Dutch Disease in Australia: A Structural VAR Model

Farhana Abedin

School of Economics

The University of Adelaide

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Abstract

We applied a Structural VAR model to empirically investigate the adverse effect of positive growth shock in the resource sector on economic activity in a small open economy, like Australia. We observed the key eight variables important for explaining the evidence of Dutch disease over the period of 1984:Q1 to 2016:Q4. The 2000s boom is the first mining boom in Australia after the adoption of the floating exchange rate, inflation targeting, and de-centralised wage system. We analysed how different sectors have adapted from the mining boom shock, and whether the changes in policies have influenced the sectors capacity to adjust to an economic shock. We identified the structural shocks using short-run Cholesky decomposition by making system recursive. The result showed that the foreign demand shock caused to raise the price of the commodity, and shock to the commodity price cause the real exchange rate to appreciate and has a positive impact on resource output. However, the aggregate real GDP, the non-resource tradeable and non-tradeable gross value-added declined in the long-run.

Declaration

I, Farhana Abedin, certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

I also give permission for the digital version of my thesis to be made available on the web, via the University's digital repository, the Library Search and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

I acknowledge the support I have received for my research through the provision of an Australian Government Research Training Program Scholarship.

Farhana Abedin

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Signature   Date: 18 November, 2019

Dedication

To My Daughter

&

My Parents

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Chapter 1

Introduction

Australia is considered as one of the resource-abundant small open economies. It is one of the largest producers and exporter of minerals in the world. The resource sector is an integral part of Australian development and culture. The history of Australian mineral industry has started since the discovery of coal in 1788 in New South Wales.[1] Since the discovery of coal, it has experienced five major mining booms over the last 170 years.[2] These major booms occurred in the 1850s (the gold rush), in the 1870s/early 1900s, in the 1960s/early 1970s, in the late 1970s/early 1980s and in the 2000s.[3] The resource boom played a very vital role in the development of the country. The growth in the resource sector generally increase aggregate real GDP, led higher incomes for individuals, increase investments, employment, the government earns resource revenue, and companies gain significant profits engaged in mining-related activities.

Our research focuses on the 2000s boom, which is one of the sequences of the mineral boom. The cause of the 2000s boom was an unprecedented surge in export in resource commodities. The positive shock in the mining sector helped Australia to grow faster than other developed countries during that period. For example, in 2003, the average annual real aggregate GDP growth rate was 2.7%, and at the end of the boom in 2012, the average yearly growth rate of real GDP was 3.9%. The annual average growth rate of the resource sector was 6.5 per cent during the expansion period (2004-2011), while during the period of 1992/93 to 2002/3 the sector' growth rate was only 0.5 per cent. The growth in the mining industry

[1] http://www.australianminesatlas.gov.au/history/index.html.
[2] & [3] See Battellino (2010).

contributed to maintaining real output (in gross value added) growth rate 3 per cent at an annual average between the period of 2003/4 and 2011/12 (Plumb et al., 2013). In contrast, major OECD counties (except Korea) was experiencing an annual average growth rate of real GDP of below 3 per cent during that period. For this context, we provided the data of the annual GDP growth rate of major OECD countries and two non-OECD (China and India) in appendix B, table1 and 2.

The mining boom is not only substantially raise real GDP, but there are other effects of the boom on the domestic economy. The expansion of the mining sector induces movement of resources (labour and capital) from other non-mining sectors to the mining sector. The movement of the factor of production implicitly changes the relative prices, such as the exchange rate. The movement of relative prices is crucial determinants of production, consumption, employment and other macroeconomic indicators. The flow of resources from non-mining sectors to mining sector causes wages and inflation to rise, and an appreciation of the real exchange rate. In other words, the gain in resource revenue increases the national income, which leads to an increase in the marginal propensity to consume on goods and services over time. The higher demand for products and services requires the expansion of the sectors by producing more quantity to meet the excess demand. The higher production means higher demand for factor inputs. Assuming the economy is operating at near full employment level, then increase in domestic output of services requires factor moving out from the non-mining trading sector, such as manufacturing and agriculture. Historically, this structural adjustment accommodated by a real appreciation of nominal exchange rate and domestic inflation. The appreciation of the exchange rate reduces the demand for and competitiveness of domestically produced non-mining traded goods. Because the rise in the exchange rate makes non-resource tradeable goods more expensive compared to their foreign counterparts by reducing the relative price of imports. The higher value of domestic currency weakens the competitiveness of non-mining industries and import-competing industries, such as agriculture and manufacture in the foreign market. Therefore, non-mining trading sectors and the whole economy undergone structural changes due to the growth shock in the resource sector. Some industry may experience a positive spillover, and some may negatively be affected by the growth shock. For example, in 2003 the annual gross value added by the mining industry was 67,058 million dollars, compared to 95,952 million dollars in 2012, and in 2018 it was 139,052 million dollars. In 2003 the annual gross value added by manufacturing industries was 110,438 million dollars compared to 111,946 million dollars in 2012 and in 2018 the annual GVA by manufacturing was 105,233 million dollars. In 2003 the yearly GVA by agriculture and forestry were 31,022 million dollars, and in 2012 were 46,566 million dollars, and in 2018 agricultural GVA was 46,233 million dollars (ABS, Cat. No. 5206.0).

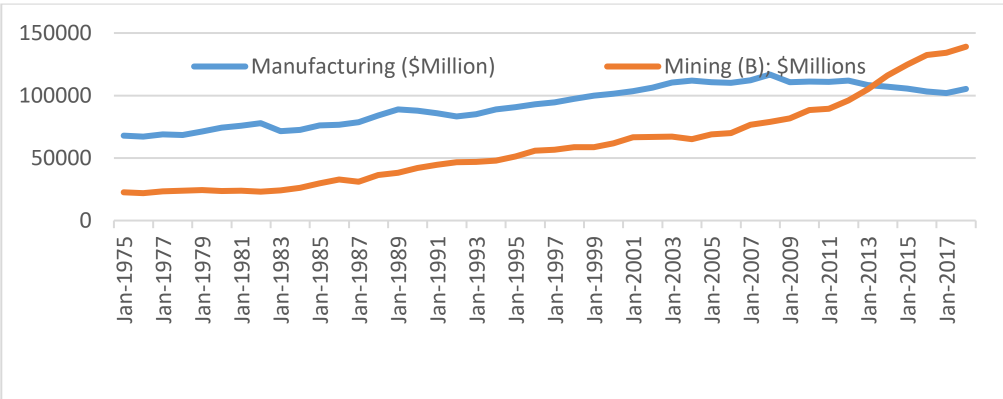

Figure 1: Industry Gross Value Added, (Chain volume measures, Annual)
Source: 5206.0 Australian National Accounts: National Income, Expenditure and Product

Figure 1 showing a persistent increase in gross value addition by mining sectors and a decline in the non-resource tradeable (manufacture) and import-competing industries after 2013. According to the Australian Bureau of Statistics industry data 2016-17, the mining sector showed a persistent growth of 38.2% ($23.1b), in contrast, manufacturing sector growth declined by 3.4% (-$1.2b).[4] We can see a structural shift between the sectors of the economy. The economy experiences structural changes whenever the shock hit the economy by altering the share of employment, gross value added of the industry and other macroeconomic indicators. When a positive growth shock in mining industry adversely affects the non-mining tradeable sector, the scenario is commonly known as Dutch disease. This phenomenon sometimes refers to as 'two-speed economy' in the literature. The Dutch disease is a transmission mechanism usually channels through by raising the price of resource commodities and the real exchange rate. The change in relative prices reduces the relative competitiveness and crowding out the non-mining tradable sector of that country.

There is a large number of cross-country analysis on the effect of the mining boom, such as Sachs and Warner (1995, 1999), Gylfason et al., (1999), Gylfason (2001), and Stijns (2005). Their studies set out the preconditions and channels via which natural resources lead to sluggish long-run economic growth. Collier and Goderis (2007) and some follow-up research argued that the negative effect of resource growth on other sector or Dutch disease concern for developing economies, such as Asia and Sub-Saharan Africa. Égert (2012) found the importance of oil production (mineral industry) in the post-Soviet countries of Central and South-West Asia. He showed that the share of manufacturing sector declined and share of the mining sector increased over the period of 1991 to 2006, and energy export positively linked to long-run growth. Égert and Leonard (2007) found evidence of fall in non-oil manufacturing industries from 1996 to 2005 in Kazakhstan. Beine, Bos and Coulombe (2012) found evidence of Dutch disease in the small open economy, like Canada. Their empirical

[4] An average percentage change (every five years and every ten years since 1980s) in growth rate in value added in all sector in Australia provided in Appendix B (table 3a and 3b).

estimate showed that the appreciation of the real exchange rate caused a decline in manufacturing employment between 33 and 39 per cent from the period 2002 to 2007.

There are, however, relatively few econometric analyses of Dutch disease in Australia. The objective of our study is to empirically investigate the question of whether the 2000s mining boom in Australia has adversely affected the non-resource tradeable sectors or not. To answer this question, we provided a macro-econometric model to analyse the impact of the structural shocks on the growth rate in real GDP and the growth rate in gross value added of sectoral output. The research contributes to the existing literature in three ways. The first contribution is a quantitative or econometric approach of Dutch disease analysis in a small open economy. The theoretical conclusion is that the rise in resource commodity price implicitly leads to appreciate the real exchange rate, which reduces the competitiveness of non-mining sectors in the world market. This adverse effect cause de-industrialisation of the non-resource tradeable sector (manufacturing and agriculture) in the long-run. This theory has been known as Dutch disease since the paper published by Gregory (1976), Corden and Neary (1982) and Corden (1984). On the other hand, Downes, Hanson and Tulip (2014) Sheehan and Gregory (2012) Lim, Chua and Nguyen (2013) and Freebairn (2014), have analysed the recent mining boom with macroeconomic models, but without econometric analysis of the existence or magnitude of Dutch disease effects. Our research contributes to an empirical application of theoretical construction. The second contribution is to complement the existing literature on the sectoral analysis of Australian economy by Dungey and Pagan (2000), Dungey and Pagan (2009), Dungey et al., (2014), Jääskelä and Smith (2011), Vespignani (2013), Knop and Vespignani (2014), Manalo et al., (2015). These literature have applied a Structural VAR model for empirical analysis. The third contribution is creating a foreign real GDP variable, which is the trade-weighted average real GDP growth of Australia's major trading partners. The variable calculated manually by aggregating 17 Australia's major trading partner's countries, plus aggregating 19 countries from the European Union, and each countries real GDP measure has weighted by their average trade weights.[5]

Australia is a unique case for empirical investigation because of the recurring feature of the mining boom, as we have mentioned that over the last 170 years this country has experienced five major mining boom. Each time it faces growth in the resource sector, the economy has undergone a structural adjustment process and requires a policy solution for a smooth transition from old equilibrium to a new equilibrium. The applied research requires rich dataset and Australia possesses a rich dataset, which is very useful for quantitative analysis and will be useful for future research work on the small open resource-rich economy.

We empirically estimated the model using the data mostly from the Australian Bureau of Statistics, the Reserve bank of Australia and the Penn World Table, and the International Monetary Fund (IMF) and the World Development Indicator (WDI). The detailed description of the data and variables provided in appendix A. We observed the variables from period 1984: Q1 to 2016: Q4. The sample period is selected from 1984 to include the commodity price boom in the 2000s and also constrained by Australia's adoption of a floating exchange rate in December 1983.[6] For this thesis, our focus is on the recent boom because according to the literature, the current export-led resource boom considered as the most substantial positive shock hit this economy. The surge in resource export sparked by an extraordinary upsurge in the world non-rural commodity prices. The commodity price started to rise around 2003 and reached its highest level in 2011 (RBA Statistical table, I2), and mining investment began to rise from around 2005 (Battellino, 2010). The tremendous rise in commodity prices

[5] A detailed calculation of the foreign real GDP variable has provided in section 5.2.
[6] See, https://www.rba.gov.au/mkt-operations/ex-rate-rba-role-fx-mkt.html.

occurred because of the strong demand for commodities from emerging Asian economies. The higher relative commodity export prices increased the value of Australia's resource exports more than 300 per cent (in US$) 2003 to 2011, and resource exports contributed about 57 per cent of total exports, with iron ore the largest and coal the second largest export. The revenue from mining industries increased from around 6 per cent of GDP in 2000 to 14 per cent of GDP by 2011, with an average annual mining growth of 15 per cent. During that period, the real exchange rate appreciated around 35 per cent (Connolly and Orsmond, 2011).

The literature which focused on the study of the recent mineral boom is Connolly and Orsmond (2011), Sheehan and Gregory (2013), Plumb et al., (2013), Freebairn (2014), Downes et al., (2014). Their papers discussed the impact of the mineral boom on the economy and the structural adjustment process without providing a standard econometric approach. Downes, Hanson and Tulip (2014) estimated the effect of the current mining boom with a large quarterly time-series data of the Australian economy, called 'the Australian Macroeconomic (AUS-M) model', originally developed by the Australian Treasury. Their paper concludes that the de-industrialisation or Dutch disease has not been strong because manufacturing sector benefited from higher demand for inputs to mining sector. They also mentioned that the Australian macroeconomic performance during the decade was much more stable than during the earlier mining boom, reflecting a stronger institutional framework. On the other hand, Dungey et al., (2014), Vespignani (2013), Knop and Vespignani (2014), Manalo et al., (2015), Jääskelä and Smith (2011) applied Structural VAR model on the Australian economy. Dungey et al., (2014) and Knop and Vespignani (2014) studied the effect of the commodity price shock on the aggregate economy and an industry level. Vespignani (2013) showed the impact of monetary policy on an industry level and found that the policy is ineffective for limiting the conditions for the industries in the resource boom.

Manalo et al. (2015) empirically estimated the exchange rate shock on aggregate and industry level. Jääskelä and Smith (2011) investigated the causes of the terms of trade shock. None of these directly studied the Dutch disease in the Australian case.

The sectoral analysis of mining boom dated back from the work by Australian economists Salter (1959) and Swan (1960). Gregory (1976) and Snape (1977) extended Salter-Swan model and analysed the impact of the rise in relative prices on the sectoral level. The most cited paper on Dutch disease proposed by Corden and Neary (1982); Corden (1984) including three sectors – a booming sector, a lagging tradeable sector, and the non-tradeable (service) sector. They systematically analysed the de-industrialisation mechanism of the lagging sector due to resource movement and spending effect. These standard theoretical models of Dutch disease do not account for resource boom caused by commodity price shock, instead of analysing the structural changes of the economy because of mineral discoveries and technological changes.

