 was also much higher than in 2005, leading to a large increase in private consumption.

7.5 Concluding remarks

The Mongolian economy underwent a massive change for the period 2005 to 2012. The historical and decomposition simulations provide an explanation of some of the main macro developments in the Mongolian economy during the period. Through historical simulation, we estimated a number of structural variables, industry technologies, household preferences, required rates of return on capital, and positions of export-demand curves and import supply curves. The changes in these variables are, in fact, the sources of structural change in Mongolia. We estimated several aspects of technology change for industries. These include changes in sector-specific primary factor productivity, sector-specific input *c* saving technology in current production and capital formation, sector-specific all-input using technology and sector-specific labour-capital twist. The historical simulation was carried out in multi-steps, which were designed carefully due to the large sizes of the shocks so as to avoid computational problems.

We tracked changes in multifactor productivity and changes in input-using technology affecting the use of each industry's commodities per unit of output across all industries. The simulation reveals that the economy needs efficiency and productivity improvement. In particular, the changes in sector-specific input *c* saving technology in current production and capital formation, as well as sector-specific all-input using technology, were unfavourable. Agriculture, followed by the manufacturing sector, is the worst performer in terms of technical change, and this requires policy reform.

In addition, we estimated changes in capital/labour choices beyond those that can be explained by changes in relative factor prices. Due to the capital-intensive nature of mining industries and the development phase of major mining deposits such as the Ouy Tolgoi mine, we found a large shift towards capital. Mongolia is a net importer of machinery, vehicles and fuel. There was a massive increase in imports of those commodities due to rapid growth, the surge in investment and changes in consumer taste, leading to a huge shift towards imported commodities in the composition of overall and industry-level import and domestic mixes.

For the historical simulation results, we conducted a decomposition simulation to explain the movements of various macro and micro variables relative to the effect of world commodity prices. The decomposition simulation provided quantitative evidence of the effects of policy changes relative to the effects of other exogenous variables, and, most importantly for our study, the effects of export demand changes for Mongolian mineral commodities. The results reveal the main sources of economic growth in the Mongolian economy during the study period. The shifts in foreign demand for Mongolian mineral export commodities contributed most of the economic growth. The terms of trade dictate the real purchasing power of domestic output and are one of the key determinants of Mongolia's economic prosperity. The impacts of the shifts in international trade position are realised through the terms of trade change. Many of the effects of the mining boom, however, are still unfolding; in particular, major mining projects are transitioning from their construction phase to production.

Chapter 8. Conclusions and Future directions

8.1 A Brief Synopsis

The aim of this thesis has been to develop CGE models to analyse Mongolia's recent mining boom and to make a contribution to the modelling capacity for policy analysis in Mongolia. Two CGE models of the Mongolian economy, ORANIMON and MONAGE, were constructed, tested and applied. The theoretical frameworks, database creation, and the set-up and results of applications have been presented in the thesis.

Mongolia has transitioned from a centrally planned to a market-oriented economy. Mongolia's geographical location, the structure of the economy and its mineral wealth give it unique characteristics. The resources boom in recent years directly impacted remarkable economic growth, and affected Mongolia's economic structure, social welfare, institutional quality and environment. Mongolia is rich in natural resources. Tapping its natural resources in a way that equally benefits the social and economic well-being of Mongolians is the greatest challenge.

One of the negative impacts generated by a resources boom is the Dutch disease. There is a large body of literature on the Dutch disease, predominantly developed by Australian economists. We classify the literature into the classic and new Dutch disease literature. COPS-style CGE modelling has been defined as a well-recognised school of economic modelling, thought and analysis, with distinctive technical characteristics and transferable know-how, and a related brief review was undertaken of the models and literature in Chapter 2.

The theoretical frameworks and database construction of two CGE models developed for the thesis were provided in Part II (Chapters 3, 4 and 5). An overview of the theoretical framework of the COPS-style comparative static CGE model ORANIMON was given in Chapter 3. The theoretical additions of ORANIMON's dynamic successor, MONAGE, focusing on dynamics, closures and additional technical innovations, were presented in Chapter 4. The procedures, methods and sources to create databases for two years (2005 and 2012) for the models and related results from validity analysis were described in Chapter 5. The detailed nature of the models and the databases allow ORANIMON and MONAGE to capture salient features of the Mongolian economy. A number of new variables and related equations were added to facilitate the applications of the models.

The applications of the models were presented in Part III (Chapters 6 and 7). The ORANIMON sequential simulations on the Mongolian macroeconomy and on the economic sectors of the effects of the resources boom were detailed in Chapter 6. The ORANIMON simulations were concerned with the implications of the resources boom for macroeconomic performance, employment, the balance of trade, overall price level and the level of output in each ORANIMON industry. The historical and decomposition simulations for determining and quantifying the underlying sources of structural change and their contributions to economic growth in Mongolia were described in Chapter 7. The MONAGE applications were concerned with the growth of the Mongolian economy from 2005 to 2012, with reference to the recent mining boom. In conducting the historical and decomposition simulations, we used data for 2005 and 2012 on a wide variety of variables. These included macro variables such as GDP, NFL, aggregate consumption and aggregate investment, industry variables such as employment, capital, output and value added, and commodity variables such as prices and quantities of exports, imports and consumption.

8.2 Summary of Findings

Mongolia's endowment in natural resources has given it a comparative advantage in the production and export of mineral products. Mongolia's terms of trade increased greatly over the past decade, reaching a peak in 2011. This unprecedented improvement in the terms of trade, coupled with the large inflow of FDI, had been driven by the industrialisation and urbanisation of Mongolia's neighbour and main trading partner, China.

Externally generated growth is, however, a double-edged sword. The Mongolian economy had undergone a massive change between 2005 and 2012. Thus, the boom brought with it economic fragility, notably vulnerability to commodity price slumps and an adverse shock to FDI.

In building a CGE model the crucial step is to set up a database. The twin databases of two years, 2005 and 2012, were constructed. The databases contain IO and various other data and information concerning every aspect of the Mongolian economy.

The ORANIMON two scenario-two step sequential simulations to assess the impacts of the recent mining boom in the short and medium run were carried out with three main aims.

The first aim was to validate the modelling. We employed different types of validation techniques, such as BOTE calculations and statistical methods. Non-parametric tests were utilized to summarize industry results at the economy-wide level, and to explore the relationship between various industry characteristics and industry performance. The additional tests and regression analysis were further used to examine the relationship between various industry characteristics and industry performance and to check the sensitivity of the parameters. Taking account of the results from the statistical methods, we carried out three SSAs to check the robustness of the ORANIMON results.

The second aim was to evaluate the impact of the mining boom in the short and medium run. The mining boom resulted in a massive increase in Mongolia's terms of trade, which, in turn, increased the real purchasing power of domestic output. The boom stimulated the employment of labor and the overall performance of the economy. The balance of trade, the overall price level of the economy and main macroeconomic variables were greatly affected by the boom.

However, the impacts were not always beneficial. In the short and medium run, the increase in commodity exports and the surge in capital inflows put upward pressure on real exchange rates, pressuring trade-sensitive industries. The manufacturing sector was the most pressured sector. This impact is consistent with the Dutch disease hypothesis. The services sector was a major winner, as its output increased markedly. The agriculture sector was relatively mildly affected, with mixed results in our two scenarios.

ORANIMON determined the effects and decomposed those into the contributions of the factors to the changes in macro and industry level variables in greater detail. We employed statistical methods, in addition, to summarize industry results at an economy-wide level. Of different characteristics of industries and commodities, import competitiveness and export orientation were significantly associated with industry performance, according to non-parametric test results.

We defined trade sensitivity measures that are regressed to changes in outputs of industries. These trade sensitivity measures have been found to explain the variations in the performance of the industries, significantly leading to the investigation of two parameters: intermediate Armington and export elasticities though SSAs. Parameter choices within ORANIMON over a reasonably wide range do not affect the simulated changes in the macro and industry level variables.

The third aim of the ORANIMON applications was to assess and propose the policy measure against the negative effects of the mining boom. The simulation results indicate that the policy measurements of restricting domestic consumption and/or establishing saving could counteract and lessen the de-industrialization effect of the mining boom in the short and medium term. There are countercyclical policy methods, such as a Sovereign Wealth Fund (SWF), a method often advanced to counter many of the potential negative consequences of natural resource extraction in developing countries. The results from the ORANIMON sequential simulations with two scenarios may help to understand the reasons and may provide confidence in utilizing methods like a SWF for reducing negative structural change effects of the mining boom.