We shed light on the mining boom shock through the lens of the foreign demand shock, commodity price shock and exchange rate shock. The study of the propagation mechanism of the shocks and their importance for explaining macroeconomic volatility began in the early 20th Century. In 1926 Mathematician Yule, and 1927 Eugen Slutsky described that moving sums of random variables resemble the oscillations of economic time series. In 1933 Frisch extended their research to study the sources of random shocks or causes which are the source of the business cycle. From 1940 to 1970, monetary and fiscal policy shocks were studied with large-scale or single equation models (Ramey, 2016). Kydland and Prescott (1982) integrated the growth models and business cycle theory to study variances, co-variances, autocovariance of real output and set of macroeconomic variables using the U.S post-war quarterly time-series data. The significant contribution of their paper is to incorporate the exogenous technology shock and shock to imperfect indicators of productivity into their model. Sims (1980) revolutionised the analysis of propagation mechanism of shocks. He proposed Vector Autoregressive (VAR) model to study the macroeconomic shocks in the multivariate linear system.

We choose a structural vector autoregressive (SVAR) model for empirical analysis as it identifies the structural shock and defines the actual structure of the economy. The model can analyse the collective dynamic behaviour of the variables and explains how these variables interact. It examines the effect and contribution of purely exogenous shocks to the response of the variables in the system over time. The estimation in the SVAR model presents with the structural impulse response function, variance decomposition and historical decomposition analysis. We identified the shock using short-run Cholesky decomposition, which is making the system recursive.

Our empirical investigation found that the foreign demand shock raised the commodity price to 5.4 per cent, and the price was above the steady-state level for nearly four years. The resource export and non-resource export increased initially, but impulse response declined for both of the variables in the longer horizon. There was a substantial increase in terms of trade, which declined steadily. The change in relative prices caused the real exchange rate to appreciate, and it remained higher over the estimated period. The result from the impulse response function showed that aggregate real GDP is more volatile than sectoral output when the shock hit the economy, and in the more extended horizon impulse responses of the non-mining output and non-tradeable sector output were negative, leads real domestic GDP to falls below the steady-state level. Our estimated 24 periods ahead forecast error variance showed that the foreign demand shock contributed to the 11.65% variance of commodity price, the commodity price shock explains around 40% and 26% of the variation of the real exchange rate and terms of trade respectively. The exchange rate shock attributed 4.33% variation of the aggregate real GDP, 3.16% variation of the non-mining tradeable sector's output, 1.50% variation of the service sector's production and only 0.91% variation of resource sector's output. The historical decomposition of the growth cycle of the variables showed that overseas activity caused Australia's commodity price to surge and export-led resource boom. The rise in terms of trade and sustained appreciation of real exchange rate leads a negative steady-state output gap of the non-resource tradeable sector, non-tradeable sector and aggregate real GDP. However, the growth rate of the mining sector output showed a positive output gap. Our empirical analysis is robust as it is consistent with the literature and theory for providing evidence of the existence of Dutch disease in Australia.

The rest of the thesis has the following structure. In *Chapter Two*, we provide a brief history of the Australian mining sector, and causes, characteristics of mining booms and policies adopted overtime to manage mining boom shock. The discussion about causes, characteristics help us to choose the selection of variables for our applied work; and compare the policy interventions to dampen Dutch disease. In *Chapter Three*, we provide a literature review on Dutch disease and stylised facts of the recent boom and structural composition of the Australian resource sector, non-resource sector and non-tradeable sector. The methodology and identification described in *Chapter Four* and *Five* include empirical model and description of the data. *Chapter Six* reports the results and outlines the sensitivity analysis or robustness checks of the model, and *Chapter Seven* concludes.

Chapter 2

History, Causes, Characteristics, and consequences of the booms

The purpose of this chapter is to provide a comparison of recent (the 2000s) boom in historical perspective. The reason for comparing the five major booms in Australia in retrospective, as it will give us useful insights on how the 2000s boom is different from the earlier booms concerning causes, characters, policy perspective. This discussion guided us to choose key macroeconomic variables for our empirical analysis.

2.1 A Brief History of the mining sector

According to the Australian Bureau of Statistics (hereafter ABS) 'Mining industry' encompasses the industries which are involved in exploring for and extracting non-rural commodities (including coal) and petroleum (oil and gas). The history of mining industry of this country began with the discovery of coal mine in 1788 near Newcastle in New South Wales, followed by the gold discovery in New South Wales in 1823. After the coal and gold discovery, the first metal, 'lead' discovered in South Australia in 1841.[7] Over time, the industry has had its booms and busts. But the industry has been a significant contributor to economic development and growth, especially, from the discovery of gold.

The European settlement and colony started to develop around the mining areas. The discovery of gold in Victoria, particularly at Ballarat and Bendigo in the 1850s, known as 'Gold-rush' made Australia famous for mining. People around the world started to immigrate to Australian colonies, increased population contribute to developing agriculture, industries and infrastructure. Australia started to export coal, lead and gold. By mid-1800s Australia was

[7] Australian Bureau of Statistics (Cataloue no. 8414.0).

producing the world's 40 per cent of the gold. The revenue earnings from exporting coal and lead exceed the export earnings from wool and wheat. Between 1870 to 1900 tin, copper, gold, silver, lead, zinc and Iron ore mines established in Tasmania, Queensland, New South Wales, Western Australia and South Australia.[8]

Even though the continued rise in the value of production, the mining activity in Australia declined from 1900 to 1950. Australia's resurgence of mineral began around 1960 with the aid by information and exploration technology from the Bureau of Mineral Resources (now Geoscience Australia). The new metal – bauxite (the source of aluminium), nickel, tungsten, rutile (the source of titanium), uranium, oil and natural gas discovered. The information technology helped to increase the production of iron ore and other minerals, and Australia became the major exporter of raw materials, especially to Japan and Europe. Australia's research and development on mining-related activities made this country one of the world's leading resource-rich economies. It is the largest producer of refined bauxite gem, industrial diamonds, zircon, lead, tantalum, and mineral sands ilmenite, rutile and the most substantial resources of low-cost uranium. It is the second-largest producer of zinc, the third-largest producer of gold, iron ore and manganese ore, the fourth-largest producer of primary aluminium and nickel, and the fifth largest producer of copper and silver.[9] According to the Geoscience Australia database, the number of operating mines in Australia was 421 in 2015. Among those operating mines, 188 mines are working in Western Australia, 85 in New South Wales, 82 in Queensland, 23 in South Australia, 16 in Victoria, 15 in Northern Territory, and 11 in Tasmania and 1 in Christmas Island (figure 23, in appendix B).

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[8] http://www.australianminesatlas.gov.au/history/

[9] Australian Bureau of statistics (catalogue no. 8414.0)

2.2 Causes of the mining boom

There is no single cause for the recurrence of the mining booms. The main reasons for development in the mining sector include expansion of world economy or development of Australian major trading partners (MTP), global events, the discovery of mines, and technological advancement, and the change in the relative price of the commodity in the world market. The prospecting activity also plays a role; for example, the California gold rush in the late 1840s linked to Australia's gold-rush in 1850s.[10] Australia's economy expanded significantly from 1800 to 1890 because of the development of primary commodities. The boom in the 1850s to 1890s was due to mineral discovery, especially gold and other metals across the country. The economic prosperity due to the exploration of minerals made Australia attractive to foreign investors to invest capital. The availability of international capital to fund for mining investment in the 1890s considered as prospecting activity.

The booms between the 1960s and 1980s were quite broadly based. In the 1960s to early 1970s mining activities in coal, iron ore, oil and bauxite expanded, and in the late 1970s to the early 1980s energy sector, particularly steaming coal, oil and gas industries expanded. The growth in commodities was not the only reason for the 1960s to the early 1980s boom. The development of the international and domestic economy played an important role in increasing the demand for minerals and energy. For example, the industrialisation in Japan required the import of Australian commodities, leads to rising commodity prices, particularly coal, iron ore and bauxite. The oil price shock in the 1970s leads to expansion of the energy sector and energy-intensive activity, mainly steaming coal, oil, gas and smelting aluminium.

[10] See Battellino (2010).

After the 1850s, there was another gold boom that occurred in the early 1980s. Unlike Goldrush, the early 1980's boom was not caused by discoveries of the gold mine. In 1968 the fixed price system of gold had abolished, and most of the old gold mine reopened till 1989. The flexible gold pricing system increases the confidence in re-investing in gold and subsequently increase in price created a boom.[11]

The recent 2000s boom characterised by an increase in foreign demand for Australian minerals, which drives the world commodity prices. Along with dropping import prices translated into a dramatic improvement of the terms of trade. There was not any mineral discovery or technological development related to this boom. Following the example of re-economic development of Japan during the 1960s, the 2000s commodity price boom is related to the urbanisation of Asian countries, especially China. The increase in demand for steelmaking industries in China caused an expansion of Australian bulk commodities, such as coking coal, thermal coal and iron ore. There was also a rise in demand for liquefied natural gas (LNG) as well. The Asian countries proximity to Australia relative to other commodity-exporting countries, for example, Brazil, played a significant role in international trade (for exporting resources). While involving international trade, proximity or distance between the trading nation's matters hugely due to reducing transportation cost. Not only the distance but also the other reasons such as Australia's relative efficient operation in mining, low cost-supply of mine, and Australia's vast reserve of hematite iron ore influenced the commodity trade between China and Australia (Connolly and Orsmond, 2011).

[11] Australian Bureau of Statistics (Catalogue no. 8414.0).

2.3 Characteristics of the mining boom

In this section, we compared the five major booms based on some key features of the mining boom, such as share of labour-capital in the mining production, the share of mining investment on GDP, resource export, and the reason for the end of the boom.

The composition of the share of labour and capital in the mineral production changed a lot from earlier boom's in the 1800s to a later period in the 1900s. The capital-labour share in the mining production is a key factor for the investment decision, employment and the labour movement between sectors. In the late 1800s, a large amount of capital was not required for the production process. The production of the mineral was mainly surface alluvial. Gold mining was primarily executed by Australian abundant and mobile labour. The production of gold was taking place by substantial input of labour and little amount of capital. The share of labour and capital in the production of the mineral has changed from the 1900s. The mining industries in the 1800s was mainly labour intensive, while the booms in the 1900s and 2000s were capital intensive.[12]

From mid-1960 to 1970s, employment grew strongly on an annual average rate of 3 per cent due to massive-scale immigration and an increase in female participation in the labour force. During the 2000s boom, the share of employment in the mining sector was under 1 per cent of total employment, while by the end of the 1st decade of the 2000s the percentage increased to only 1.7 per cent. As the current mining industry share an only very small amount of labour relative to total employment, hence we did not study the labour movement affect in our empirical analysis.

[12] See Battellino (2010).

Though 1850-90s boom considered as one of the largest booms from the perspective of value-added of the mining industry to the national production. But atypical to later booms, the mining investment in 1850-90s was not substantial. One reason could be during that time mining production was labour intensive, and a copious amount of capital investment was not required for the labour incentive production process. Nevertheless, the labour-capital share in the mineral production started to change from the early 1890s, when ample of foreign-owned (particularly England) companies invested capital for Australia's mining exploration. Then the mining investment share raise from about 0.5 per cent of GDP in 1960 to 3 per cent in the early 1970s as a result of the development of the world capital market and technological advancement. The economy was experiencing a surplus in its current account balance from high export prices in the 1960s to early 1970s, but hyper-inflation in the mid-1970s lead investment to a very low level. The mining investment sharply raised in 1981 and 1982, however, the early 1980s mining investment stalled because of global oil price shock. During the current boom, the share of mining investment was 1.5 per cent of GDP and it raised over 4 per cent of GDP by 2009/10 (Battellino, 2010). The investment started to pick up around 2005, but the North-Atlantic financial crisis (in 2007-09) affected the investment and production phase. However, the productive capacity and flexibility of the Australian economy were able to offset the effect of the recession.

The mining investment in the 2000s was significantly more substantial (as a share of GDP) than the previous booms. The gross value added of the mining industry to GDP was higher than all other booms except for the 1980s. The gross value added of the resource sector in 1850-90 was 35 per cent of GDP. But in the recent boom, it was much more substantial in terms of investment, and export revenue. The export revenue uplifted from 6 per cent of GDP in 2000 to 14 per cent by 2009-10 (Connolly and Orsmond, 2011). In the mid-

1800s the mining export value of booming regions (Victoria and New South Wales) raised by a factor of six within 1852-1858, and for the subsequent 18 years, gold export outstrips the export of wool. After the 1890s boom, the economy significantly shifted from wool and grain export and became the leading exporter of metals.

Delving our discussion on the duration of the mining boom reveals that, the 1850s (the gold-rush) boom lasted for about a decade and a half. The late 19th century's boom faced a recession as a consequence of the property bubble burst and associated with the financial collapse in the world market. The downturn leads Australia into a current account deficit, but the economy managed to get to surplus by early 1900s from mining export revenue. The boom in the 1960s/early 70s was linked to Japan's catch up with economic development with other emerging nations. Conversely, the early 1980s boom was short-lived due to global recession and oil price shock, and contractionary monetary and fiscal policy. The 2000s boom was linked to the urbanisation/industrialisation of Asian economies and the boom fade away with the fall in demand for Australian bulk commodities from emerging economies. The influence of world economic conditions and global event on the mining boom is quite evident in retrospect.

2.4 Consequences of the mining boom

In the last section, we discussed that the mining booms are characterised by some demand-side effects, such as a growth in GDP and national income, an increase in import and consumption of service sector, rise in investment and mining export. Besides the demand-side effect, resource movement considered as the supply-side effect of the mining boom. However, the magnitude of the supply-side effect depends on the factor requirements within the sectors. The adjustment of supply-side effect channel through via rising nominal wage rate and domestic inflation and the expansion of resource export translate into an acceleration of terms of trade. The demand-side adjustment takes place through a rise in the exchange rate and inflation.

The consequences of the structural adjustment process of both demand-side and supply effect are Dutch disease or de-industrialisation, lately the 'two-speed economy'. Therefore it is a policy problem, which requires policy intervention to reverse or dampen the de-industrialisation process created by the mining boom. There are few policy differences between the recent and previous boom. The 2000s boom is the first boom after the introduction of labour market deregulation and floating exchange rate.[13] The importance of floating exchange rate on economic adjustment is, when there is an influx of money supply and capital inflow and rise in terms of trade then the nominal and real exchange rate appreciates to cushion the economy and provide more flexibility for adjustment from the shock. The framework for monetary policy, the inflation targeting was first adopted in 1993 by the central bank but formally endorsed by the government in 1996. The goal of inflation targeting is to preserve the purchasing power of the currency by maintaining low and stable inflation and also retain full employment, which requires economic growth on a sustainable path.

Over time various policy interventions took places to manage the Dutch disease, but the structural adjustments resonated through the economy in a disruptive way. The reason

[13] See https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/

for the disruptive outcome will be clear while comparing the policies with the earlier booms and the recent one.