The methods for studying structural change in an economy through COPS-style CGE models are historical and decomposition simulations. Through these simulations the features of the economy's structure, such as changes in industry production technologies, household tastes and the positions in export demand and import supply curves, are estimated and their respective contributions to the changes in macro and industry economic variables, such as GDP, industry output, and various prices, are decomposed.

The Mongolian economy underwent a massive change for the period 2005 to 2012. We estimated several aspects of technology change for industries, focusing on those who were the biggest winners and losers in ORANIMON simulations. The historical simulation was carried out in multi-steps, which were designed carefully due to the large sizes of the shocks so as to avoid computational problems. The model variables were defined differently from the typical COPS-style model variables.

Detailed estimates of changes in technologies (changes in production functions) and changes in consumer preferences (changes in utility functions) were obtained for the period 2005 to 2012. We tracked changes in multifactor productivity and changes in input-using technology affecting the use of each industry's commodities per unit of output across all industries. In addition, we estimated changes in capital/labour choices beyond those that can be explained by changes in relative factor prices. Due to the capital-intensive nature of mining industries and the development phase of major mining deposits such as the Ouy Tolgoi mine, we found the large shift was towards capital. Mongolia is a net importer of machinery, vehicles and fuel. There was a massive increase in imports of those commodities, bringing a huge change towards imported commodities in the composition of overall and industry-level import and domestic mixes.

For the historical simulation results, we conducted a decomposition simulation to explain the movements of various macro and micro variables relative to the effect of world commodity prices. In the thesis, we illustrated the macro results, along with the results for two chosen industries: 'LeatherPrd' and 'Drinks'. The decomposition simulation provided quantitative evidence of effects of policy changes relative to the effects of other exogenous variables, and, most importantly for our study, the effects of export demand changes for Mongolian mineral commodities. The results reveal the main sources of economic growth in the Mongolian economy during the study period. The shifts in foreign demand for Mongolian mineral export commodities contributed most of the economic growth. Many of the effects of the mining boom are still unfolding; in particular, major mining projects are transitioning from their construction phase to production.

Re-based in 2012, ORANIMON and MONAGE were readily available to carry out simulations for forward-looking policy and forecasting analysis. The extrapolations of changes in structural variables in our historical simulation are important for developing those simulations. The next section discusses future avenues of the research.

8.3 Future directions

GDP and GNI increased substantially during the mining boom, but what happened to inequality?

Since the economy is highly dependent on natural resources, the management of natural resource revenues and spending has a very important welfare implication. One of the policy challenges Mongolia has faced is ensuring that its economic growth is inclusive. Although the poverty headcount ratio declined from 2005 to 2012 according to the NSO, the distributional impact of growth that resulted from the mining boom remains in question. In particular, the impact of government policies related to the spending of mining revenues on poverty and inequality needs to be examined. The successful management of natural resource revenues and spending depends on careful examination of endogenous and casual inference of the relationship between inequality/poverty and the extraction of natural resources (Ross 2007). Anderson, Cockburn and Martin (2011) remind us that the need for undertaking poverty and inequality analysis remains strong.

The increasing availability and quality of large-scale socio-economic survey data have allowed researchers to explore causal inference within-country by deploying various estimation methodologies, in particular, *microsimulation*. Models based on household surveys are built to identify and analyse the determinants of the evolution of inequality. The majority of the analyses based on *microsimulation* models are conducted within a framework of partial equilibrium.

Any analysis of the impact of natural resources on poverty and inequality requires an economy-wide framework that incorporates significant detail on how households earn and spend their incomes and on labour market decisions. In the conventional CGE framework, the distributional impact of shocks has generally been analysed by considering the representative household. A prominent work by Adelman and Robinson (1978) takes into account distributional impact in standard CGE modelling by allowing income distribution within household types. The more appealing methodology is *microsimulation*, where the distribution of incomes is generated by a household module in which the units correspond to individual household observations in a survey.

There are two main approaches, 'layered' and integration, to merge CGE and *microsimulation* for the analysis of distributional impacts of shocks. A comprehensive review of these approaches has been done by Davies (2009) and Colombo (2010). The 'layered' approach consists of two alternative methods: 'Top-Down' by Bourguignon, Robilliard and Robinson (2003) and 'Top-Down/Bottom-Up' by Savard (2003). Robilliard, Bourguignon and Robinson (2008) applied the layered approach to analysis of the effects of the financial crisis on poverty inequality in Indonesia. The authors conclude that their result of poverty and inequality is quite different from the representative household approach.

The integration of CGE and *microsimulation* is a challenging approach for the analysis of impacts of shocks on income distribution. Cororaton, Cockburn and Corong (2005), Cororaton and Corong (2009), Corong (2014), for the Philippines, and Cockburn (2006), for Nepal, have advanced the development of integrated economy-wide frameworks.

Exploring the distributional impacts of natural resource exploitation and the shocks and policies related to mineral sector development is one immediate future project, using the models developed. Sen (1976) argues that the depth of poverty in inequality analysis is important and proposes new dimensions and methods to estimate poverty. Foster, Greere and Thorbecke (1984) generalise the poverty measure and provide additively decomposable poverty measures: the Foster-Greere-Thorbecke poverty measures. By adding *microsimulation* to the MONAGE framework, complemented by household survey, we may obtain detailed results for the complex impacts of various shocks on income distribution and on poverty and investigate the changes in different poverty measures.

What is unique about the Mongolian livestock industry?

Livestock have been the foundation of Mongolia’s economy and culture for millennia (WB 2009). Livestock are declared to be Mongolia’s national wealth and are protected by the state in its constitution.

The number of livestock has been increasing at an unprecedented rate, reaching 55.9 million head for the first time in 2015 and growing 84.5% from the level in 2005. Mongolia’s livestock are raised on open pasture under extensive grazing. Pasture land is public. Over 70% of pasture land had been degraded due to climate change and overgrazing by the early 2000s. The degradation rate has intensified in recent years, and drought, desertification and water scarcity have become serious policy issues in Mongolia. The ‘tragedy of the commons’ arises from the common right of access to a scarce resource (Hardin 1968). Even though Mongolia has vast pasture land, amounting to 73.5% (NSO 2014) of its land, it may face the tragedy of commons problem unless properly addressed in the years ahead. Livestock production is highly dependent on weather and climate. Herders are reliant on the productivity of pasture land. In general, there has not been technological improvement for the livestock industry during the past decade. Rae and Hertel (2000) tested for convergence in livestock productivity among the Asia-Pacific economies and found evidence of recent convergence in productivity for pig and poultry production, but generally not in ruminant production. Mongolia exemplifies this finding, as its newly re-developed poultry production uses state of the art technologies, whereas ruminant production is completely dependent upon pasture land and lags far behind in terms of technology and productivity.

Mongolia could enhance its comparative advantage- livestock production through research and development that raises productivity. Nin et al. (2004) provide a rigorous analysis of both the supply and demand determinants underlying Mongolia's neighbour and a main trading partner China's future net trade position in livestock products, using the modified GTAP model, and they conclude that China could become a major market for future meat exports due to slower than expected diffusion and adoption of livestock technology, coupled with a rapidly growing macro economy. In fact, China has started to import meat from Mongolia in the past year, signalling a boon to the sector.

There are avenues and demands for policy-relevant CGE research related to the livestock sector in Mongolia, from evaluating the potential for meat exports, investigating the impacts of the 'dzud' disaster, and estimating GHG emissions. In those applications, the modelling of land is crucial. Since Mongolia's pasture land is diverse, stretching from the ranges to the steppes, and from the steppes to the Gobi Desert, the heterogeneity and the degradation level of the land need to be taken into account. When analysing the impact of policies to reduce environmental impacts in the New Zealand dairy sector, Rae and Strutt (2011) model New Zealand's agricultural land in detail. Their procedure and underlying theories can be used for modelling the livestock industry in Mongolia.

Is a long-termism important for Mongolia's sustainable development?

According to Osborne et al. (2015) short-termism persists in Mongolia, from organisational planning through to high-level political decision making, and long-term visions and plans rarely exist. A long-term view and analysis are crucial for Mongolia's sustainable development. MONAGE is equipped to carry out forecasting and policy simulations. The creation of a long-term baseline for the Mongolian economy is crucial for long-run policy evaluations and welfare analysis in Mongolia.

What can we do when foreign capital flow is reversed?

While capital inflows were generally beneficial for Mongolian economy during the study period, the surge in capital inflows brought with them risks for the economy and financial system. These risks are:

- Macroeconomic risk;
- Financial instability, including exchange rate overshooting, boom-bust cycles of credit/asset prices, financial fragility and credit risk;
- Capital flow reversal; and
- Risks associated with recently issued sovereign bonds.

Capital inflows can accelerate the growth of domestic credit, create economic overheating including inflation, and cause the real exchange rate to appreciate, thus affecting macroeconomic performance in a way not consistent or compatible with domestic policy objectives such as sustainable economic growth with price stability.

Capital inflows may also create maturity and currency mismatches in the balance sheets of private sector debtors, push up equity and other asset prices, and potentially reduce the quality of assets, thereby contributing to greater financial fragility.

Capital inflows could stop suddenly or even reverse themselves within a short period, resulting in depleted reserves or sharp currency depreciation.

Capital controls had traditionally been criticized for many years because they have often been associated with unnecessary burdens on capital outflows, which may in turn change investor sentiment, rent-seeking, financial repression, subsidized and directed credit, and ‘over-controlling’ inefficient government policies. But in the light of the recent financial and currency crisis, even one of the strong supporters of free capital mobility, the IMF, recognises capital controls as a ‘legitimate part of the toolkit to manage capital inflows’, but only as temporary measures and under specific circumstances: the economy should be running near its potential, the level of reserves should be adequate, and the exchange rate should not be undervalued (Ostry 2012).

Developing countries tend to encourage capital inflows and favour an opening of their financial accounts in their recovery from crisis. However, as these economies grow and appreciating pressures on their domestic currency ensue, capital inflows start to look too large to be absorbed, and capital controls re-appear in the discussion. An increasing variety of instruments has been created by academics and policymakers, in addition to the 'traditional' capital controls; these are called macro-prudential regulations.

For the past few decades, international macroeconomics has postulated the 'trilemma': with free capital mobility, independent monetary policies are feasible if, and only if, exchange rates are floating. The global financial cycle transforms the trilemma into a 'dilemma' or an 'irreconcilable duo': independent monetary policies are possible if, and only if, the capital account is managed (Rey 2015).

One of the potential applications of MONAGE is to conduct empirical assessments for examining the dynamic responses of macroeconomic policies to large capital outflows over time and the effect of possible capital controls in response.

Could we utilize econometric methods to estimate elasticities and parameters?

Attempts have been made to estimate the elasticity of substitution between labour and capital across broad industry classes in the case of Mongolia. Firstly, we have attempted to extend an approach initially used by Phipps (1983), and further developed by Rimmer (1990), adopting the zero pure profit constraint, in keeping with the assumptions in ORANI. The attempts to utilize the panel estimation techniques with the fixed and random effects, as well as the error correction models, have been made. Due to lack of detailed data, these are still a work in progress. Ideally, we could estimate short- and long-run general equilibrium elasticities if there were adequately detailed data.

CGE models and their databases and parameter sets are now closely scrutinized by those with a stake in their funding, since CGE analysis has become a chief contributor to policy analysis (Anderson, Martin & Van der Mensbrugghe 2012). A main criticism levelled against CGE analysis is associated with its reliance on external sources for the elasticity values needed in calibration (Partridge & Rickman 1998).

However, the elasticities in CGE models are conditional on database weights. In other words, numerous input-output coefficients have a substantial influence on elasticities.

Moreover, setting of key parameters reflects judgements sometimes supplemented by sensitivity analysis in the majority of influential CGE analysis (Dixon & Rimmer 2013). For CGE modelling, we think that having a reasonable CGE database is a good start. Parameters estimated by time-series econometrics have often proved unrealistic in a simulation context (Dixon & Rimmer 2013).

There is an avenue for estimations of general equilibrium elasticities combining historical simulations and Bayesian econometrics. An example of this kind of approach is the historical simulation with USAGE for the period 1992-1998 (Dixon & Rimmer 2004b). In their simulation, Dixon and Rimmer find that historical simulation results showed preference shifts against nearly all food products. This indicated the possibility of too-high expenditure elasticities of demand for food products. When income growth generated excessive growth in modelled food consumption, it created negative preference changes toward food products. When they adopted lower elasticities, the problem of a preference shift against food disappeared. In this way, they used results from historical simulations to refine parameter estimates. This method can be called as an informal Bayesian analysis and can be extended in terms of Bayesian econometrics terms.

Bayesian econometrics nowadays is being used to solve a broad range of problems in natural and social sciences. Zellner (1988, 2008) provides insights on the past, present and future of Bayesian econometrics. Greenspan (2004) states: ‘In essence, the risk management approach to policymaking is an application of Bayesian decision making’. Further, he argues that ‘our problem is not, as is sometimes alleged, the complexity of our policy making process, but the far greater complexity of a world economy whose linkages are continuously evolving. Our response to that continuous evolution has been disciplined by the Bayesian type of decision making in which we have been engaged’(p. 39).

Zellner (2008, p. 44) predicted that the future of Bayesian econometrics ‘will involve use of much more disaggregation, the virtues of which have been extolled by many over the years, including Tinbergen, Leontief, Stone, Orcutt, Friedman, Modigliani and others. The issue has been how to disaggregate’.

Bayesian inference remained extremely difficult to implement until the late 1980s and early 1990s, when powerful computers became widely accessible and new computational methods were developed. The subsequent explosion of interest in Bayesian statistics has led not only to extensive research in Bayesian methodology but also to the use of Bayesian methods to address pressing questions in diverse application areas such as astrophysics, weather forecasting, health care policy, and criminal justice (Weber, McLure & Turkington 2010).

8.4 Policy discussions

What are the lessons can be learnt from Australian experience?

✓ **Flexible currency and wage adjustment**

As a small and open economy and as a large commodity exporter, Mongolia is very susceptible to external shocks. Fiscal policy in Mongolia has been pro-cyclical, that is, expansionary in booms and contractionary in busts, rather than countercyclical. These 'boom and bust' type policies often exacerbate volatility and create larger cycles of fluctuation; in turn, the Mongolian economy has become more exposed to external factors. In addition, government revenue in a mineral economy unavoidably fluctuates due to frequent volatility in commodity prices. As a result, budgeting and planning have become more problematic. The changes, cost overruns and redrafts to the budget have become frequent. These are causing trouble in private investment.

The Mongolian government created the Fiscal Stability Fund which initially meant to be a form of SWF. Instead, is has been doing opposite, borrowing heavily from the international financial market since 2012 leveraging resources wealth. Large public infrastructure investment projects funded from loans are currently underway. But the transparency and efficiency of those projects are in serious question. To guard against excessive spending and borrowing, the parliament approved the Fiscal Stability Law (FSL), which became effective in 2013. However, the caps on public debt and a structural budget deficit have been changed several times since the FSL's implementation, undermining the impact of the law. Limiting budget expenditure growth to non-mining GDP growth is also in question, as the results indicate that non-tradable sectors grow at a faster rate than the mineral sector. There is uncertainty regarding the discount rate and frequent cost overruns in the FSL.

The Central Bank of Mongolia, an equivalent of the RBA, is relatively independent and has been implementing monetary policies, although it often faces political pressure. It maintains a flexible exchange rate system for the Mongolian currency. To smooth structural adjustment, the Mongolian economy needs to be able to adjust to changed circumstances through currency movements and wage adjustments. The authority and independence of monetary policy are fundamental for sustainable economic development in Mongolia.

- ✓ **Cultivating productivity through micro-economic reform**

Productivity is often viewed as a key to raising living standard in the long run. Australian governments undertook a series of economic reforms through the 1980s that delivered exceptional growth in national income and helped mitigate Dutch disease effects. In particular, the microeconomic reforms that aimed to increase technical, allocative and dynamic efficiencies have helped the Australian economy to increase its flexibility and have sustained long-run economic growth for a quarter of a century. The MONAGE historical simulation results confirm that this type of reform is necessary for the Mongolian economy. The historical simulation results show that the economy lacks technical efficiency improvements. Especially when confronted by ‘dog days’, productivity improvement through microeconomic reforms, coupled with enhancement in institutional quality, may help Mongolia to avoid falling into the ‘resources trap’.

- ✓ **Importance of independent institutions**

The Australian economic situation, lessons and economic reforms in the 1970s and 1980s are highly relevant to contemporary issues in Mongolian economic policy discussions. We define the fourth factor for structural change, termed ‘institutions’, in Chapter 1. In Australia, these ‘institutions’ have been built up to implement economic policy at arm’s length from politics. The independence of organizations such as the Australian Competition and Consumer Commission, the Australian Securities and Investments Commission, the Australian Prudential Regulation Authority and the Productivity Commission has played an important role in Australia in harnessing its mineral wealth to boost its economic development. Unfortunately, in Mongolia the counterparts of those organizations are heavily influenced by the political process and are often used for political purposes, creating instability and inefficiency. To improve institutional quality in Mongolia, it is necessary to create an institutional framework that enables government organizations to make tough decisions and provide independent and sustainability-oriented economic policy advice and carry out those policies in accordance with long-term goals.