A comparison of the consequences of labour movement effect in the 2000s boom with the earlier booms is very different. The different outcome is particularly obvious in relation to nominal wage and domestic inflation. The growth in the mineral sector impacted the inter-regional migration of labour and international immigration and put upward pressure on wages. For example, during the mid-1800s boom, the labour moved out from non-booming states to booming states (Victoria and New South Wales). The number of male working-age people dropped in South Australia by 3 per cent and Tasmania by 17 per cent. The people from all over the world were settling in Australia. During the gold rush, the number of population trebled within ten years. During 1881 to 1891 people flowed to Western Australia, New South Wales and Queensland from other Australian states. The steady inter-regional labour migration raised Western Australian population from 48,000 to 180,000 and New South Wales (notably Broken Hill) from 6,000 to nearly 20,000. The unemployment rate dropped sharply, and between 1850 and 1853, wages in Victoria increased by 250 per cent.[14] In the 1960s to early 1980s mining boom put upward pressure on nominal wage. For instance, in 1973-74 the growth of nominal wage rate reached 17 per cent and increased nearly up to 30 per cent in 1974-75.[15] The centralised wage-setting system in Australia which introduced in the late 1960s channelled the excess demand pressure into the parts of the economy through accelerating the aggregate wage and inflation. For instance, the money supply trebled in the 1850s. In the early 1970s, the growth of money supply was an annual average rate of over 20 per cent, and the economy experienced hyperinflation. In the early 1980s

[14] See Battellino (2010).
[15] See Banks (2011).

boom economy experienced high inflation as well. On the contrary, the 2000s boom took place under the decentralised wage bargaining system started since in 1986-87.[16] The upward pressure of the wage rate was subdued in recent boom due to the decentralised wage setting, which allowed wages to adjust according to changes in demand and supply in specific sectors, and Australia was able to manage inflation under control.

The current boom is the first in which the Australian central bank adopted a macroeconomic policy 'floating exchange rate' in 1983 and 'inflation-targeting' in 1993. Before that under the fixed exchange rate regime the rise in export and terms of trade adjusted through an appreciation of the real exchange rate via a relative increase in the domestic price level. An appreciation of the real exchange rate reduces the competitiveness of the non-mining trading sectors or de-industrialisation. For instance, during the 1850s the Australian colonial government has little power to take policy actions for controlling the money supply, inflation and the nominal exchange rate, and the consequences was an increase in the real exchange rate 50 per cent. The non-mining sectors faced the difficulty of retaining factor of production and increased input cost. The number of manufacturing industries in New South Wales dropped from 165 in the 1850s to 140 within a few years. The economy suffered from Dutch disease in the late 19th century, and there was a significant effect on the exports of wool and grains. The metal becomes the leading export commodity, and industrial composition shifts significantly during that time.

The share of manufacturing export increased in the first half of the 1900s, but its share declined from around the mid-1960s. However, some policies such as the imposition of tariffs in the 19th century to protect urban industries from the Dutch disease. Similarly, in the 1973

[16] See Coelli, Fahrer and Lindsay (1994).

tariff cuts was introduced to control inflation and import quotas were imposed to protect manufacturing industries and jobs. The policy authority contracted monetary and fiscal policy to offset the high money supply, upward pressure on wage and inflation in the late 1970s/early 1980s and involved the management of the Australian dollar against a trade-weighted index of currencies. The managed exchange rate system was intended to control rising inflationary pressure. But, the appreciation of the exchange rate and contractionary monetary and fiscal policy distorted the economy by high inflation and wage. Following the world economic depression, the Australian economy ended up recession by 1982/83. On the other hand, in the mid-1980s, the depreciation of the Australian dollar made manufacturing industries competitive in the world market, associated with government-industry plans and assistance. The share of manufacturing also raised after the early 1980s mining boom and was uplifted till around 2005, but in the 2000s there was an absolute decline in metal processing, iron and steel manufacturing export. The discussion here, signalling the presence of Dutch disease in Australia in the 2000s boom, which motivated us to investigate the evidence of 'two-speed economy' with an econometric approach. In the next chapter, we discuss the most relevant literature on Dutch disease and stylised facts related to the Dutch disease.

Chapter 3

Dutch disease and Stylised facts of the Australian economy

3.1 Dutch disease in literature

The phenomenon of Dutch disease considered as one of the transmission mechanisms explaining the natural 'resource curse'. Auty (1993) coined the term 'resource curse' for the countries which were gained a windfall from the resource boom in the 1970s but failed to maintain that growth in the long run. In his study, he found that the countries were experiencing high growth from natural resources in the 1970s, were performed poorly in the 1980s. Sachs and Warner (1995, 1999) empirically showed that countries rich in natural resources tend to experience a slower growth rate in the long-run. Their seminal work formed as a near-consensus supporting the existence of a 'resource curse'. The transmission mechanisms identified as causes of resource curse are price effects (Dutch Disease), volatility and institutional degradation.

The term Dutch Disease first mentioned in an article in the Economist (1977) when Netherland's manufacturing sector adversely affected by an appreciation of exchange rate and the discovery of an essential reserve of natural gas in the 1970s. Krugman (1987) described this phenomenon as a disease when the manufacturing sector of a country does not rebound after the resource boom. He described the non-resource sector as dynamic scale economies and has positive externalities, such as learning by doing. Therefore, de-industrialisation of the non-resource sector might be harmful to the whole economy in the long-run.

Dutch disease refers to a situation where export-oriented industries experience boom fuelled by strong demand for resource commodities causes the exchange rate to appreciate. The exchange rate appreciates when the inflow of foreign currency channelled into the domestic economy through export earnings. Appreciation of exchange rate makes import cheaper, which leads non-resource export-oriented industries less competitive.

There is a long history of the study of the Dutch disease, which focused on the sectoral analysis of how a small open economy adjusts to its resource boom. The first sectoral model proposed by the Australian economist's Salter (1959) and Swan (1960). Salter (1959) developed a model with an economy, which total production and total expenditure decomposed into two categories: the traded goods and non-traded goods and examined the balance of payment policy effects on price and spending. He argued that the domestic policies, such as a change in the value of the local currency (devaluation) and deflation do not affect the terms of trade, but other countries domestic policies can affect the terms of trade. Swan (1960) illustrated a model of the economic system with three objectives, which are, internal balance, external balance, and internal price stability. The aggregate volume of demand is measured by domestic and foreign production with the average price level and money, assuming the long-run level of full employment and inflation prevailing in the economy.

The most cited paper on the 'Dutch Disease model' was introduced by Gregory (1976); Corden and Neary (1982); Corden (1984), who extended Salter-Swan two-sector model to three sectors model, such as booming sector, lagging tradeable sector, and non-tradeable sector. Gregory (1976) explained that growth in Australian mineral export affects the balance of payment and cause structural changes in other sectors of the economy. The agricultural and manufacturing industries produce goods for export and compete with imports. His model portrayed that the measurement of structural adjustments between the sectors due to an increase in the balance of payment is equal to the indirect measure of the increase in tariff on them. The model is based on two assumptions, one, Australia cannot influence world prices, and second, the units of exports and imports are chosen in such a way so that the terms of trade at prices is unity. He argued that the impact of balance of payments on the manufacturing and agricultural industries would be similar to the effect of substantial tariff changes. The impact of the rapid growth of mineral exports on the demand and supply price elasticities for rural or non-mining exporting and import-competing industries is double the amount of increase in tariff on those industries in the absence of export mineral growth. The effect of mineral discoveries on import-competing sectors is the same as imposing import subsidy on them. The export and import-competing sectors become less competitive compared to their overseas trading partner due to a change in relative price level through exchange rate and inflation rates. The model estimated that the rise in mineral exports effects as a 25 per cent reduction in imports tariff on the flow of overseas imports, therefore imports rose by 6.5 per cent of the total export. He mentioned that it will be self-defeating if the government want to assist one export or import-competing industry by taxing on other export or import-competing industries.

Corden and Neary (1982) and Corden (1984) systematically analysed the aspects of structural change caused by the mining boom, referred to as Dutch disease in an open economy. They mentioned that in a country, a mining boom could occur any of the following three reasons. The reasons are, the exogenous technological improvement, a discovery of new resources or mine, which can be thought of as an increase in the supply of specific factor, and the third reason is an exogenous rise in the world commodity prices. Their model builds on the assumption that the cause of boom is the Hicks-neutral improvement in technology, rather than the discovery of minerals or a rise in world commodity prices. The traditional manufacturing sector experience pressure of 'de-industrialisation' because of the extractive resource boom. However, they mentioned that the de-industrialisation pressure could occur, where the booming industry is not extractive; for example, old traditional industries replaced by new advanced technology. They analysed the medium-run effects of asymmetric growth of resource allocation and income distribution. That is the effects of the booming sector on the functional distribution of income and the size and profitability of the manufacturing industry. They mentioned there might not be equal distribution of windfall gain among the three industries and hence the welfare of the nation. Among the three sectors, two sectors produce tradeable goods, such as energy and manufacturing goods. Other than traded goods, the domestic economy also produces services or non-tradable. The energy sectors represent a booming sector, or resource sector and manufacturing sector describes a lagging sector. All the tradeable goods are traded at the exogenous world price, assuming the domestic economy have no market power over the traded goods. The price and quantity of non-traded goods are determined by domestic supply and demand.

Corden (1984) mentioned, when an economy experiences an energy boom, either due to the discovery of new mine or technological improvement, then the non-booming sectors negatively impacted via two ways: through resource movement effect and by the spending effect. The resource movement effect occurs when demand for the marginal product of labour is higher in the booming sector causes mobile factor (labour) to move from non-booming sector to the booming sector. In other words, the resource boom causes commodity prices to rise, which encourage investment in the resource sector. The increase in investment and expansion of that sector requires higher labour and hence, their marginal productivity to rise. These cause upward pressure on wages and attracts more labour to move from non-resource sector to the resource sector, owing to the shortage of labour in the non-booming sectors. Corden (1984) called this resource movement effect as 'direct de-industrialisation' in the non-resource tradeable sector. The expansion of the commodity sector through higher investment, the high volume of exports and terms of trade impact aggregate economy positively. The higher income gain from the booming sector leads to extra spending on non-tradable goods and services when the income elasticity of demand for non-tradeable is positive. This additional income can be spent directly by factor owners or indirectly through taxed and government spending, which is positively related to the marginal propensity to consume. The sudden rise in consumption due to extra spending leads to higher demand for services and their wage to go up. A real appreciation of the price of that sector, but the rise in wage in non-tradeable here is not due to the marginal productivity gain. The economy needs adjustment because of spending effects, and the changes channel through the real exchange rate. The increase in relative prices of non-tradeable to tradeable cause an appreciation of the exchange rate, and the real rise exchange rate reduces the competitiveness of the non-mining traded industries. The real exchange rate does not appreciate in case of direct de-industrialisation as it does not involve market for non-tradable. At a constant real exchange rate, when labour moves out from non-tradable to the booming sector, the supply of non-tradeable falls, creates excess demand for non-tradeable. The pressure on demand will be higher due to the spending effect and leads to real appreciation and further labour movement from the lagging sector into the non-tradeable sector. Corden (1984) mentioned the spending effect as 'indirect de-industrialisation' on the lagging industry. He argued that if the booming industry employs relatively less labour in the production process, then the magnitude of adverse resource movement effect will be less, and the size of the spending effect will be higher.

The magnitude of the change of output in the non-tradeable sector depends on both the resource movement effect and spending effect. The resource movement effect might lower production; however, the spending effect will increase production. The resource movement and spending effect has an impact on factor income distribution. Both effects reduce the real rents of a specific factor in the lagging sector. This is the adverse effect of Dutch disease from that factor's point of view, and both effects increase the nominal wage because both effects cause a higher demand for labour. But only the price of non-tradeable (services) rises due to the spending effect. The higher aggregate income creates a higher demand for services. The change of real wage is unambiguous in case of resource movement effect because, moving out of labour from the service sector, reduces supply and hence output falls, which leads to a rise in nominal wage and a real wage. But in the case of the spending effect, output rises in the service sector; hence, real wage falls. Therefore, with the rise in nominal wage in the non-tradeable sector, real wage might fall or rise. Similarly, real rent can be risen or fallen in this sector.

In some cases, especially the oil sector does not require additional mobile factor in their booming periods. In that case, an economy needs to adjust to the spending effect or indirect de-industrialisation through real appreciation. The spending on services will go up initially, and output will be higher than the pre-boom period as the lagging sector produces both non-boom exportable and importable, such as manufacturing and agricultural products. And if the prices of lagging sectors product are not determined by world prices, rather than determined by their domestic supply and demand conditions, then the implications of spending effect on the lagging sector would be same as the service sector, even though they are potentially tradable and locally produce manufactures are close to importable, but they are not perfectly substitute for importable. The binding quantitative restrictions would be beneficial for the lagging sector from spending affect point of view.

Corden (1984) extended the basic model, assuming both labour and capital are mobile between lagging and non-tradeable sectors, but the booming sector has its specific factors of production. Labour is mobile among all three sectors. In this scenario, the results of resource movement and spending effects would be ambiguous, and the result will depend on the share of labour and capital in the production process of the non-boom industries. At a constant real exchange rate, the capital-intensive industry will expand due to the movement of labour out of the mini-Heckscher-Ohlin economy into the booming sector. If the lagging sector is capital intensive, then the resource movement effect will result in the lagging industry to pro-industrialisation. However, the spending effect will offset the pro-industrialisation through real appreciation as both capital and labour will move out from the lagging sector to non-tradeable sector. But overall, the lagging sector could expand if it is capital-intensive. In the case of the non-tradable sector being capital-intensive, then boom could cause real depreciation in the paradox model.

Corden (1984) also incorporate the endogenous terms of trade with the basic model. There are two impacts when the terms of trade are endogenous. One implication is, for a small open economy, the world market determines the price of the booming products, so the domestic country is a price taker. The domestic economy could earn export revenue due to improvement in technology may lower the cost of the booming product. The second implication is regarding the adjustment of the lagging sector with the endogenous terms of trade gain from the boom. The lagging industry produces both importable (which is a perfect substitute for imports) and exportable. If the price of import is considered as numeraire, then the price of export will rise for endogenous terms of trade improvement. The spending effect will raise the demand for exportable at a constant price. The resource movement effect will reduce output in the lagging sector. As spending effect will boost the demand for exportable, and resource movement effect will reduce the production of exportable, there will be a shortage of supply, will cause the rise of the price of exportable and services as well. If the exportable is more capital-intensive compared to importable, then the output of exportable will rise and importable will fall, assuming a constant price of exportable.

Freebairn (2014) provided a model which portrays the long-run responses of the real exchange rate due to mining-related activities in the economy. To show this long-run relationship, he proposes a model of balance of payments and national income identity, which equates the aggregate level of the current account with the foreign capital account and domestic savings and investment. He argued that the mining boom increase net domestic investment and foreign capital inflow of the local economy and causes the exchange rate to appreciate. The response of the exchange rate depends on the sources of the mining boom, and it varies throughout different stages of the mining boom, such as the investment phase and production phase. He also mentioned that the industry characteristics, resident and non-resident investment funds, the share of domestically sourced the investment and the distribution of resource income gain and its expenditure pattern influence the value of exchange rate.

From the above literature review, we could sum up two testable conditions under which we could conclude the evidence of Dutch disease. First, the effect of the exogenous increase in commodity prices. The cause of the surge in commodity prices due to world event or an increase in foreign demand for mineral commodities. The rise in commodity prices channels through the appreciation of the exchange rate. Second, the sectoral structural adjustment due to the commodity price and real exchange rate shock. The sectoral change measured by the difference in the gross value added of the resource sectors, non-resource tradeable and non-tradeable sectors.