8.5 Main contributions of the thesis

There are four main contributions of the thesis to existing research.

The first contribution is the creation and development of economy-wide CGE models for Mongolia: a comparative static CGE model, ORANIMON, and a dynamic CGE model, MONAGE. Both ORANIMON and MONAGE can serve as laboratories for economic analysis in order to develop informed views on policy in Mongolia. In fact, MONAGE became an in-house model of the Economic Research Institute (ERI) in Mongolia and has been used in economic studies, from evaluating impacts of new mineral projects to simulating an introduction of shale oil use on the Mongolian economy.

A second contribution is the compilation of a master database for CGE models in two base years for the Mongolian economy. The construction of the database began with the latest available IOTs of 2005. Further compilations of the Mongolian IOTs enabled the extension of the database's 2012 base year data, which is more comprehensive and detailed. The dissemination of the database through adding and updating into the GTAP database is underway.

A third contribution is the COPS-style CGE analysis of the impacts of the resources boom on the Mongolian economy through short-run, medium-run and long-run simulations. The set-up, procedure, facilitation and validity analyses for these simulations are considerably different from those in existing literature.

A fourth contribution is the definition of COPS-style modelling and the provision of a literature review on this type of modelling. We define COPS-style modelling as a well-recognised school of economic modelling, thought and analysis, with distinctive technical characteristics and transferable know-how.

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Appendices

Appendix 1. Industries and Commodities in ORANIMON and MONAGE

Appendix 1.1 Industries and Commodities in ORANIMON (2005)

	Industries/Commodities	ORANIMON name
01	Crops	Crops
02	Animal husbandry and other agriculture	Livestock
03	Forestry and logging	ForestryLogs
04	Fishery	Fishery
05	Coal	Coal
06	Oil (petroleum) and natural gas	OilNatGas
07	Iron and copper ore: Metal ore	MetalOres
08	Other mining	OtherMining
09	Meat, meat products, fruit, vegetables, oils and fats	MeatFrVgOilF
10	Dairy products	DairyPrd
11	Flour mill products and cereal foods	FlourCereals
12	Other food products	OtherFoodPrd
13	Soft drinks, cordials and syrups	Drinks
14	Tobacco products	TobaccoPrd
15	Knitting mill products	KnittingMill
16	Clothing and fur, fur products	ClothingFurs
17	Leather and leather products	LeatherPrd
18	Wooden products (excluding wooden furniture)	WoodenPrd
19	Pulp, paper and paperboard	PulpPaper
20	Printing and services to printing, Publishing, recorded media, etc	PrintingMdia
21	Coke, liquid and nuclear fuel	FuelPrd
22	Chemical products	ChemicalPrd
23	Rubber and ceramic products	RubberPlasti
24	Non-metal mineral products	NMetalMinPrd
25	Iron and steel	IronAndSteel
26	Metal products excluding machinery and equipment	MetalPrd
27	Machinery and equipment	MachineryEqp
28	Document processing and calculation equipment	Computers
29	Electrical equipment	ElectEquip
30	Radio, TV and communication equipment	RadioTVEqp
31	Medical equipment	MedicalEqp
32	Transport equipment	TransportEqp
33	Furniture	Furniture

34	Secondary raw material processing	SecRawMatPrc
35	Electricity, water and heating supply	ElecWatrHeat
36	Water supply, sewerage and drainage services	WaterDrains
37	Construction	Construction
38	Trade: wholesale and retail trade	Trade
39	Accommodation, cafes and restaurants	HotelCafes
40	Land transport: road and rail	LandTransprt
41	Air transport	AirTransport
42	Services to transport, storage, water transport	SvcToTrnsprt
43	Communication services	CommunicSvc
44	Insurance	Insurance
45	Other financial services excluding compulsory social security	OthFinancSvc
46	Services to finance, investment and insurance	SvcToFinance
47	Real estate services	RealEstate
48	Vehicle, equipment and household appliance rental	EquipRental
49	Technical and computer services	TechnicalSvc
50	Scientific research	ScienceResch
51	Other business activities	OthBusActvts
52	Government administration and defence	GovAdminDfnc
53	Education	Education
54	Health and social services	HealthSocSvc
55	Other community, social and personal service activities	OtherSvc

Appendix 1.2 Industries and Commodities in MONAGE (2005)

2005	N	55	44	44
Crops	01	Crops	Crops	1
Animal husbandry and other agriculture	02	Livestock	Livestock	2
Forestry and logging	03	ForestryLogs	ForestFish	3
Fishery	04	Fishery		
Coal	05	Coal	Coal	4
Oil (petrolium) and natural gas	06	OilNatGas	OilNatGas	5
Iron and copper ore: Metal ore	07	MetalOres	MetalOres	6
Other mining	08	OtherMining	OthMinServ	7
Meat, meat products, fruet, vegetables, oils and fats	09	MeatFrVgOilF	FoodProd	8
Dairy products	10	DairyPrd		
Flour mill products and cereal foods	11	FlourCereals		
Other food products	12	OtherFoodPrd		
Soft drinks, cordials and syrups	13	Drinks	Drinks	9
Tabbacco products	14	TobaccoPrd	TobaccoProd	10
Knitting mill products	15	KnittingMill	Textiles	11
Clothing and fur, fur products	16	ClothingFurs	WearApparel	12
Leather and leather products	17	LeatherPrd	LeatherProd	13
Wooden products (excluding wooden furniture)	18	WoodenPrd	WoodenProd	14
Pulp, paper and paperboard	19	PulpPaper	PulpPaper	15
Printing and services to printing, Publishing, recorded media, etc	20	PrintingMdia	PrintingMdia	16
Coke, liquid and nuclear fuel	21	FuelPrd	CokeFuelPrd	17
Chemical products	22	ChemicalPrd	ChemPhar	18
Rubber and ceremic products	23	RubberPlasti	RubberPlast	19
Nonmetal mineral products	24	NMetalMinPrd	OthNMetProd	20
Iron and steel	25	IronAndSteel	BasMetalPrd	21
Metal products excluding machinery and equipment	26	MetalPrd	FabricMet	22
Machinery and equipment	27	MachineryEqp	MachTransEqp	23
Document processing and calculation equipment	28	Computers	CompElectOpt	24
Electrical equipment	29	ElectEquip		
Radio, TV and communication equipment	30	RadioTVEqp		
Medical equipment	31	MedicalEqp	ManufNec	25
Transport equipment	32	TransportEqp	MachTransEqp	23(Cockburn)
Furniture	33	Furniture	Furniture	26
Secondary raw material processing	34	SecRawMatPrc	ManufNec	25(Cockburn)
Electricity, water and heating supply	35	ElecWatrHeat	ElecGasHeat	27
Water supply, sewerage and drainage services	36	WaterDrains	WaterSeWaste	28

Construction	37	Construction	Construction	29
Trade: wholesale and retail trade	38	Trade	Trade	30
Accommodation, cafes and restaurants	39	HotelCafes	HotelCafes	31
Land transport: road and rail	40	LandTransprt	Transport	32
Air transport	41	AirTransport		
Services to transport, storage, water transport	42	SvcToTrnsprt	SvcTransNec	33
Communication services	43	CommunicSvc	CommunicSvc	34
Insurance	44	Insurance	InsuranceSup	35
Other financial services excluding compulsary social security	45	OthFinancSvc	FinSvc	36
Services to finance, investment and insurance	46	SvcToFinance	FinSvcNec	37
Real estate services	47	RealEstate	(47+48) RealEstOth	38
Vehicle, equipment and houshold appliance rental	48	EquipRental		
Technical and computer services	49	TechnicalSvc	(49+50) ProTecAdmSvc	39
Scientific research	50	ScienceResch		
Other business activities	51	OthBusActvts	OtherActvts	40
Government administration and defence	52	GovAdminDfnc	GovAdminDfnc	41
Education	53	Education	Education	42
Health and social services	54	HealthSocSvc	HealthSocSvc	43
Other community, social and personal service activities	55	OtherSvc	OtherSvcAct	44

Appendix 1.3. Industries in MONAGE (2012)

ISIC	2012	N	54	MONAGE HD	44
011-013,	Crop production, related service activities	1	Crops	Crops	1
014, 017	Animal production, hunting	2	Livestock	Livestock	2
02	Forestry and logging	3	Forestry	ForestFish	3
03	Fishing and aquaculture	4	Fishery		
05	Mining of coal and lignite	5	Coal	Coal	4
06	Extraction of crude petroleum and natural gas	6	CrudeOil	OilNatGas	5
07	Mining of metal ores	7	MetalOres	MetalOres	6
08	Other mining and quarrying	8	OtherMining	OthMinServ	7
09	Mining support service activities	9	MiningServ		
10	Manufacture of food products	10	FoodProd	FoodProd	8
11	Manufacture of beverages	11	Drinks	Drinks	9
12	Manufacture of tobacco products	12	TobaccoProd	TobaccoProd	10
13	Manufacture of textiles	13	Textiles	Textiles	11
14	Manufacture of wearing apparel	14	WearApparel	WearApparel	12
15	Manufacture of leather and related products	15	LeatherProd	LeatherProd	13
16	Manufacture of wood and of products of wood and cork, except furniture manufacture of articles of straw and plaiting materials	16	WoodenProd	WoodenProd	14
17	Manufacture of paper and paper products	17	PulpPaper	PulpPaper	15
18	Printing and reproduction of recorded media	18	PrintingMed	PrintingMdia	16
19	Manufacture of coke and refined petroleum products	19	CokeRefinOil	CokeFuelPrd	17
20	Manufacture of chemicals and chemical products	20	ChemicalProd	ChemPhar	18
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	21	PharmaProd		
22	Manufacture of rubber and plastics products	22	RubberPlast	RubberPlast	19
23	Manufacture of other non-metallic mineral products	23	OthNMetProd	OthNMetProd	20
24	Manufacture of basic metals	24	BasMetalPrd	BasMetalPrd	21
25	Manufacture of fabricated metal products, except machinery and equipment	25	FabricMet	FabricMet	22
26	Manufacture of computer, electronic and optical products	26	CompElectOpt	CompElectOpt	23

27	Manufacture of machinery and equipment	27	MachineryEqp	MachTransEqp	24
28-30	Manufacture of motor vehicles, trailers and semi-trailers; other machinery and	28	MotorVecEqp		
31	Manufacture of furniture	29	Furniture	Furniture	25
32	Other manufacturing	30	OtherManuf	ManufNec	26
325	Manufacture of medical and dental instruments and supplies	31	MedicalEqp		
33	Repair and installation of machinery and equipment	32	RepairInst		
35	Electricity, gas, steam and air conditioning supply	33	ElecGasHeat	ElecGasHeat	27
36-37	Water supply; sewerage management	34	WaterDrains	WaterSeWaste	28
38-39	Waste management and remediation activities	35	WasteRemed		
41-43	Construction	36	Construction	Construction	29
45-47	Wholesale and retail trade; repair of motor vehicles and motorcycles	37	Trade	Trade	30
49-50	Land and water transport	38	Transport	Transport	31
51	Air transport	39			
52	Warehousing and support activities for transportation	40	Warehousing	SvcTransNec	32
53	Postal and courier activities	41	PostalCour	CommunicSv	34
55-56	Accommodation and food service activities	42	HotelCafes	HotelCafes	33
58-63	Information and communication	43	InfCommunic	CommunicSvc	34
64	Financial service activities, except insurance and pension funding	44	FinanSvc	FinSvc	35
65	Insurance, reinsurance and pension funding, except compulsory social security	45	InsurancePen	InsuranceSup	36
66	Activities auxiliary to financial service and insurance activities	46	OthFinanSvc	FinSvcNec	37
68	Real estate activities	47	RealEstate	RealEstOth	38
69-75	Professional, scientific and technical activities	48	ProfTechSvc	ProTecAdmSvc	39
77-82	Administrative and support service activities	49	AdminSupSvc		
84	Public administration and defence; compulsory social security	50	GovAdminDfnc	GovAdminDfnc	40
85	Education	51	Education	Education	41
86-88	Human health and social work activities	52	HealthSocSvc	HealthSocSvc	42
90-93	Arts, entertainment and recreation	53	ArtEntRecSvc	OtherSvcAct	43
94-96	Other service activities	54	OtherSvc		
97-99	Other activities	55	OtherAct	OthActvts	44

Appendix 1.4 MONAGE and GTAP map

	COM	Gtap 57 Commodities	2012 CC 67	GTAP map
1	PDR	Paddy rice	1 Crops	wht
2	WHT	Wheat	2 Livestock	ctl
3	GRO	Cereal grains nec	3 Forestry	frs
4	V_F	Vegetables, fruit, nuts	4 Fishery	fsh
5	OSD	Oil seeds	5 Coal	coa
6	C_B	Sugar cane, sugar beet	6 CrudeOil	oil
7	PFB	Plant-based fibers	7 MetalOres	omn
8	OCR	Crops nec	8 StoneSandCla	omn
9	CTL	Cattle,sheep,goats,horses	9 OtherMine	omn
10	OAP	Animal products nec	10 ElecGasHeat	ely
11	RMK	Raw milk	11 NatWater	b_t
12	WOL	Wool, silk-worm cocoons	12 FoodProd	ofd
13	FRS	Forestry	13 DairyProd	mil
14	FSH	Fishing	14 MillProd	tex
15	COA	Coal	15 Beverages	b_t
16	OIL	Oil	16 TobaccoProd	b_t
17	GAS	Gas	17 YarnThread	tex
18	OMN	Minerals nec	18 Textiles	tex
19	CMT	Meat: cattle,sheep,goats,horse	19 WearApparel	wap
20	OMT	Meat products nec	20 LeatherProd	lea
21	VOL	Vegetable oils and fats	21 WoodenProd	lum
22	MIL	Dairy products	22 PulpPaper	ppp
23	PCR	Processed rice	23 CokeRefinOil	p_c
24	SGR	Sugar	24 BasChemiProd	crp
25	OFD	Food products nec	25 OthChemiProd	crp
26	B_T	Beverages and tobacco products	26 RubberPlast	ppp
27	TEX	Textiles	27 OthNMetGlPrd	nmm
28	WAP	Wearing apparel	28 Furniture	omf
29	LEA	Leather products	29 WasteScraps	omf
30	LUM	Wood products	30 BasMetalPrd	i_s
31	PPP	Paper products, publishing	31 FabricMet	fmp
32	P_C	Petroleum, coal products	32 GenMachine	ome
33	CRP	Chemical,rubber,plastic prods	33 SpecMachine	ome
34	NMM	Mineral products nec	34 OffComMachin	ome
35	I_S	Ferrous metals	35 ElectMachin	ele
36	NFM	Metals nec	36 RadioTVEqp	ele
37	FMP	Metal products	37 MedicalEqp	omf
38	MVH	Motor vehicles and parts	38 TransEquip	otn
39	OTN	Transport equipment nec	39 Construction	cns
40	ELE	Electronic equipment	40 Trade (61+62)	trd
41	OME	Machinery and equipment nec	41 AccoBeveServ	trd

42	OMF	Manufactures nec	42 PassenTrns	atp
43	ELY	Electricity	43 Transport	otp
44	GDT	Gas manufacture, distribution	44 RentTrns	ofi
45	WTR	Water	45 SuppTrnsServ	otp
46	CNS	Construction	46 PostalCour	otp
47	TRD	Trade	47 ElecWatDist	otp
48	OTP	Transport nec	48 FinanServ	ofi
49	WTP	Sea transport	49 RealEstate	dwe
50	ATP	Air transport	50 LeasRentServ	ofi
51	CMN	Communication	51 RandD	ros
52	OFI	Financial services nec	52 LegAccServ	obs
53	ISR	Insurance	53 OthProfTech	obs
54	OBS	Business services nec	54 TeleComm	cmn
55	ROS	Recreation and other services	55 SuppServ	obs
56	OSG	PubAdmin/Defence/Health/Educat	56 AgriSuppServ	obs
57	DWE	Dwellings	57 ReInSuppServ	obs
			58 ManuSuppServ	obs
			59 OthManuServ	obs
			60 GovAdminDfnc	osg
			61 Education	osg
			62 HealthSoServ	osg
			63 SewaWasServ	wtr
			64 MemOrgServ	ros
			65 CulSportServ	ros
			66 OtherServ	ros
			67 DomServ	ros