3.2 Stylised facts of the Australian economy

3.2.1 The rise in commodity prices in the world market

The evolution of the index of commodity prices (ICP) from the period 1982 to the end of 2018 displayed in figure 2. It is a Laspeyres index, implies that ICP is the weighted average of changes in commodity prices, where the weights reflect each commodity share in export volume. The figure 2 shows that the commodity prices are almost stagnant from1982 to 2002. In the late 1990s the price of base metal, coal and oil were historically low. The downward pressure on prices discouraged investment in commodities and growth of the resource sector.

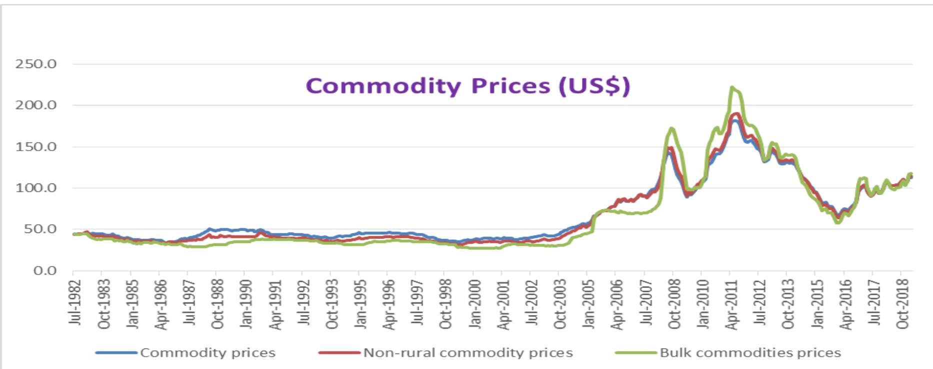

Figure 2: Australian commodity price index
Source: Reserve bank of Australia (Statistical table I2)

From 2003 to 2011, there was a broad-based rise in the index of commodity prices. However, the extraordinary growth came from bulk commodity prices (green line in figure 2). The price of bulk commodities was higher than other non-rural commodity prices. Bulk commodities are consisting of iron ore, metallurgical coal and thermal coal. The expansion of steelmaking industries in Asian countries caused an increase in demand for Australian bulk commodities, especially, iron ore, coking coal and liquefied natural gas (LNG). There was a steady growth in Australian energy commodities as well, such as oil and thermal coal. The share of global energy consumption from emerging economies (especially China, India and the Middle East) increased around 40 per cent in 2000 to over 50 per cent in 2010. The tremendous rise in prices indicated global supply of commodities unable to keep pace with the sudden surge in demand. Also, there was an anticipation error for forecasting China's growth from 1999 through 2007 and an increase in commodity price. The change in demand pattern for Australian commodities, shifted the resource industry to expand towards energy production, and away from metal processing.

According to Connolly and Orsmond (2011), the value of copper ore has started to increase rapidly from 2004, and it became Australia's one of the top ten exported commodities. The price of iron ore has risen at an average annual rate of 23 per cent and the price of coal by about 8 per cent (measured in AUD) throughout 2005 and 2010. Connolly and Orsmond (2011) mentioned the following reasons for this unexpected rise in commodity prices. The reasons are, (1) the Asian financial crisis in the late 1990s and the early 2000s global recession affected the growth rate of several Australian major trading partners, (2) Japan's economic stagnation or lost decade (1991-2000), followed by the Japanese asset price bubble's collapse in the late 1991 and early 1992, (3) the collapse of the former Soviet Union in late 1991, where steel production and energy consumption reduced by more than a third,

(4) the stagnant commodity prices through the 1980s and 1990s discouraged investors form capacity expansion. For this reason, the lack of investment and production capacity couldn't meet that demand when there was a sudden rise in demand for metal and energy making commodities from the Asian emerging countries. The shortage of supply of products caused a rapid increase in their prices. The soaring Chinese demand for steel and energy industry led to significant changes in the commodity markets, especially iron ore and coking coal. The contract prices for thermal coal rise by 70 per cent in 2004, coking coal prices increased by 120 per cent, while iron ore raised 70 per cent in 2005. The market for the commodity was down during the global financial crisis, but shortly after the collapse, there was a substantial rise in the bulk commodity contract prices when the steel and energy demand from China overhauled from the financial crisis.

3.2.2 The rise in commodity export prices

The higher relative commodity export prices increased the value of Australia's resource exports more than 300 per cent (in US$) 2003 to 2011, and resource exports contributed about 57 per cent of total exports, with iron ore the largest and coal the second largest export.

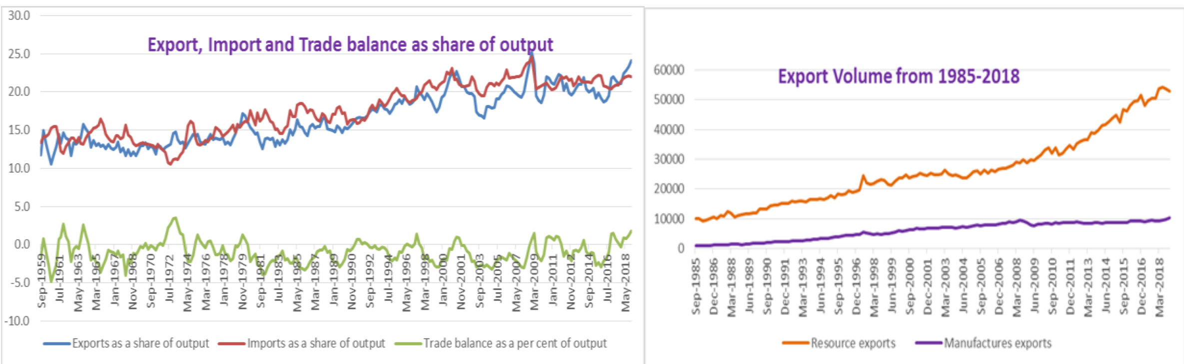

Figure 3: Export, Import and Trade balance share of GDP
Source: Reserve Bank of Australia (Statistical table I1)

In figure 3, the picture on the left represents the export and import as a share of GDP from 1959 to 2018 and the right one shows the volume of resource and manufactured exports over the period of 1985 to 2018. In comparing the export volume between mining and manufacturing industry, we see that from around 2008 to 2018 the time series of manufacturing export volume showing a constant pattern, while mineral showing an increasing trend during the same period. Though the volume of resource export increasing over the period, the overall export share of GDP is volatile.

On the contrary, over the first decade of the 2000s and until 2016, the import share of GDP was higher than the export share of GDP. From around 2016 the export share started to rise more than import. The trade balance was negative from about 2002 till 2008, and it was quite volatile from the period 2009 to 2015, but showing a positive trend since 2016. The rapid growth of the price of iron ore and coking coal triggered the growth of resource export. The increase of commodity prices on an average was 9 per cent (in Australian dollar), but remarkably, the resource export growth was 3 per cent on an average. The increase in resource export contributes to rising in mining investment, revenue and share of employment.

In comparison to previous Australian boom, 2000s boom impacted economy much larger. For example, the revenue from mining industries increased from around 6 per cent of GDP in 2000 to 14 per cent of GDP by 2011, with an average annual mining growth of 15 per cent. In 2000 the investment growth was 1.5, but by the end of 2011, the growth increased to over 4 per cent. In particular, the investment for coal was 8 per cent in 2000 and rose 14 per cent in 2010, and iron ore was 4 per cent in 2000 and went up by 14 per cent in 2010. Following the rise in the contract prices in 2004 and 2005, investment soared at its historical averages as a per cent of GDP. The employment by mining industry was below 1 per cent of total employment in 2000, which raised to 1.7 per cent by the end of the decade, which is considered as the highest employment by the industry in over 50 years. Despite doubling the employment, a strong accumulation of capital stock and resource windfall, the growth of output was only 3 per cent at an annual average. Consequently, the multifactor productivity has dropped from around 2003. The reason behind this was the depletion of lower-graded minerals with a larger share of inputs coupled with higher commodity prices, and the time lag between the investment phase and actual production on resources.

3.2.3 The improvement in the terms of trade

The terms of trade defined as the relative price of exports to imports. In figure 4, we see that the terms of trade began to rise around 2003/04 associated with the rise in commodity price. The terms of trade remained high for a prolonged period, also due to relatively falling import prices.

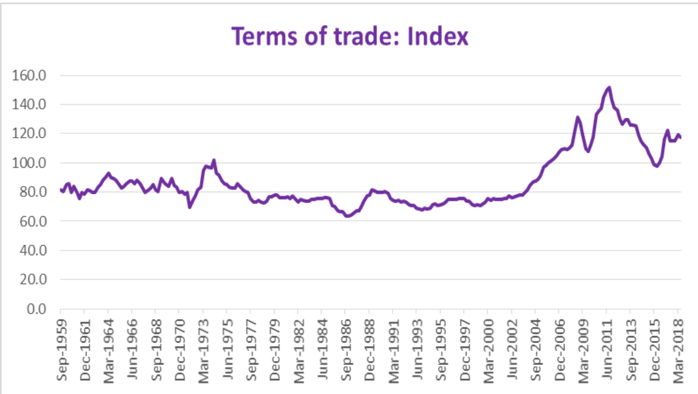

Figure 4: Australian Terms of Trade
Source: Australian Bureau Statistics (Cat. No. 5206.0 Australian National Accounts)

The time trend of Australian terms of trade from 1959 to 2018 shows a tremendous rise in terms of trade around 2003 to 2012. The terms of trade started to decline after 2012, but until 2018 the trend is still higher than the historical average. This upsurge was above the historical standard, sometimes mentioned as 'terms of trade boom'.

3.2.4 An appreciation of the real exchange rate

The real trade-weighted index (RTWI) is the average value of the Australian dollar in relation to currencies of Australia's trading partners adjusted for relative price levels using core consumer price indices (where CPI data available from these countries, if the data are not available then headline measures are used).

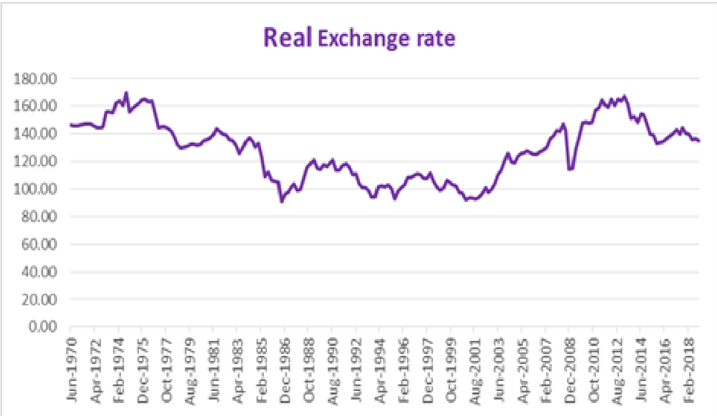

Figure 5: Evolution of Australian real exchange rate since 1970
Source: Reserve Bank of Australia (Statistical table F15: Real trade-weighted index)

Australian real trade-weighted index (we used this RTWI as real exchange rate while estimating econometric model) from 1970 to 2018 presented in figure 5. The real exchange rates appreciated around 35 per cent during the current boom (Connolly and Orsmond, 2011). In the long-run economy experience a compositional shift because of the movement of commodity prices, the terms of trade and the real exchange rate, and the compositional shifts in the economy defined as structural change, measured by the long-run change in sectoral share of output and employment.

3.2.5 Composition of sectoral output and employment

The nature of structural change due to the resource boom is well known, the relative share of the manufacturer and agriculture output and employment decline, with an increasing share of mining output and employment. The sectoral share of industry value-added presented in figure 6. According to growth theories, over the longer-term country's relative share of output and employment in manufacturing and agriculture decline permanently. The mineral and construction experience cyclical fluctuations, but the services sectors will dominant over the other industries with a steady increase in the share of output and employment. The data from Australian Bureau of Statistics (November 2016) provide us evidence of the dominance of Australian service sector accounting for 72 per cent of gross value added of total GDP and 79 per cent of total employment.

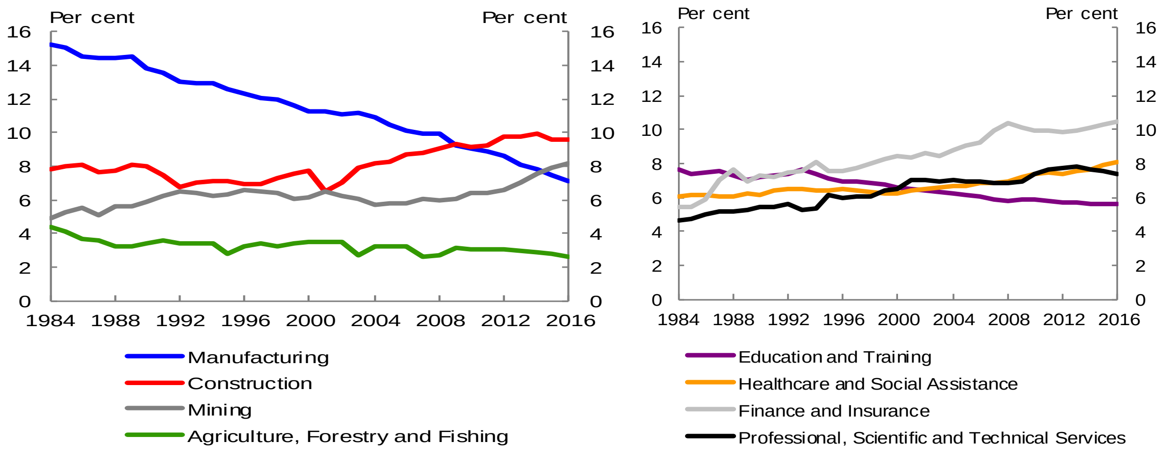

Figure 6: Sectoral shares of industry gross value added
Source: Jones and Tee (2017), ABS Cat. No. 5204.0 (Table 5)

According to the Australian Bureau of Statistics' Industry data 2016-17 (Cat. No. 8155.0), the mining sector showed persistent growth of 38.2% ($23.1b). Coal and metal ore industries contributed to this growth. The growth of export price index for coal mining in 2016-17 was 61.5%, while for metal ore was 22.4%. We mentioned earlier that the allocation of windfall gain has been not equally distributed among states and welfare has not been egalitarian. The Australian states which dominate mining industries are Western Australia, followed by Queensland. The growth of agriculture, forestry and fishing are strong by 8.6% ($7.6b), in contract manufacturing sector growth declined by 3.4% (-$1.2b). The Australian states which produce manufacturing goods are South Australia, followed by Tasmania. The Australian non-tradeable sector or service sector is expanding and plays a vital role in terms of its share of employment, sales and service income and wages and salaries.

Figure 7: Labour employed in different industries (left) and gross value added by industry (right)
Source: ABS Cat. No. 6291.0.55.003 (Table 4) and ABS Cat. No. 5204.0 (Table 5).