Appendix 1.5 ORANIMON and MONAGE map to GTAP

ORANIMON 55	GTAP map	MONAGE 54	GTAP map
Crops	wht	Crops	wht
Livestock	ctl	Livestock	ctl
ForestryLogs	frs	Forestry	frs
Fishery	fsh	Fishery	fsh
Coal	coa	Coal	coa
OilNatGas	oil	CrudeOil	oil
MetalOres	omn	MetalOres	omn
OtherMining	omn	OtherMining	omn
MeatFrVgOilF	cmt	MiningServ	omn
DairyPrd	mil	FoodProd	ofd
FlourCereals	pcr	Beverages	b_t
OtherFoodPrd	ofd	TobaccoProd	b_t
Drinks	b_t	Textiles	tex
TobaccoPrd	b_t	WearApparel	wap
KnittingMill	tex	LeatherProd	lea
ClothingFurs	wap	WoodenProd	lum
LeatherPrd	lea	PulpPaper	ppp
WoodenPrd	lum	PrintingMed	ppp
PulpPaper	ppp	CokeRefinOil	p_c
PrintingMdia	ppp	ChemicalProd	crp
FuelPrd	p_c	PharmaProd	crp
ChemicalPrd	crp	RubberPlast	crp
RubberPlasti	crp	OthNMetProd	nmm
NMetalMinPrd	nmm	BasMetalPrd	i_s
IronAndSteel	i_s	FabricMet	fmp
MetalPrd	fmp	CompElectOpt	ele
MachineryEqp	ome	MachineryEqp	ome
Computers	ele	MotorVecEqp	mvh
ElectEquip	ele	Furniture	omf
RadioTVEqp	ele	OtherManuf	omf
MedicalEqp	omf	MedicalEqp	omf
TransportEqp	mvh	RepairInst	omf
Furniture	omf	ElecGasHeat	ely
SecRawMatPrc	omf	WaterDrains	wtr
ElecWatrHeat	ely	WasteRemed	wtr
WaterDrains	wtr	Construction	cns
Construction	cns	Trade	trd
38 Trade	trd	Transport	otp
39 HotelCafes	trd	Warehousing	otp
40 LandTransprt	otp	PostalCour	trd
AirTransport	atp	HotelCafes	trd

SvcToTrnsprt	obs	InfCommunic	cmn
CommunicSvc	cmn	FinanSvc	ofi
Insurance	isr	InsurancePen	isr
OthFinancSvc	ofi	OthFinanSvc	ofi
SvcToFinance	ofi	RealEstate	dwe
RealEstate	dwe	ProfTechSvc	obs
EquipRental	obs	AdminSupSvc	obs
TechnicalSvc	obs	GovAdminDfnc	osg
ScienceResch	ros	Education	osg
OthBusActvts	ros	HealthSocSvc	osg
GovAdminDfnc	osg	ArtEntRecSvc	ros
Education	osg	OtherSvc	ros
HealthSocSvc	osg	OtherAct	obs
OtherSvc	ros		

Appendix 2. GDP and Sectoral Value Added at constant 2005 prices (million MNT)

Economic sectors	2005 database			2012 database		
	1995	2005	Ave. Growth	2000	2012	Ave. Growth
GDP	1,941,470	3,041,406	**4.39%**	2,221,690.3	5,492,723	**6.73%**
Agriculture, hunting,	639,698	602,136	**-0.61%**	617,417.5	801,269.2	**1.99%**
Mining & quarrying	355,554	642,089	**5.74%**	433,109.8	861,511.4	**5.15%**
Manufacturing	166,863	175,156	**0.48%**	114,258.9	295,225	**7.04%**
Electricity and gas	63,670	75,928	**1.75%**	66,751.8	111,667.2	**3.88%**
Water supply, drainage	10,932	13,769	**2.28%**	11,562.4	20,388.4	**4.27%**
Construction	43,480	81,408	**6.08%**	35,649	102,604.2	**7.81%**
Trade	115,657	227,478	**6.54%**	158,917.7	591,110.6	**9.61%**
Transport, storage	85,005	256,726	**10.46%**	125,470.9	605,013.9	**11.40%**
Hotels & cafes	12,143	19,342	**4.55%**	15,243.8	60,167	**10.02%**
Communications	32,703	96,261	**10.23%**	47,486.2	226,794.4	**11.33%**
Financial intermediation	44,804	112,279	**8.78%**	44,342.1	249,875	**12.45%**
Real estate, renting & other	122,801	160,523	**2.64%**	134,350.9	217,574.6	**3.64%**
Science, Research & Technical Services	6,167	18,025	**10.17%**	6,803.2	50,763.4	**14.32%**
Other public supporting services	11,021	34,071	**10.67%**	14,721	80,097.5	**12.22%**
Public administration & defense	66,111	66,923	**0.12%**	68,499.6	72,982.2	**0.49%**
Education	83,579	86,529	**0.35%**	101,513.4	102,230.4	**0.05%**
Health & Social services	32,696	37,517	**1.37%**	35,455.7	50,946	**2.75%**
Cultural services (Arts, entertainment, and	3,115	7,745	**8.70%**	4,062.6	12,933.8	**8.52%**
Other services	6,345	15,764	**8.70%**	8,275.6	24,238.5	**7.93%**

Appendix 3. Elasticities of the substitutability between primary factors

	Sectors	
01	Crops	0.239
02	Animal husbandry and other agriculture	0.239
03	Forestry and logging	0.2
04	Fishery	0.2
05	Coal	0.2
06	Oil (petroleum) and natural gas	0.2
07	Iron and copper ore: Metal ore	0.2
08	Other mining	0.2
09	Meat, meat products, fruit, vegetables, oils and fats	1.12
10	Dairy products	1.12
11	Flour mill products and cereal foods	1.12
12	Other food products	1.12
13	Soft drinks, cordials and syrups	1.12
14	Tobacco products	1.12
15	Knitting mill products	1.26
16	Clothing and fur, fur products	1.26
17	Leather and leather products	1.26
18	Wooden products (excluding wooden furniture)	1.26
19	Pulp, paper and paperboard	1.26
20	Printing and services to printing, Publishing, recorded media, etc	1.26
21	Coke, liquid and nuclear fuel	1.26
22	Chemical products	1.26
23	Rubber and ceramic products	1.26
24	Non-metal mineral products	1.26
25	Iron and steel	1.26
26	Metal products excluding machinery and equipment	1.26
27	Machinery and equipment	1.26
28	Document processing and calculation equipment	1.26
29	Electrical equipment	1.26
30	Radio, TV and communication equipment	1.26
31	Medical equipment	1.26
32	Transport equipment	1.26
33	Furniture	1.26
34	Secondary raw material processing	1.26
35	Electricity, water and heating supply	1.26
36	Water supply, sewerage and drainage services	1.26
37	Construction	1.4

38	Trade: wholesale and retail trade	1.68
39	Accommodation, cafes and restaurants	1.68
40	Land transport: road and rail	1.68
41	Air transport	1.68
42	Services to transport, storage, water transport	1.26
43	Communication services	1.26
44	Insurance	1.26
45	Other financial services excluding compulsory social security	1.26
46	Services to finance, investment and insurance	1.26
47	Real estate services	1.26
48	Vehicle, equipment and household appliance rental	1.26
49	Technical and computer services	1.26
50	Scientific research	1.26
51	Other business activities	1.26
52	Government administration and defence	1.26
53	Education	1.26
54	Health and social services	1.26
55	Other community, social and personal service activities	1.26

Appendix 4. Armington,Household expenditure and Export elasticities

	Commodities	Armington Elasticities	Household expenditure elasticities	Export elasticities
01	Crops	4.45	0.47	8.9
02	Animal husbandry and other agriculture	2	1.04	4
03	Forestry and logging	2.5	1.27	5
04	Fishery	1.25	1.04	2.5
05	Coal	3.05	1.28	6.1
06	Oil (petroleum) and natural gas	5.2	1.08	10.4
07	Iron and copper ore: Metal ore	0.9	1.14	1.8
08	Other mining	0.9	1.14	1.8
09	Meat, meat products, fruit, vegetables, oils and fats	3.85	0.68	4
10	Dairy products	3.65	0.67	7.3
11	Flour, mill products and cereal foods	2.6	0.31	7.5
12	Other food products	2	0.52	4
13	Soft drinks, cordials and syrups	1.15	0.53	2.3
14	Tobacco products	1.15	0.53	2.3
15	Knitting mill products	3.75	0.87	7.5
16	Clothing and fur, fur products	3.7	0.69	7.4
17	Leather and leather products	4.05	0.72	8.1
18	Wooden products (excluding wooden furniture)	3.4	0.96	6.8
19	Pulp, paper and paperboard	2.95	0.78	5.9
20	Printing and services to printing, Publishing, recorded media, etc	2.95	0.78	5.9
21	Coke, liquid and nuclear fuel	2.1	0.95	4.2
22	Chemical products	3.3	0.86	6.6
23	Rubber and ceramic products	3.3	0.86	6.6
24	Non-metal mineral products	2.9	1.01	5.85
25	Iron and steel	2.95	1.08	5.9
26	Metal products excluding machinery and equipment	3.75	0.93	7.4