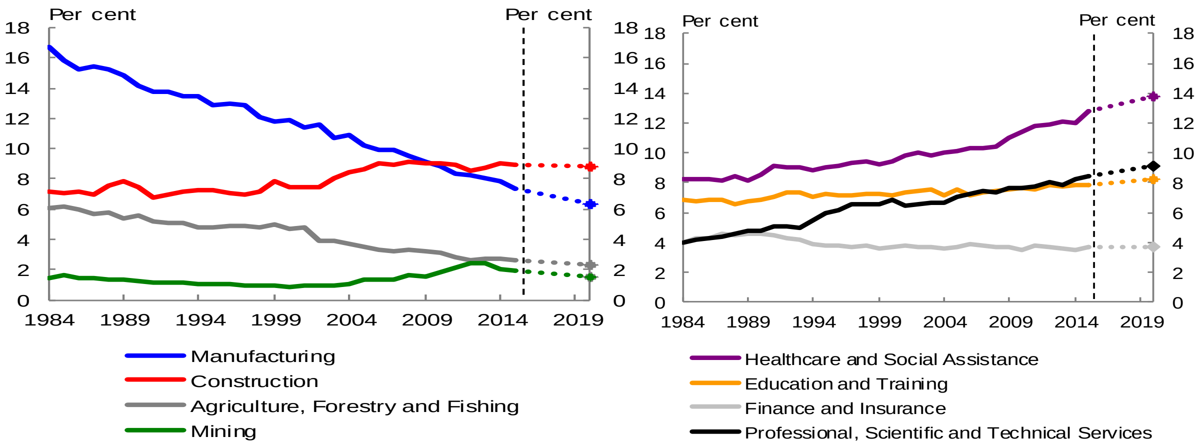

Figure 8: Sectoral share of employment
Source: Jones and Tee (2017)

The Australian states which are showing sustained long-run economic growth are mainly producing services, such as New South Wales, followed by Victoria and Queensland. According to of ABS, at June 2017, New South Wales providing the largest share 33.3% (about 3.6 million population) of national employment, with sales and service income at 32.55 % ($1,002.9b) and wages and salaries at 33.2% ($182.9b) mainly from the service sector. Followed by Victoria 25.9% share of employment (about 2.8 million people), sales and service income 25.1% ($773.3b) and wages and salaries 25.3% ($139.2b), Queensland at 19.3% share of employment (about 2.1 million people), sales and service income 19.2% ($591.7b) and wages and salaries 18.8% ($103.5b). Within the non-tradable sector, the professional, scientific and technical services industry showed long term growth trend of 9.1% ($2.3b) and rental, hiring and real estate service industry 13.2% (% 6.3b).

Chapter 4

Methodology

Professor Christopher Sims introduced the Vector Autoregressive (VAR) models in the paper 'Macroeconomics and Reality' in 1980. Back then, the macroeconomic analysis was involved with large models with many equations and restrictions. The variables of interest were interrelated while studying the business cycle in large-scale macroeconomic models. Sims (1980) argued that the econometric analysis involved analysing the fluctuations of macroeconomic variables are over-identified. He mentioned that large-scale macro-models are useful for forecasting and policy analysis. However, restrictions imposed for identification of the models are not necessary and feasible. As an alternative, he proposed Vector Auto-regressive (VAR) model for macro econometrics analysis. He estimated a six variables dynamic system under the neo-monetarist framework, which implies all cyclical fluctuations of the real variables could be explained by monetary policy shocks. Since then the multivariate simultaneous equations models have been using for dynamic modelling and forecasting in the macro-econometric analysis.

By assumption, the variables in the VAR models are stationary stochastic process without time trend and treat all variables as endogenous. The reason behind for all variables in the model are endogenous instead of exogenous, Sims (1980) mentioned that policy variable is not changed once due to change in policy. The variable instead responds to a rule of systematic change; therefore, the variables are endogenous in the system. He mentioned, however, some variables can be exogenous based on the statistical procedure. The VAR models analyse the stochastic trends and help us to understand the dynamic interaction of multiple time series. It describes, summarises and makes a forecast of the time series, and useful for estimating the causal relationship among the variables, structural inference and policy analysis.

The Cowles Commission defines reduced-form VAR as a model that shows the relationship between endogenous variable to lagged endogenous (predetermined) variables and exogenous variables. They explain the structural vector autoregressive (SVAR) model as similar to reduced-form VAR, and the only distinction is the SVAR allows a contemporaneous relationship between the endogenous variables. Therefore, few variables entered into the SVAR system, compared to the VAR system.

The structural VAR model is a system of 'n' equations where each of the 'n' variables are explained by its own lagged values, plus contemporary and past values of the '$n-1$' remaining variables and the error term. The structural VAR models analyse the structural economic hypothesis. The structural form of the model implies that the parameterisation of the model derives from economic theory and institutional knowledge. The Structural VAR model identifies the structural shocks and defines the real structure of the economy.

The structural shocks by definition distinct from innovation. Innovation is the error from reduced-form VAR, while structural shocks are fundamental exogenous forces, and orthogonal to each other and have economic interpretation. These models estimate the dynamic effects of the structural shocks on a set of macroeconomic variables, and the dynamic interactions of these endogenous macroeconomic variables appear in the model in a system rather than a single equation.

The structural analysis typically proceeds by first specifying, checking and estimating a reduced form VAR. When the VAR is satisfied the checking stage, then stationarity vector autoregressive process can be represented as a moving average process, known as Wold decomposition; and the coefficients of the moving average representation are the responses of the variables contained in the system to impulses in these structural shocks. Then the structural VAR model disentangles the dynamic relationship of the variable by proposing tools such as impulse response analysis, forecast error variance decompositions, and historical decompositions.

The impulse response function (IRF) describes the effect of a shock on the dynamic behaviour of the variables in the sample. In the structural VAR, the impulse response functions used to interpret the economic behaviour of the variables. IRF represents the dynamics response of current and future values of each of the variables in the model due to a one-unit increase in the current value of one of the orthogonal shocks. In the linear VAR model, stationarity assumption satisfies that, holding other shocks constant, a one-unit change in one of the shocks die out in subsequent periods.

The variance decomposition evaluates the importance of each shock in the system by calculating the relative share of variance that each shock contributes to the total variance of each variable. The forecast error variance decomposition investigates the impact of each shock on the variance of each component or structural residual in the certain forecast horizon. In other words, the forecast error variance decomposition quantifies the contribution of the j^{th} shock to the h-step forecast error of the variance of k^{th} variable. Stock and Watson (2001) stated that in forecasting a variable at a certain horizon, the forecast error decomposition quantifies the percentage of the variance of the error made due to a specific shock. Hence, they mentioned forecast error decomposition is comparable to partial R^2 for the forecast error by forecast horizon.

The historical decomposition investigates the contributions of each shock to the observed time series. The historical decomposition represents the relative contribution of the structural shock to the variable throughout the sample period. The time series $y_{k,t}^{j}$ represents the relative contribution of the j^{th} shock to the k^{th} component series of y_t.

4.1 Assumptions

We consider the following assumptions to estimate our empirical model

- **Stationarity of the time-series:** A time series variable x_t is said to be integrated of order d ($I(d)$) if the stochastic trend of the variable x_t can be removed by differencing d times, but differencing $d-1$ times a stochastic trend remained. The variable x_t is $I(d)$ if differencing d times is stationary while differencing $d-1$ times has a stochastic trend. That is, the variable of a time series is assumed to be integrated of order d ($I(0)$).[17] A stochastic process X_t is said to be covariance-stationary if it's first $\left(E(X)\right)$ and second $\left(VCV(X)\right)$ moments exist and are constant over time. Similar to a univariate time-series, if we suppose an $(n\ X\ 1)$ vector time series y_t process of order p of the form

$$y_t = A_1 y_{t-1} + \cdots \ldots \ldots \ldots \ldots \ldots \ldots .. + A_p y_{t-p} + u_t \tag{1}$$

Then the $VAR\ (P)$ is stable if

$$det\, A(z) = det\left(I_n - A_1 z - \cdots - A_p z^p\right) \neq 0\ for\ z \in \mathbb{C}, |z| \leq 1 \tag{2}$$

Here, $\mathbb{C}$ denotes the set of complex numbers. Therefore, y_t is stable or stationary ($I(0)$) if all the roots of the determinantal polynomial are outside the complex unit circle. In other words, all eigenvalues of A lie inside the unit circle or eigenvalues have modulus less than one. When

[17] see Johansen (1995) for formal defination.

VAR satisfy the condition of equation (2), then it is said to be stable and has the time-invariant mean, variance, and covariances, and hence stationary. A stationary $VAR(p)$ process y_t can be represented as the weighted sum of past and present errors, commonly known as Wold representation or moving average (MA) process.[18]

- **Selection of variable:** In structural VAR, the endogenous variables are selected following economic theory, institutional knowledge, empirical evidence. The exogenous variables can be constant, time trends.

- **Linearity:** The non-stationary level data is often transformed into their log levels, log levels, first differences and growth rates.

- **The parsimony of the model and lag order:** The vector autoregressive models are densely parameterised. If the autoregressive lag (p) is extremely short, the model would be poorly specified, and if it (p) is extremely long, too many degrees of freedom will be lost. The number of lags (p) should be sufficient for the errors from the estimation to constitute individual white noises. Therefore, the model needs to be parsimonious. The information-based autoregressive lag-length selection criteria test suggest choosing a parsimonious model.

- **Lag order selection process:** There is a different method of selecting lag order in the VAR model. We decided the lag order of time-series using 'information criteria'. According to Kilian and Lütkepohl (2017) the information criteria have the following general form

$$C(p) = \log(det(\textstyle\sum_{\tilde{e}}(p))) + C_T\varphi(p) \qquad (3)$$

Where, $\hat{e}_t$ is the LS estimated residual of reduced-form VAR, and $\sum_{\tilde{e}}(p) = T^{-1} \sum_{t=1}^{T} \hat{e}_t \, \hat{e}_t'$ is the residual covariance matrix of VAR(p). The function $\varphi(p)$ of the order (p), which penalises

[18] See Hamilton, 1994 for details.

if VAR orders are large, and C_T is the sequence of weights that depend on the sample size. Suppose, N is the number of equations is the VAR, and pN is the number of lagged regressors in each equation. Then in the absence of intercept (or deterministic component) the function $\varphi(p) = pN^2$, and including intercept, we will have $\varphi(p) = pN^2 + N$.

For VAR models, the most commonly used information criteria are the Akaike Information Criterion (AIC), Hannan-Quinn Criterion (HQC), Schwarz Information Criterion (SIC).[19]

Akaike Information Criterion (AIC) is proposed by Akaike (1974).

$AIC(p) = log(det(\sum_e^{\sim}(p))) + \frac{2}{T}(pN^2 + N)$, where, $C_T = \frac{2}{T}$

Hannan-Quinn Criterion (HQC) is suggested by Hanna and Quinn (1979).

$HQC(p) = log(det(\sum_e^{\sim}(p))) + \frac{2\log(\log(T))}{T}(pN^2 + N)$, where, $C_T = \frac{2\log(\log(T))}{T}$

Schwarz Information Criterion (SIC) is named after the work by Schwarz (1978) and Rissanen (1978). As Schwarz (1978) information criteria calculation based on the Bayesian method, therefore, it is also called as Bayesian Informatin Criterion (BIC).

$SIC(p) = log(det(\sum_e^{\sim}(p))) + \frac{\log(T))}{T}(pN^2 + N)$, where, $C_T = \frac{\log(T)}{T}$

Based on the estimated result of the three criteria, the order of VAR is chosen such that the estimator is minimised over the possible orders of $p = 0, \ldots\ldots, p_{max}$. For example, suppose, true lag order is VAR (P_0), provided $P_{min} \leq P_0 \leq P_{max}$. For $T \geq 16$, SIC will be more parsimonious than HQC, and HQC will be more parsimonious than AIC if we have the estimator in the following order $\widehat{P_{SIC}} \leq \widehat{P_{HQC}} \leq \widehat{P_{AIC}}$. However, we can have same order from three estimators.

[19] See Kilian and Lütkepohl (2017).

The Structural Vector Autoregressions system of order (p) is defined as follows (Hamilton, 1994; Kilian and Lütkepohl, 2017, and Ouliaris, Pagan and Restrepo, 2016).

$$A_0 X_t = \; C + A_1 X_{t-1} + \ldots\ldots\ldots + A_p \, X_{t-p} + \; \varepsilon_t \tag{4}$$

Equation (4) can be expressed compactly as following

$$A(L) X_t = \varepsilon_t \tag{5}$$

where, $A(L) = A_0 - A_1 L + \ldots\ldots\ldots + A_p \, L_p$ represents the autoregressive lag polynomial.

A_0, A_1 , ….., A_p are metrics of coefficients. A_0 is a non-singular matrix, summarises the contemporaneous relationships between the endogenous variables in X_t. X_t is a $(n \; x \; 1)$ vector of endogenous variables. $\varepsilon_t \; is \; (n \; x \; 1)$ is independently, identically distributed (*i.i.d)*, a vector of white noise. A stochastic process ε_t is called 'white noise' if the mean $E(\varepsilon_t)$ of ε_t's are zero and has positive definite covariance matrix $E(\varepsilon_t \varepsilon'_\tau) = \; \Omega$.

In SVAR ε_t are the serially uncorrelated vector of structural shocks; i.e. $E(\varepsilon_t) = 0 \; and \; E(\varepsilon_t \varepsilon'_\tau) = \; \Omega \;\; for \; t = \tau$, $E(\varepsilon_t \varepsilon'_\tau) = 0 \quad for \; t \; \neq \tau$. Ω is a symmetric, positive diagonal covariance matrix, contains the variances of the structural disturbances in the diagonal. An $(n \; x \; 1)$ vector of endogenous variables are driven by a $(n \; x \; 1)$ distinct shocks, therefore variance-covariance matrix Ω is of full rank. This assumption rules out the case in which the data generated by economic models have fewer than N structural shocks.

The standard VAR models can be estimated by ordinary least squares (OLS). But the structural VAR equation (4) can't be estimated directly by those methods, because regressors are correlated with errors, and produce inconsistent estimates of the parameters. Therefore, we need to estimate the SVAR model through a reduced-form representation of VAR. The reduced form representation of the corresponding SAVR equation (4) can be obtained by multiplied both sides of the equation by $A_0{}^{-1}$, which uncover the structural shocks and reduced-form VAR as follows

$$X_t = C + G_1 X_{t-1} + \ldots\ldots\ldots + G_p X_{t-p} + e_t \quad (6)$$

where, $G_1 = A_0^{-1} A_1$,

$G_2 = A_0^{-1} A_2$

…. ….

…. ….

$G_p = A_0^{-1} A_p$ and $e_t = A_0^{-1} \varepsilon_t$

The endogeneity problem disappears by imposing restrictions on the contemporaneous dependence of the endogenous variables, and the shocks can be defined as structural shocks. The reduced-form equation (6), requires knowledge of contemporaneous A_0 matrix. The structural impact multiplier matrix A_0^{-1} demonstrate the instantaneous relationship between the variables.

Matrix A_0 relates the non-orthogonal innovation e_t and the structural shocks ε_t as follows

$$e_t = A_0{}^{-1} \varepsilon_t \quad (7)$$

where, e_t is forecast error from reduced-form residual.

The matrix $e_t = A_0^{-1} \varepsilon_t$ express that the mutually correlated reduced-form forecast error is a function of weighted averages of the orthogonal structural shocks (ε_t), with the elements of A_0^{-1} used as weights.

4.2 Identification of the structural shocks

Once we have the reduced-form representation, our next focus is to recover the parameters of A_0 and inverse of A_0 (${A_0}^{-1}$). We will be able to recover the structural representation from the consistent estimates of the reduced-form parameters. We start from the relationship of equation (7) $e_t = {A_0}^{-1} \varepsilon_t$, which follows

$$\sum_e = E(e_t e_t') = A_0^{-1} E(\varepsilon_t \varepsilon_t') A_0^{-1'} = A_0^{-1} \sum_\varepsilon A_0^{-1\prime} = A_0^{-1} A_0^{-1\prime} \quad (8)$$

By assumption as $\sum_\varepsilon = I_N$, hence $\sum_e = A_0^{-1} I_N A_0^{-1\prime}$, therefore, $\sum_e = A_0^{-1} A_0^{-1\prime}$ is a system of nonlinear equations, where A_0^{-1} is unknown parameters. The elements in the variance-covariance matrix are known; hence, the parameters in the matrix will be estimated consistently. So, the equation (9) can be solved for unknown parameters A_0^{-1} using a numerical method. However, the number of unknown parameters in A_0^{-1} might exceed the number of independent equations. We need to impose restrictions on selected parameters of A_0^{-1} to exactly identify the number of independent equations and unknown parameters. The restriction can impose in the form of exclusion restrictions, proportionally restrictions, or other equality restrictions. In the covariance matrix $\sum_e$ there are $\frac{N^2+N}{2}$ number of free parameters which follows that the fact that covariance matrix is symmetric about the principal diagonal. Therefore equation (8) can be represented as a system of $\frac{N(N+1)}{2} = \frac{N^2+N}{2}$ Independent equations. After imposing restriction on A_0^{-1} matrix, we will have $\frac{N(N+1)}{2}$ maximum number of parameters in A_0^{-1} matrix, and equation (9) will be uniquely identified.

In applied work, there are three ways to recover the elements of A_0 matrix or A_0^{-1} matrix. In the first approach, the equation (8) solved by imposing restriction on A_0^{-1} matrix, and normalising $\sum_{\varepsilon} = I_N$, leaving the principal diagonal parameters of A_0 matrix is unrestricted. This implies a unit shock to the structural shocks represents a magnitude of one standard deviation of an innovation. The structural analysis of impulse response functions follows the dynamic response to one-standard deviation shocks. The second approach makes the diagonal elements of A_0 matrix to unity means $e_t = A_0\varepsilon_t$, and leaving $\sum_{\varepsilon}$ matrix unrestricted. This requires imposing $\frac{N(N-1)}{2}$ restriction on A_0 to be just identified, but not counting the unit restrictions on the principal diagonal of A_0. As $\sum_{\varepsilon}$ remain unrestricted in this approach, it is essential for shocks to be rescaled by one standard deviation of the structural error, so that structural impulse responses represent the response to one-standard deviation innovation. The third approach combines the above two approach assuming $A_0 e_t = B\varepsilon_t$. In this approach $\sum_{\varepsilon} = I_N$, and $\sum_e = A_0^{-1}BB'A_0^{-1'}$, allows to relax either $A_0 = I_N \; or \; B = I_N$. By assuming diagonal elements of A_0 are unity and $\sum_{\varepsilon} = I_N$, we need $\frac{N^2+N(N-1)}{2}$ number of restrictions to be placed on A_0 and, including the restrictions of the diagonal component of A_0. On the other hand, the order condition requires $\frac{N^2+N(N+1)}{2}$ restrictions (including the normalised diagonal elements of the metrics), when the diagonal element of both A_0 and B are restricted to unity and $\sum_{\varepsilon}$ remain unrestricted.[20]

4.2.1 Identification by Short-run restrictions

Following the above discussion regarding the approach to impose restrictions on the impact matrix. The popular way to disentangle the structural shocks from reduced-form error by orthogonalise the reduced-form error, which is commonly known as recursive ordering or

[20] See more details about identification methods, Fry and Pagan (2011), Ouliaris, S., Pagan, A. and Restrepo, J. (2016).

orthogonalisation by Cholesky decomposition. Mathematically, let assume D is lower-triangular $(N\ X\ N)$ positive diagonal matrix, such that $DD' = \sum_e$. Mentioned earlier that $\sum_e = A_0^{-1}A_0^{-1'}$, hence assuming $D = A_0^{-1}$ be the solution to recover the structural shocks. D is lower-triangular, which has $\frac{N(N-1)}{2}$ number of zero restriction on the upper triangular, which satisfy the uniquely identifying order condition. As A_0^{-1} is a lower triangular matrix, which follows the fact that A_0 also, a lower triangular matrix and the matrix D is known as the lower-triangular Cholesky decomposition of $\sum_e$. The Cholesky decomposition of $\sum_e$ implies that the structural VAR model is recursive, which means we impose a causal-chain ordering relationship of variables.

Sims (1992) modelled a VAR to trace the effect of monetary policy shock (nominal interest rate) on the other variables in a recursive system from 1958:Q4 to 1991:Q2. He ordered the federal funds rate as a first variable followed by the exchange rate, commodity prices, money supply, consumer price index and industrial production with 14 lags. A shock to the monetary policy variable impacts all other variables contemporaneously. He assumed the non-policy variables are observed with a lag, and the variable is ordered the last is affected by all other variables within the period.

The economically meaningful identifying restrictions can be achieved from the following sources. In a non-recursive identification method, we need a minimum number of restrictions to solve for the parameters of the structural model without any specific order.

- **The economic theory:** The sources of identifying restriction may come from existing economic theory, such as short-run Keynesian model, price-setting equations of demand and supply model, the Philips curve, IS-LM curve, monetary policy rule, Okun's law. For example, Gali´(1992) estimated the dynamic properties of postwar U.S money, interest rate, prices and

GNP times series and identified the sources of four exogenous shocks and their importance for fluctuations of those macroeconomic variables. In macroeconomics the boom and busts, the financial crisis is considered as the short-run study. The policies related to the short-run phenomenon are fiscal policies and monetary policies. Sometimes existing or traditional economic theory may not be available, then identification is achieved by applying insight from the economic theory.

- **Information delays:** Sometimes, the required information or data may not reveal immediately, due to lag or information delay, such as short-run sticky-price assumption. It says that an economic agent does not adjust changes in inflation instantaneously. According to theory, inflation is the percentage change of price level. Therefore, for recursive ordering price should be ordered first, followed by inflation. Sims (1998) argued that monetary policy authority reacts to the variables whose information is available without delay, such as prices, monetary aggregates and interest rate, not to variables such as real GDP.
- **Physical constraints:** The information regarding investment decision, adjustment cost, installing new physical capital do not reveal contemporaneously. These facts are common in macroeconomic modelling. Sims(1998) mentioned that investment, real GDP, industrial production does not react instantaneously to the monetary policy shock.
- **Institutional knowledge:** The source of recursive ordering follows institutional knowledge, such as quantity supply, does not respond immediately to the demand shock, as it takes time for supply product to match with the increased demand. Because, new investment, adjustment cost, transportation cause delay in the production process in the short-run. Blanchard and Perotti (2002) analysed the dynamic effect of shocks in Government spending and tax on U.S real GDP in the post-war period using a semi-recursive method. In

their three variable SVAR model, the fiscal policy shocks were identified using institutional information on public expenditure, tax collection and transfer payment.

- **The assumption about market structure:** While modelling a small open economy, it is common to identify that variables of the small open economy do not affect contemporaneously to the rest of the world. Therefore, the variables of the rest of the world ordered first, followed by domestic variables.
- **Homogeneity of demand functions:** This short-run restriction on demand function assumes that change in prices does not have an instantaneous effect on demand for money, this rule out the assumption the cost of adjustment of holding nominal money (Gali´,1992).
- **Extraneous parameters estimate:** When the variables are in the log, the coefficients have measured the elasticity of the variables. If the parameters in the impact matrix are viewed as elasticity, then the identification restriction can be imposed based on extraneous information (Blanchard and Perotti, 2002).
- **High-frequency data:** Using high-frequency data, such as daily data, rule out the exclusion restrictions, contemporaneous feedback from monthly data.

4.2.2 Identification by long-run restrictions

The identification of structural shock by long-run restriction was first introduced by Blanchard and Quah (1989). They proposed a simple SVAR model to study the effect of aggregate demand and aggregate supply shock on U.S real GDP and unemployment. They assumed that aggregate demand shock does not have a long-run effect on the real GDP, however, aggregate supply shock has a permanent effect on real GDP. Therefore, the idea of long-run restriction is, when the variables are $I(0)$, then they are not-cointegrated, and the shock does not have any long-run effect on the variables. The shock has a permanent effect on the variable when the order of integration is at least $I(1)$ or higher, implies the variables are cointegrated with rank greater than zero. Therefore, the long-run effect of shock demonstrates the vector error correction representation of the VAR model. The effect of structural shock is obtained from MA representation. The parameters of the long-run matrix are identified by imposing exclusion restriction on long-run matrix, and knowledge of the reduced-form VAR model parameters and symmetry of $\sum_e$ covariance matrix.

4.3. Structural Analytical tools

We can identify the structural shocks once A_0 and the covariance matrix is identified. In the following section, we provided a summary of structural VAR analytical tools, such as structural impulse response functions, variance decompositions and historical decomposition.[21]

4.3.1 Structural Impulse Response

The impulse response function allows us to access the response of the variables $x_t = (x_{1,t}, x_{2,t}, \dots, x_{n,t})'$ in the system to a one-time impulse in shocks $\varepsilon_t = (\varepsilon_{1,t}, \varepsilon_{2,t}, \dots \dots ., \varepsilon_{n,t})'$, such that $\frac{\partial x_{t+h}}{\partial \varepsilon_t'} = \Theta_h, \quad h = 0,1,2, \dots \dots \dots ., T$. Here, Θ_h is a $(N \; X \; N)$ matrix. The elements of the matrix for given h are denoted as $\theta_{jn,h} = \frac{\partial x_{j,t+h}}{\partial \varepsilon_{n,t}}$ therefore, $\Theta_h = [\theta_{jn\,,h}]$. If we plot the IRF over the horizon $T + 1$, then the maximum length of the propagation of the shock is given by T, and we will have N^2 impulse response functions. As we have N variables and N structural shocks in the system. Discussed earlier, we identified the structural shocks through reduced-form errors. Hence, structural impulse responses $\theta_{jn,h}$ are the responses of x_{t+h} to

[21] See, Kilian and Lütkepohl (2017) for details about impulse response function, forecast error variance decomposition, and historical decomposition.

corresponding reduced-form error e_t. Thus, in the $VAR(P)$ a one-time impulse to shock e_{nt} in $'h'$ period ago and the response of variable j is given by

$\Phi_h = [\varphi_{jn,h}]$, where, $n = 1, 2, \ldots\ldots, N$ and $j = 1, 2, \ldots\ldots\ldots, N$.

Kilian and Lütkepohl (2017) referred Φ_h as VAR forecast error, or dynamic multipliers, or reduced-form impulse responses. We know that covariance stationary process can be expressed as a weighted average of current and past errors. Hence, if x_t is a covariance stationary then the moving average representation is given by

$$x_t = \sum_{h=0}^{\infty} \Phi_h \, e_{t-h} = \sum_{h=0}^{\infty} \Phi_h \, A_0^{-1} A_0 e_{t-h} = \sum_{h=0}^{\infty} \Theta_h \, \varepsilon_{t-h}$$

The Φ_h or Θ_h are the $(N \, X \, N)$ coefficient matrices of the lag polynomial. In the above equation, with weights Φ_h demonstrate that the more distant a shock lies in the past, the weights in Φ_h decline. Under stationarity, it follows that $\frac{\partial x_t}{\partial \varepsilon'_{t-h}} = \frac{\partial x_{t+h}}{\partial \varepsilon'_t} = \Theta_h$.

4.3.2 Forecast error Variance Decomposition

Assuming at horizon $s = 0, 1, 2, \ldots\ldots, T$ how much of the forecast error variance or the prediction mean squared error (MSPE) of y_{t+h} is attributed by each structural shock $\varepsilon_t = (\varepsilon_{1,t}, \varepsilon_{2,t}, \ldots\ldots\ldots, \varepsilon_{n,t})'$. The forecast error variance decomposes the Θ_h matrix, which we calculated for the impulse response analysis. The forecast can compute recursively. For a $VAR(P)$ process, the s-step ahead forecast error is given by

$$x_{t+s} - x_{t+s|t} = \sum_{h=0}^{s-1} \Phi_h \, e_{t+s-h} = \sum_{h=0}^{s-1} \Theta_h \, \varepsilon_{t+s-h}$$

As $e_t = {A_0}^{-1} \, \varepsilon_t$, we can replace $\Phi_h e_{t+s-h}$ by $\Theta_h \varepsilon_{t+s-h}$

At horizon s the MSPE is given by

$$MSPE(s) \equiv \mathbb{E}\,[\left(x_{t+s} - x_{t+s|t}\right)\left(x_{t+s} - x_{t+s|t}\right)' = \textstyle\sum_{h=0}^{s-1} \Phi_h \sum_e \Phi_h'$$

$$= \textstyle\sum_{h=0}^{s-1} \Theta_h \sum_\varepsilon \Theta_h'$$

$$= \textstyle\sum_{h=0}^{s-1} \Theta_h \, \Theta_h'$$

where $\sum_e \; and \sum_\varepsilon = I_N$ are the variance-covariance matrix of reduced-form error and variance-covariance matrix of structural error, respectively, which is identity matrix by assumption. Let $\theta_{nj,s}$ be the nj^{th} element of Θ_s. Then we can find the contribution of shock j to the MSPE of $x_{nt,}$ $n = 1, 2, \dots \dots, N$ at horizon s as follows

$MSPE_j^n(s) = \theta_{nj,0}^2 + \theta_{nj,1}^2 \dots \dots \dots . + \theta_{nj,s-1}^2$, the total MSPE of $x_{nt,}$ $n = 1, 2, \dots \dots, N,$ at horizon s is

$$MSPE^n(s) = \sum_{j=1}^{N} MSPE_j^n\,(s) = \sum_{j=1}^{N} \theta_{nj,0}^2 + \theta_{nj,1}^2 + \cdots \dots \dots + \theta_{nj,s-1}^2)$$

Dividing both sides of the equation by $MSPE^n(s)$ we have the following decomposition for s and n

$$1 = \frac{MSPE_1^n(s)}{MSPE^n(s)} + \frac{MSPE_2^n(s)}{MSPE^n(s)} \dots \dots \dots \dots \dots .. + \frac{MSPE_N^n(s)}{MSPE^n(s)}$$

The ratio $\frac{MSPE_j^n(s)}{MSPE^n(s)}$ is the fraction of the shock $j's$ attribution to the forecast error variance of variable n, and by multiplying by 100, we have the percentage contribution of the shock to each variable in the system.