27	Machinery and equipment	4.05	0.88	8.1
28	Document processing and calculation equipment	4.4	0.71	8.1
29	Electrical equipment	4.4	0.71	8.8
30	Radio, TV and communication equipment	4.4	0.71	8.8
31	Medical equipment	3.75	0.82	7.4
32	Transport equipment	2.8	1.57	5.6
33	Furniture	3.75	0.82	7.4
34	Secondary raw material processing	3.75	0.82	7.4
35	Electricity, water and heating supply	2.8	1.12	5.6
36	Water supply, sewerage and drainage services	2.8	1.09	5.6
37	Construction	1.9	1.28	3.8
38	Trade: wholesale and retail trade	1.9	1.19	3.8
39	Accommodation, cafes and restaurants	1.9	1.19	3.8
40	Land transport: road and rail	1.9	0.92	3.8
41	Air transport	1.9	2.1	3.8
42	Services to transport, storage, water transport	1.9	1.63	3.8
43	Communication services	1.9	0.85	3.8
44	Insurance	1.9	1.04	3.8
45	Other financial services excluding compulsory social security	1.9	1.67	3.8
46	Services to finance, investment and insurance	1.9	1.67	3.8
47	Real estate services	1.9	1.49	3.8
48	Vehicle, equipment and household appliance rental	1.9	1.63	3.8
49	Technical and computer services	1.9	1.63	3.8
50	Scientific research	1.9	1.48	3.8
51	Other business activities	1.9	1.48	3.8
52	Government administration and defence	1.9	1.45	3.8
53	Education	1.9	1.45	3.8
54	Health and social services	1.9	1.45	3.8
55	Other community, social and personal service activities	1.9	1.48	3.8

Appendix 5. Cross tabulations and Chi-square tests

A.5.1 Cross-tabulation between industry performance and import share in the CONSUME scenario

			Import threat		Total
			Not import competing	Import competing	
Consume	Loser	Count	3	24	27
		Expected count	12.7	14.3	27.0
		% within w_con	11.1%	88.9%	100.0%
	Winner	Count	21	3	24
		Expected count	11.3	12.7	24.0
		% within w_con	87.5%	12.5%	100.0%
Total		Count	24	27	51
		Expected count	24.0	27.0	51.0
		% within w_con	47.1%	52.9%	100.0%

A.5.2 Chi-square test between industry performance and import share in the CONSUME scenario

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	29.760[a]	1	0		
Continuity Correction[b]	26.773	1	0		
Likelihood Ratio	33.603	1	0		
Fisher's Exact Test				0	0
Linear-by-Linear Association	29.176	1	0		
N of Valid Cases	51				

A.5.3 Cross-tabulation between industry performance and export orientation in the CONSUME scenario

			ITEX		Total
			Collective	Individually	
Consume	Loser	Count	9	18	27
		Expected count	14.3	12.7	27.0
		% within w_con	33.3%	66.7%	100.0%
	Winner	Count	18	6	24
		Expected count	12.7	11.3	24.0
		% within w_con	75.0%	25.0%	100.0%
Total		Count	27	24	51
		Expected count	27.0	24.0	51.0
		% within w_con	52.9%	47.1%	100.0%

A.5.4 Chi-square test between industry performance and export orientiation in the CONSUME scenario

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	8.854[a]	1	0.003		
Continuity Correction[b]	7.261	1	0.007		
Likelihood Ratio	9.161	1	0.002		
Fisher's Exact Test				0.005	0.003
Linear-by-Linear Association	8.681	1	0.003		
N of Valid Cases	51				

A.5.5 Cross-tabulation between industry performance and capital intensiveness in the CONSUME scenario

			Capital		Total
			Not intensive	Intensive	
W_con	Loser	Count	22	5	27
		Expected count	21.7	5.3	27
		% within w_con	81.50%	18.50%	100.00%
	Winner	Count	19	5	24
		Expected count	19.3	4.7	24
		% within w_con	79.20%	20.80%	100.00%
Total		Count	27	41	10
		Expected count	27.0	41	10
		% within w_con	52.9%	80.40%	19.60%

A.5.6 Chi-square test between industry performance and capital intensiveness in the CONSUME scenario

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.043[a]	1	0.835		
Continuity Correction[b]	0	1	1		
Likelihood Ratio	0.043	1	0.835		
Fisher's Exact Test				1	0.556
Linear-by-Linear Association	0.042	1	0.837		
N of Valid Cases	51				

A.5.7 Cross-tabulation between industry performance and labour intensiveness in the CONSUME scenario

			Labour		Total
			Not labour intensive	Labour intensive	
W_con	Loser	Count	20	7	27
		Expected count	17.5	9.5	27
		% within w_con	74.10%	25.90%	100.00%
	Winner	Count	13	11	24
		Expected count	15.5	8.5	24
		% within w_con	54.20%	45.80%	100.00%
Total		Count	27	33	18
		Expected count	27.0	33	18
		% within w_con	52.9%	64.70%	35.30%

A.5.8 Chi-square test between industry performance and labour intensiveness in the CONSUME scenario

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.205[a]	1	0.138		
Continuity Correction[b]	1.419	1	0.234		
Likelihood Ratio	2.216	1	0.137		
Fisher's Exact Test				0.156	0.117
Linear-by-Linear Association	2.162	1	0.141		
N of Valid Cases	51				

A.5.9 Cross-tabulation between the winners and losers in CONSUME and SAVE

			Save		Total
			Loser	Winner	
W_con	Loser	Count	20	7	27
		Expected count	17.5	9.5	27
		% within w_con	74.10%	25.90%	100.00%
	Winner	Count	13	11	24
		Expected count	15.5	8.5	24
		% within w_con	54.20%	45.80%	100.00%
Total		Count	27	33	18
		Expected count	27.0	33	18
		% within w_con	52.9%	64.70%	35.30%

A.5.10 Chi-square test between the winners and losers in CONSUME and SAVE

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.205[a]	1	0.138		
Continuity Correction[b]	1.419	1	0.234		
Likelihood Ratio	2.216	1	0.137		
Fisher's Exact Test				0.156	0.117
Linear-by-Linear Association	2.162	1	0.141		
N of Valid Cases	51				

Appendix 6. Regressions results

Dependent Variable: Z_CON
Method: Least Squares (Gauss-Newton / Marquardt steps)
Sample: 1 51
Included observations: 51
Z_CON=C(1)+C(Cockburn)*TRDS

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	22.65720	3.764169	6.019176	0.0000
C(Cockburn)	-15.80855	1.561803	-10.12198	0.0000

R-squared	0.676471	Mean dependent var	-4.416471
Adjusted R-squared	0.669868	S.D. dependent var	32.91903
S.E. of regression	18.91433	Akaike info criterion	8.756143
Sum squared resid	17529.84	Schwarz criterion	8.831900
Log likelihood	-221.2816	Hannan-Quinn criter.	8.785092
F-statistic	102.4546	Durbin-Watson stat	1.555329
Prob(F-statistic)	0.000000		

Dependent Variable: Z_CON
Method: Least Squares (Gauss-Newton / Marquardt steps)
Sample: 1 51
Included observations: 51
Z_CON=C(1)+C(Cockburn)*IMP_SENS+C(3)*EXP_SENS

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	16.18321	3.763300	4.300272	0.0001
C(Cockburn)	-3.289314	0.660071	-4.983275	0.0000
C(3)	-17.07973	2.090177	-8.171428	0.0000

R-squared	0.621920	Mean dependent var	-4.416471
Adjusted R-squared	0.606167	S.D. dependent var	32.91903
S.E. of regression	20.65871	Akaike info criterion	8.951174
Sum squared resid	20485.56	Schwarz criterion	9.064811
Log likelihood	-225.2549	Hannan-Quinn criter.	8.994598
F-statistic	39.47864	Durbin-Watson stat	1.601037
Prob(F-statistic)	0.000000		

Dependent Variable: Z_CON
Method: Least Squares (Gauss-Newton / Marquardt steps)
Sample: 1 51
Included observations: 51
Z_CON=C(1)+C(Cockburn)*IMP_SENS+C(3)*EXP_SENS+C(4)*LABSH