4.3.3 Historical Decompositions

The impulse response functions and forecast error variance decompositions represent the average (unconditional expectation) movements in the data. For example, the structural analysis of impulse response and forecast error variance decompositions access the average effect of the commodity price shock to the variability of the real exchange rate over the 2000s but we might interested to know whether the commodity price shock caused the appreciation of real exchange rate between 2004 to 2012. The analysis of historical decomposition quantifies the historically observed fluctuations of the variables in the system due to a given shock. In other words, the historical decomposition plots the cumulative effect of a specific structural shock on each variable at every given point in time. Suppose we have data from 1 to t, then for a covariance stationary VAR the historical decomposition for any t is given by

$$x_t = \sum_{s=0}^{t-1} \Theta_s \, \varepsilon_{t-s} + \sum_{s=t}^{\infty} \Theta_s \varepsilon_{t-s}$$

Here, the value of x_t depends on the estimated shocks $\varepsilon_1, \dots \dots, \varepsilon_t$. For covariance-stationary process, and their moving average die out as we move further into the past, as $t \to \infty$ (t increases) the second term of the equation has a diminishing effect on x_t. After dropping the second term, we only have

$$x_t \approx \sum_{s=0}^{t-1} \Theta_s \, \varepsilon_{t-s}$$

Another way to interpret the historical decomposition is that the cumulative effect of each shock on each variable up to the sample period.

4.4 Strength and weakness of Structural VAR model

There are some strengths and weaknesses of the VAR model. Dungey and Pagan (2000) mentioned that the SVAR model has the advantage to analyse the policy and economic conditions with a set of variables which are required for that specific policy analysis. Unlike the TRYM model which include a large number of variables and strong restrictions on data, while SVAR imposes few restrictions upon dynamics. However, a large number of parameters identified through recursive method sometimes may hard to interpret.

Stock and Watson (2001) assessed how the statistical tool used in VAR able to perform the four macro econometrics tasks, such as describe and summarising time-series data, make a forecast on macroeconomic variables, quantify and analyse the true structure of the economy and advice policy. They argued that VAR is a powerful tool for describing the data and forecasting. However, in econometrics structural inference and policy analysis require proper identification method to separate correlation and causation. The reduced form and recursive VAR address co-movements of the macroeconomic time series and forecast the variables, and the structural VAR quantify the effect of a policy-induced shock. While considering the performance of VAR for describing data as one of the four tasks, the VAR is superior methods for capturing the co-movements of the variables compared to univariate or bivariate models. The standard summary statistics tools, such as Granger-causality test, impulse response functions and variance decompositions which detect the co-movements of the variables. These tests are well-accepted and widely used. However, the tools might provide misleading results while quantifying the standard errors for impulse responses for variables are highly persistent. Another limitation they mentioned for data description that the VAR might miss nonlinearities, conditional heteroskedasticity, drifts and structural breaks without modification. Nonetheless, Sims (1993) observed nine variable in quarterly frequencies for macroeconomic forecasting. He allowed each times series for time-varying variances and autoregressive coefficients and nonnormality of forecast error.

Stock and Watson (2001) mentioned three main criticisms while comparing VAR with other econometric methods. First, in ordinary least square regression model if any variable omitted from the model that include in the error. In standard VAR shocks are related, therefore if any variable omitted then parameters in the VAR reflect omitted variable bias, and lead to bias the impulse response estimates. Second, low-dimensional structural VARs provide instable statistics when estimating the effect of the policy variable. Third, contemporaneous restrictions imposed in the structural VAR sometimes less plausible as it does not consistent with real-time data. For example, GDP and sticky inflation do not respond to monetary policy shock contemporaneously. The assumptions may consistent for a single day, but not consistent over a month or quarter.

Stock and Watson (2001) described VAR as a powerful macro-econometric analysis tool for data description and multivariate benchmark forecasts and can be extended to higher dimensions and nonlinear structures. However, for policy analysis and structural inference depends on institutional knowledge, economic reasoning and identification scheme.

Chapter 5

Empirical Model

Our empirical model consists of two parts. In the first part, we estimated one structural VAR model incorporating multiple production sectors, such as the resource sector, the non-resource tradeable sector, and the non-tradeable sector, and the aggregate real GDP. The system contains eight variables, which observed for 130 periods. There are two blocks in the system, the foreign block (external) includes three variables: The growth rate of Australia's major trading partners (MTP) real GDP (${y^*}_t$), the index of Australian bulk commodity price in $U.S (${P_t}^*$), the terms of trade index (tot_t). The domestic block includes five variables – the growth of Australian real GDP ($y_{a,t}$), the growth rate of value-added output in the Australian resource ($y_{z,t}$), the growth rate of non-resource ($y_{m,t}$), the growth rate of non-tradeable sectors ($y_{n,t}$), and the Australian dollar trade-weighted exchange rate index (r_t).

In the second part, we extended the model following Manalo et al. (2015). They estimated the SVAR model with seven variables. Among seven variables, domestic economic activity measured by Australian real GDP and industrial production. They estimated a separate SVAR for each industry and excluded industrial production from the system when they included aggregate real GDP measure. We compiled the industrial output data and categorised them into three sectors. Hence, we modelled three SVAR, each contains one sector to represent domestic sectoral economic activity, and the fourth SVAR include aggregate real GDP and excluded sectoral productions. The reason behind to extend the model is, we were interested to see how the growth rate of aggregate real GDP and growth rate of sectoral output behave separately in the system due to the structural shocks. The other reason was, the separate SVAR allowed us to incorporate more variables in the system, such as inflation, monetary policy variable, resource export and non-resource export. Each SVAR contains eight variables and observed for 130 periods. The recursive method of identification has applied to identify structural shocks based on economic theory and stylised facts. The choice of variables and identification method followed from the following literature.

5.1 Literature on Structural VAR model on the Australian economy

The essays on recent resource boom with the application of Structural VAR model, include Dungey and Pagan (2000, 2009), Dungey, Fry-McKibbin and Linehan (2014), Knop and Vespignani (2014), Vespignani (2013), Jääskelä and Smith (2011), Manalo, Perera and Rees (2015), Dungey et al., (2017).

Dungey and Pagan (2000) considered as one of the earliest works on the SVAR model in the Australian context. Their model captures eleven variables, which includes foreign output, the terms of trade, foreign and domestic asset prices, foreign real interest rates, exports, domestic output, aggregate demand, inflation, a monetary policy instrument, and a real exchange rate. The variables were estimated over the period of 1980:Q1 to 1998:Q3. They assume all the variables have stable root, and shocks are persistent rather than permanent. If the shocks show permanent behaviour, they argued that would have captured in the impulse response functions. While estimating structural equations in the system, they eliminated a variable and all of its lags when the presence of the variable is not necessary for a particular equation. The system is block recursive between the foreign variables and domestic variables, implies domestic variables were not contemporaneously affected the external variables. They estimated the model with VAR (3) identified with the recursive method and also imposed some restrictions upon the lag structure of the specific variables. Their results demonstrate the impulses of the real variables in the Australian economy over time due to eleven shocks. Their model features, including more foreign variables and asset markets. The estimated historical decompositions from 1980 to 1997 showed that overseas activity and capital market plays a vital role in the growth cycle of Australia.

Dungey et al. (2014) examined the impact of Chinese resource demand shock on Australian macroeconomy. They found that the shock increased the price of Australian mineral commodities, mining investment, resource export and gross value added of the mining industry, but in the long-run real GDP declined. They noted that Australia has some market power as a natural resource supplier. They provide insight into the resource movement from non-mining sectors to resource sector caused the reduction of domestic output. But they did not empirically estimate the presence of Dutch disease, because they did not examine the sectoral adjustment. They estimated the SVAR with nine endogenous variables with quarterly data from March 1988 to June 2011 for $T = 94$. It has two blocks, an external block and domestic block. There are four endogenous variables in the foreign block, such as Chinese resource demand, real commodity prices, foreign output and the real value of Australian resource exports. The domestic module includes five variables, such as mining investment, domestic production, the inflation rate, the cash rate and the real exchange rate. They constrained the sample starting period from 1988 because the mining investment data series is available from 1988. The sample end period is consistent with Jääskelä and Smith (2011).

Following Dungey and Pagan (2000, 2009) the non-stationary series were linearly de-trended and expressed in logarithm in their paper. The structural shocks were identified by placing restrictions informed by economic theory on the contemporaneous structural parameters. They analysed the results by calculating impulse response functions of the shocks and through variance decompositions of the variables in the system.

Manalo, Perera and Rees (2015) investigated the effect of movement of the real exchange rate on the aggregate and industry level. They found that a 10% appreciation of exogenous real exchange rate (unrelated with commodity price and interest rate differentials) decreased the real GDP by 0.3% and inflation by 0.3 percentage points within one to two years after the shock. At the industry level, the gross value added of some industry is more sensitive to real exchange rate than the others. The output of the mining, manufacturing, personal services, construction and business services are more effective to the movement of the real exchange rate. Their model consists of seven variables observed from the period 1985: Q1 to 2013: Q2. In their model, the foreign block includes US real GDP and Australian terms of trade. The domestic block includes aggregate real GDP, trimmed mean inflation, the cash rate, the real trade-weighted index and a measure of sectoral production (gross value added of industries). For each sector of the economy, they estimated a separate VAR, and also a SVAR at an aggregate level. While calculating the aggregate model, they exclude the measures of industrial production.

Knop and Vespignani (2014) and Vespignani (2013) developed the SVAR model in different industries. Vespignani (2013) and Knop and Vespignani (2014) followed the same method for constructing SVAR. They created two variables, one a non-farm GDP as a measure of Australian real GDP (denoted by $AGDP_{-it}$) and the second variable is the real gross value of industry i (denoted IND_{it}). The idea is that the sum of $AGDP_{-it}$ and the IND_{it} will be the total Australian non-farm real GDP when evaluating each industry. Knop and Vespignani (2014) examined the effect of commodity prices on nominal and real gross value added and profits on different industries in Australia from March 1993 to March 2013 using quarterly data ($T = 81$). The foreign block includes three exogenous variables, such as world real GDP in U.S dollars, a world inflation rate and a world interest rate. The domestic module includes the real Australian GDP, the gross value added of each industry, inflation rate, the cash rate and the trade-weighted index. For robustness check, they replaced real GVA IND_{it} by industry profit before income tax and nominal GVA $NIND_{it}$ one at a time. They extended the model by disaggregating commodity price indices into bulk commodity prices, base metals and rural commodity and investigated the impact of three different commodity price shocks on the industry level. They found that the commodity prices have a significant positive effect on the gross value added and profits of the mining sector in the short run. But in the long-run nominal GVA of mining sector decline. They argued that the extraction of mineral activity raised due to sudden rise in commodity prices. As the mining sector operates in full capacity, the extraction work requires an immediate increase in demand for a factor of production, such as labour. The higher demand for labour causes their wages to rise, hence an increase in the cost of production. So, mining GVA declined in the long run. The rise in commodity price had a positive spillover on the construction industry due to an increase in demand for mining-related construction, but the gross value-added, and profits decline significantly due to the commodity price shock.

Vespignani (2013) analysed the impact of monetary policy shock on Australian six major industries. He showed that an anticipated increase in cash rate significantly reduce the gross value added of manufacturing and construction. However, the gross value added of the industries which are less sensitive to change in interest rate is unaffected by those shocks.

5.2 Data Description

We estimated the model using seasonally adjusted data at quarterly frequencies from 1984: Q1 to 2016: Q4. The variables observed for a total of 130 quarters. The model includes two blocks of variables, foreign block (F_t) and domestic block (D_t). We added three variables in the international module, such as the growth rate of Australia's major tradeing partners (MTP) real GDP (y^*), the index of Australian bulk commodity prices in $U.S ($p^*$), and the index of terms of trade. On the other hand, in the extended part of the empirical model the foreign sector variables include four variables, the growth rate of Australia's major tradeing partners (MTP) real GDP (y^*), index of Australian non-rural commodity price in $U.S ($p^*$), the growth rate of resource export (z^x) and the growth rate of non-resource export (m^x). The index of non-rural commodity prices includes the price of base metals, bulk commodities, other resources, and the index of bulk commodities include prices of iron ore, metallurgical coal, and thermal coal.[22] The Reserve Bank of Australia measured the price for the commodities using the average export values in 2015/16 and 2016/17. They updated the price measured based on average export values each year, say 2016/17 and 2017/18.[23] We estimated the model using the index of non-rural commodity prices and index of bulk commodity prices, with a different measure of units, such as $U.S, $ AUS and Special Drawing Right (SDR).[24]

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[22] https://www.rba.gov.au/publications/bulletin/2013/mar/pdf/bu-0313-3.pdf
[23] https://www.rba.gov.au/statistics/frequency/weights-icp.html
[24] SDR – Special Drawing Right. Used as an international reserve asset to settle transactions between countries and help balance international liquidity. The value of the SDR is calculated by the International Monetary Fund (IMF) on the basis of a weighted basket of five currencies: US dollar; European euro; Chinese renminbi;

However, our results did not vary for different measurement of units of the index of commodity prices.

The variable MTP RGDP calculated manually by aggregating the RGDP of Australia's major trading partners, which entered into the system as quarterly percentage changes. To capture the major trading partners GDP growth on the Australian economy, the foreign output calculated by aggregating 17 Australia's major trading partner's countries, plus aggregating 19 countries from European Union from 1983 to 2018. The real GDP of the countries measured in output-side real GDP at chained PPPs (in mil. 2011US$) collected from the Pen World Table 9.0 (Feenstra, Inklaar and Timmer, 2015) in levels. The real GDP measure for Australia's major trading partner is weighted by the average trade weights. In theory, the trade weights should change each year. Therefore, we averaged the trade weights for 1983 and 1984 to weight 1984 real GDP, the average trade weights from 1984 and 1985 to weight the real GDP of 1985 and so on. Before the formation of the European Union, the trade weights have collected from Germany and France's trade-weighted index.[25] Finally, we expressed the Australian major trading partner's real GDP level data in their growth rate.

The domestic block include a measure of Australian economic activity $y_{j,t}$; $j = \{a, z, m, n\}$, were, the growth of Australian real GDP ($y_{a,t}$), the growth rate of value-added output in the Australian resource ($y_{z,t}$), the growth rate of non-resource ($y_{m,t}$), the growth rate of non-tradeable sectors ($y_{n,t}$). The value-added in the non-resource tradeable output calculated by aggregating the output of agriculture, forestry, fishing, and manufacturing industries. The value-added output in the non-tradeable sector calculated by aggregating

Japanese yen; and UK pound. The IMF publishes the value of the SDR each day in terms of US dollars and the Reserve Bank of Australia provides an equivalent value in Australian Dollars.