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	15.90142	6.839677	2.324878	0.0244
C(Cockburn)	-3.287956	0.667601	-4.925033	0.0000
C(3)	-17.07402	2.115379	-8.071377	0.0000
C(4)	0.621548	12.53896	0.049569	0.9607

R-squared	0.621940	Mean dependent var	-4.416471
Adjusted R-squared	0.597808	S.D. dependent var	32.91903
S.E. of regression	20.87678	Akaike info criterion	8.990337
Sum squared resid	20484.49	Schwarz criterion	9.141853
Log likelihood	-225.2536	Hannan-Quinn criter.	9.048236
F-statistic	25.77295	Durbin-Watson stat	1.606515
Prob(F-statistic)	0.000000		

Dependent Variable: Z_CON
Method: Least Squares (Gauss-Newton / Marquardt steps)
Sample: 1 51
Included observations: 51
Z_CON=C(1)+C(Cockburn)*IMP_SENS+C(3)*EXP_SENS+C(4)*LABS+C(5)
*CAPS

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	4.438690	11.68525	0.379854	0.7058
C(Cockburn)	-3.357554	0.669958	-5.011590	0.0000
C(3)	-17.13783	2.112681	-8.111886	0.0000
C(4)	10.22551	10.89850	0.938249	0.3530
C(5)	9.777364	10.41374	0.938891	0.3527

R-squared	0.630992	Mean dependent var	-4.416471
Adjusted R-squared	0.598904	S.D. dependent var	32.91903
S.E. of regression	20.84832	Akaike info criterion	9.005318
Sum squared resid	19994.02	Schwarz criterion	9.194713
Log likelihood	-224.6356	Hannan-Quinn criter.	9.077692
F-statistic	19.66462	Durbin-Watson stat	1.666789
Prob(F-statistic)	0.000000		

Appendix 7 Additional equations to facilitate the shocks in Stage 3

We introduce the following equations in order to implement ours shocks. First, we relate the change in household expenditure on each commodity c to the changes in price and quantity via:

$$w3\_s(c) = p3\_s(c) + x3\_s(c) \quad \textbf{(A7.1)}$$

We have defined a general form of linking equation for variables with same level of disaggregation in Chapter 5 via equation 5.43. For expenditure values, we have the same level of disaggregation; that is, 52. The following equation is the specific case of 5.43:

We add, next, the equation to facilitate observed changes in household expenditure as:

$$w3\_s(c) = w3\_obs(c) + f\_w3\_obs \quad \textbf{(A7.2)}$$

where $w3\_obs(c)$ is the observed change in household expenditure and f_w3_obs is a scalar shifter.

In introducing the price shocks, we employ:

$$p3\_s\_12\_obs(g) = p3\_s\_12(g) + f\_p3\_obs \quad \textbf{(A7.3)}$$

where $p3\_s\_12\_obs(g)$ is the observed change between 2005 and 2012 of commodity group g; $p3\_s\_12(g)$ is the change in the price of commodity group g which is mapped from $p3\_s(c)$; and f_p3_obs is a scalar shift variable.

Equation (A7.3) is for 12 commodity groups, so that we use the following phantom tax equation to accommodate the difference between prices calculated by MONAGE and the observed changes for them:

$$ave\_tph3 = \sum_c S3(c) \cdot tph3(c) + f\_tph3\_12(g) \quad \textbf{(A7.4)}$$

where ave_tph3 is a budget-share weighted average change in phantom tax on household use; $tph3(g)$ is the change in phantom tax on household use of commodity group g; and $f\_tph3\_12(g)$ is a vector shifter variable to facilitate shocks. For prices, we do not have same level of disaggregation. Hence, we use (A7.3) and (A7.4) for facilitation of the shocks.

Appendix 8 Swaps required in Stage 3

For MONAGE, following swaps are required:

(i) $x3tot$ in (7.13) with apc_gnp in (7.14);

(ii) $w3_obs(c)$in (A7.2) with $a3com(c)$ in (7.12);

(iii) ave_a3com in (7.12) with f_p3_obs in (A7.3);

(iv) $p3\_s\_12\_obs(g)$ in (A7.3) with $f\_tph3\_12(g)$ in (A7.4); and

(v) ave_tph3 in (A7.4) with f_w3_obs in (A7.2).

As a result of these swaps, we are now able to introduce the shocks with historically observed values of $x3tot$, $w3\_obs(c)$ and $p3\_s\_12\_obs(g)$ for estimating $a3com(c)$ and apc_gnp. In addition, we must shock newly exogenized variable ave_a3com with 0 value to maintain the budget constraint of households.

Appendix 9 Investment

Sectors	2012
Total	9,395,798.60
Agriculture, forestry and fishing	64,573.10
Mining and quarrying	4,694,465.40
Manufacturing	139,207.70
Electricity, gas, steam and air conditioning supply, water supply	171,557.80
Construction	913,759.10
Wholesale and retail trade; repair of motor vehicles and motorcycles	1,466,502.40
Transportation and storage	510,542.50
Accommodation and food service activities	20,072.20
Information and communication	156,214.60
Financial and insurance activities	168,333.00
Real estate activities	39,264.40
Public administration and defence; compulsory social security	429,058.40
Education	122,315.30
Human health and social work activities	43,508.90
Other service activities	456,423.80

Source: ERI

Appendix 10 Swaps in Stage 6

For MONAGE, following swaps are required in this stage.

(i) $w0cif\_c$ with $twist\_c$;

(vi) $x0imp(c)$ with $ftwist\_src(c)$ for major import commodities;

(vii) $pf0cif\_c$ with ff_pf0cif;

(viii) $pf0cif\_obs(c)$ with $pf0cif(c)$ for non-major import commodities;

(ix) $w0cif(c)$ with $ftwist\_src(c)$ for non-major import commodities.

Appendix 11 Sectoral outputs (millions MNT, in 2005 prices) and changes in real outputs (%) in comparison to the GDP change

Economic sectors	2005	2012	Growth	Average growth	Speed
GDP	**3,041,405.9**	**5,492,723.0**	**80.6**	**11.5**	Bench-
Agriculture	602,136.3	801,269.2	33.1	4.7	slow
Mining & quarrying	642,089.0	861,511.4	34.2	4.9	slow
Manufacturing	175,155.9	295,225.0	68.5	9.8	Ave
Electricity and gas	75,928.2	111,667.2	47.1	6.7	Ave
Water supply, drainage	13,768.9	20,388.4	48.1	6.9	Ave
Construction	81,408.4	102,604.2	26.0	3.7	Slow
Trade	227,478.2	591,110.6	159.9	22.8	High
Transport, storage	256,726.4	605,013.9	135.7	19.4	High
Hotels & cafes	19,341.7	60,167.0	211.1	30.2	High
Communications	96,261.1	226,794.4	135.6	19.4	High
Financial intermediation	112,278.8	249,875.0	122.5	17.5	High
Real estate, renting & other business activities	160,522.7	217,574.6	35.5	5.1	Slow
Research & Development	18,024.5	50,763.4	181.6	25.9	High
Other public supporting	34,071.1	80,097.5	135.1	19.3	High
Public administration and defense	66,923.1	72,982.2	9.1	1.3	Slow
Education	86,528.6	102,230.4	18.1	2.6	Slow
Health and Social services	37,516.9	50,946.0	35.8	5.1	Slow
Cultural services	7,744.5	12,933.8	67.0	9.6	Ave
Other services	15,763.7	24,238.5	53.8	7.7	Ave
Net taxes	311,737.9	955,330.2	206.5	29.5	High

Appendix 12 Export quantity, price and value for mineral commodities

MONAGE	ERI commodity	2005 Exported quantity, Tons	2012 Exported quantity, Tons	2005 Exported unit value, US Dollar/Tons	2012 Exported unit value, US Dollar/Tons	2005 Exported value in 2005	2012 Exported value in 2012
Coal	Coal; briquettes, ovoids & similar solid fuels manufactured from coal	2,217,805	20,547,412	12	92	26,621	1,880,396
OilNatGas	Crude petroleum oils	25,719	485,242	360	693	9,262	336,053
MetalOres	Iron ores & concentrates; including roasted iron pyrites	177,794	6,415,941	27	83	4,782	532,509
MetalOres	Copper ores and concentrates	587,057	574,343	556	1,460	326,217	838,579
MetalOres	Zinc ores and concentrates	23,068	140,893	443	929	10,219	130,830
MetalOres	Molybdenum ores and concentrates	2,395	4,306	19,489	8,865	46,677	38,174