[25] https://www.rba.gov.au/statistics/frequency/twi/twi-20171130.html

production of electricity, gas, water and waste services, construction, retail trade, information media and telecommunications, financial and insurance services, rental, hiring and real estate services, professional, scientific and technical services, administrative and support services, public administration and safety, education and training, health care and social assistance, arts and recreation services, other services, and ownership of dwellings industries.

The resource export (z^x) data is available from 1985:Q3. In the SVAR literature, including real GDP, inflation, interest rate, and the real exchange rate are standard. The CPI trimmed mean inflation is used for inflation (π). The inflation rate is the objective of monetary policy in Australia in the inflation target. The overnight cash rate is used as the interest rate variable (i). The cash rate is the main monetary policy instrument since the floating of the Australian dollar has been adopted in December 1983. Australian dollar trade-weighted exchange rate index, adjusted for relative consumer price levels used as the real exchange rate variable (r).[26] Australia is a small open economy, fluctuations of Australia's major trading partner's real GDP have an impact on the Australian business cycle and also the demand-side effects of foreign economic growth has a relationship with foreign interest rate and inflation. The foreign interest rate and inflation may have an impact on the value of Australian real exchange rate through an uncovered interest rate parity condition.[27]

[26] A description of the data series used in estimation are reported in appendix A.
[27] Dungey and Pagan (2000, 2009) used US real GDP as foreign output. Manalo et al (2015) used US real GDP as world output and mentioned it is ideal to add foreign interest rate and inflation as foreign variables. Dungey et al (2014) used Reserve Bank of Australia's Index of Commodity Price in US dollars as the real commodity price variable. Dungey and Pagan (2009) and, Dungey et al (2014) use Australian exports as a foreign variable.

5.3 Model checking

Before estimating the SVAR, the model needs to pass some underlying assumptions mentioned in section 4.1. We conducted the unit-root test for the stationarity of the time-series, stability of VAR, linearity of the variables, selection of lag-length. The model was estimated following Ouliaris, S., Pagan, A. and Restrepo, J. (2016) using statistical package Eviews 10.

The stationarity test of the time series was conducted through the Augmented Dickey-Fuller test (ADF) test, the Phillips–Perron test and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test. We conducted an additional unit-root test for considering the existence of endogenous structural break in the series. The Breakpoint unit root test has done by applying the Zivot-Andrews test. The results from the test found that the series are *I(0)* or stationary. The results of the unit-root test are presented in appendix C. Most of the variables were expressed as growth rate, and the time series of growth rates are stationary. The non-stationary time series were transformed into their first differences. The Schwarz- Information Criteria (SIC) autoregressive lag length specification test suggests to choose lag 'one'. Hannan-Quinn Criterion (HQC) and Akaike Information Criterion (AIC) and Future Prediction Error suggest choosing lag 'two', and the likelihood ratio test suggests choosing 'six'. Based on the autoregressive lag specification test results, we choose lag two. The autoregressive root test confirms the VAR (2) is stationary as the roots of the characteristic polynomial >1 or eigenvalues are <1 in absolute value. The test results are presented in Appendix C.

5.4 Model Setup and identification

Following the SVAR literature in section 5.2, we include two blocks of structural equations, foreign block (F_t) and domestic block (D_t). The variables of the small open economy do not influence the variables of the rest of the world, and the domestic variables will be absent from the foreign equations in the contemporaneous matrix. The structural equations with the external variables will be ordered first, followed by variables in the domestic block (Dungey and Pagan, 2000). Hence, we modelled two sets of the vector of variables categorised as variables in the external block and variables in the domestic block. While modelling SVAR, Jääskelä and Smith (2011), Vespignani (2013) and Knop and Vespignani (2014), Dungey et al., (2014), Manalo et al., (2015), Dungey et al., (2017) used two blocks of variables. Australia is a small open economy, and therefore it does not affect foreign variables contemporaneously but maybe with lags as a commodity-exporting country might have some market power in the resource sector by increasing domestic cost (Dungey et al., 2014).

Among the external variables, the growth rate of Australian major trading partner's real GDP appeared as a first structural equation. The purpose of ordering the foreign output as the first variable was to capture the economic activity of the Australian major trading partner and to portray the stylised fact that the international demand had a flow-on influence on the commodity prices, exports and the terms of trade. The index of commodity prices ordered as a second variable, and the index of terms of trade appears as the third variable. We excluded the terms of trade variable from the extended model, instead included resource export and non-resource export as third and fourth variable respectively in the foreign block. Manalo et al., (2015) included terms of trade in the international block to capture the effect of commodity prices on Australian export. Their study showed a close relationship between the terms of trade and the exchange rate. Dungey et al., (2014) included resource export explaining that the commodity prices have a significant effect on Australian volume of resource export. In addition to resource export, the inclusion of non-resource export was to capture the impact of commodity price shock and exchange rate shock on the volume of non-resource export.

Our ordering of vector of variables representing the Australian economy $D_t = (y_{z,t}, y_{a,t}, y_{n,t}, r_t, y_{m,t})$ following the models of Dungey et al.,(2014) and Manalo et al.,(2015). We ordered resource GVA as first variables followed by aggregate real GDP. Dungey et al., (2014) modelled Australian mining investment as the first variable and real GDP as a second variable in the domestic module. They considered the mining GVA and mining investment to capture the impact of the external factor on the resource sector. However, their paper included mining investment, not the mining GVA. The order of the rest of the variables $(y_{n,t}, r_t, y_{m,t})$ follows from Corden (1984). He argued the magnitude of the spending effect would be higher when the booming sector comprises less share of labour. The growth in the resource sector will lead to higher aggregate income, which will increase the demand for service. Initially, the output in the service sector will rise and may raise the production of the non-mining sector, but the rise in nominal wage may reduce real wage and real rent, and appreciation of real exchange rate. In chapter two and three we mentioned that the labour share in the Australian mining industry is less than 2%. So, we ordered the variables to understand the dynamics of the spending effect on the economy. We ordered the non-tradable sector after aggregate GDP by assuming the service sector will react immediately due to higher GDP. To capture the real appreciation and in-direct industrialisation, we ordered the non-resource tradeable sector as the last variable assuming it is affected by all other variables contemporaneously.

The vector of Australian variables in the extended model $D_t = (y_{j,t},\ \pi_t,\ i_t,\ r_t\ )$ where, $j = \{a,\ z,\ m,\ n\}$. The first variable in this block was a measure of economic activity. We examined four measures of activity are: (i) the growth of aggregate GDP, (ii) the growth of value-added output in the Australian resource sector, (iii) the growth of value-added output in the Australian non-resource sector and (iv) the growth of value-added output in the Australian non-tradeable sector. For each measure of economic activity, we estimated a separate SVAR which alluded earlier. The trimmed mean CPI inflation ordered as the sixth variable in the system, the overnight cash rate as the seventh variable, and the real exchange rate as eight variable. The ordering is consistent with Jääskelä and Smith (2011), Vespignani (2013) and Knop and Vespignani (2014), Dungey et al., (2014).

The empirical model of VAR(2) takes the following matrix form before imposing restrictions on the impact matrix.

$$\begin{bmatrix} a_{11}^0 & a_{12}^0 & a_{13}^0 & a_{14}^0 & a_{15}^0 & a_{16}^0 & a_{17}^0 & a_{18}^0 \\ a_{21}^0 & a_{22}^0 & a_{23}^0 & a_{24}^0 & a_{25}^0 & a_{26}^0 & a_{27}^0 & a_{28}^0 \\ a_{31}^0 & a_{32}^0 & a_{33}^0 & a_{34}^0 & a_{35}^0 & a_{36}^0 & a_{37}^0 & a_{38}^0 \\ a_{41}^0 & a_{42}^0 & a_{43}^0 & a_{44}^0 & a_{45}^0 & a_{46}^0 & a_{47}^0 & a_{48}^0 \\ a_{51}^0 & a_{52}^0 & a_{53}^0 & a_{54}^0 & a_{55}^0 & a_{56}^0 & a_{57}^0 & a_{58}^0 \\ a_{61}^0 & a_{62}^0 & a_{63}^0 & a_{64}^0 & a_{65}^0 & a_{66}^0 & a_{67}^0 & a_{68}^0 \\ a_{71}^0 & a_{72}^0 & a_{73}^0 & a_{74}^0 & a_{75}^0 & a_{76}^0 & a_{77}^0 & a_{78}^0 \\ a_{81}^0 & a_{82}^0 & a_{83}^0 & a_{84}^0 & a_{85}^0 & a_{86}^0 & a_{87}^0 & a_{88}^0 \end{bmatrix} \begin{bmatrix} y_t^* \\ p_t^* \\ tot_t \\ y_{R_t} \\ y_{a_t} \\ y_{n_t} \\ r_t \\ y_{m_t} \end{bmatrix} = \begin{bmatrix} a_{11}^1 & a_{12}^1 & a_{13}^1 & a_{14}^1 & a_{15}^1 & a_{16}^1 & a_{17}^1 & a_{18}^1 \\ a_{21}^1 & a_{22}^1 & a_{23}^1 & a_{24}^1 & a_{25}^1 & a_{26}^1 & a_{27}^1 & a_{28}^1 \\ a_{31}^1 & a_{32}^1 & a_{33}^1 & a_{34}^1 & a_{35}^1 & a_{36}^1 & a_{37}^1 & a_{38}^1 \\ a_{41}^1 & a_{42}^1 & a_{43}^1 & a_{44}^1 & a_{45}^1 & a_{46}^1 & a_{47}^1 & a_{48}^1 \\ a_{51}^1 & a_{52}^1 & a_{53}^1 & a_{54}^1 & a_{55}^1 & a_{56}^1 & a_{57}^1 & a_{58}^1 \\ a_{61}^1 & a_{62}^1 & a_{63}^1 & a_{64}^1 & a_{65}^1 & a_{66}^1 & a_{67}^1 & a_{68}^1 \\ a_{71}^1 & a_{72}^1 & a_{73}^1 & a_{74}^1 & a_{75}^1 & a_{76}^1 & a_{77}^1 & a_{78}^1 \\ a_{81}^1 & a_{82}^1 & a_{83}^1 & a_{84}^1 & a_{85}^1 & a_{86}^1 & a_{87}^1 & a_{88}^1 \end{bmatrix} \begin{bmatrix} y_{t-1}^* \\ p_{t-1}^* \\ tot_{t-1} \\ y_{R_{t-1}} \\ y_{a_{t-1}} \\ y_{n_{t-1}} \\ r_{t-1} \\ y_{m_{t-1}} \end{bmatrix} +$$

$$\begin{bmatrix} a_{11}^2 & a_{12}^2 & a_{13}^2 & a_{14}^2 & a_{15}^2 & a_{16}^2 & a_{17}^2 & a_{18}^2 \\ a_{21}^2 & a_{22}^2 & a_{23}^2 & a_{24}^2 & a_{25}^2 & a_{26}^2 & a_{27}^2 & a_{28}^2 \\ a_{31}^2 & a_{32}^2 & a_{33}^2 & a_{34}^2 & a_{35}^2 & a_{36}^2 & a_{37}^2 & a_{38}^2 \\ a_{41}^2 & a_{42}^2 & a_{43}^2 & a_{44}^2 & a_{45}^2 & a_{46}^2 & a_{47}^2 & a_{48}^2 \\ a_{51}^2 & a_{52}^2 & a_{53}^2 & a_{54}^2 & a_{55}^2 & a_{56}^2 & a_{57}^2 & a_{58}^2 \\ a_{61}^2 & a_{62}^2 & a_{63}^2 & a_{64}^2 & a_{65}^2 & a_{66}^2 & a_{67}^2 & a_{68}^2 \\ a_{71}^2 & a_{72}^2 & a_{73}^2 & a_{74}^2 & a_{75}^2 & a_{76}^2 & a_{77}^2 & a_{78}^2 \\ a_{81}^2 & a_{82}^2 & a_{83}^2 & a_{84}^2 & a_{85}^2 & a_{86}^2 & a_{87}^2 & a_{88}^2 \end{bmatrix} \begin{bmatrix} y_{t-2}^* \\ p_{t-2}^* \\ tot_{t-2} \\ y_{R_{t-2}} \\ y_{a_{t-2}} \\ y_{n_{t-2}} \\ r_{t-1} \\ y_{m_{t-2}} \end{bmatrix} + \begin{bmatrix} \varepsilon_{y_{F,t}^*} \\ \varepsilon_{p_t^*} \\ \varepsilon_{tot_t} \\ \varepsilon_{y_{R_t}} \\ \varepsilon_{y_{a_t}} \\ \varepsilon_{y_{n_t}} \\ \varepsilon_{r_t} \\ \varepsilon_{y_{m_t}} \end{bmatrix}$$

The structural model consists of more parameters to be estimated than reduced-form VAR model. We identified the structural parameters through Cholesky decomposition or recursive ordering. To exactly identify the model in the recursive system requires the imposition of restriction on A_0 matrix implies restriction should be placed on ${A_0}^{-1}$ matrix, i.e. ${A_0}^{-1}$ has zeros above the diagonal. So, ${A_0}^{-1}$ matrix is a lower triangular matrix. The matrix ${A_0}^{-1}$ can be decomposed into two triangular factors, known as Cholesky factors of the variance-covariance matrix. After imposing restrictions, we have the following form of the matrix.

$$A_0 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21}^0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{31}^0 & a_{32}^0 & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{41}^0 & a_{42}^0 & a_{43}^0 & 1 & 0 & 0 & 0 & 0 \\ a_{51}^0 & a_{52}^0 & a_{53}^0 & a_{54}^0 & 1 & 0 & 0 & 0 \\ a_{61}^0 & a_{62}^0 & a_{63}^0 & a_{64}^0 & a_{65}^0 & 1 & 0 & 0 \\ a_{71}^0 & a_{72}^0 & a_{73}^0 & a_{74}^0 & a_{75}^0 & a_{76}^0 & 1 & 0 \\ a_{81}^0 & a_{82}^0 & a_{83}^0 & a_{84}^0 & a_{85}^0 & a_{86}^0 & a_{87}^0 & 1 \end{bmatrix} \text{ and } B = \begin{bmatrix} \sigma_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \sigma_2 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \sigma_3 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma_4 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \sigma_5 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \sigma_6 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \sigma_7 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \sigma_8 \end{bmatrix}$$

When the contemporaneous matrix A_0 normalized to have ones on the diagonals, implies that every equation in the system has a dependent variable and every shock ε_{it} has a variance of ${\sigma_i}^2$. When the system is recursive implies there is a sequential change of movement of the variable in the timeline of the event. The variable which is placed first affects the economy first and is not contemporaneously affected by the variables which are ordered lower, but it may be affected by the other variables with lags. When shocks hit the economy, the magnitude of the contemporaneous effects of the variable depends on the size of coefficients in the ${A_0}^{-1}$ matrix.

The linear relationship between A_0 matrix, structural shocks and forecast error, which is defined as, $e_t = {A_0}^{-1}\, u_t$ are represented in the following matrix.

$$\begin{bmatrix} e_{y^*_{F,t}} \\ e_{p^*_t} \\ e_{tot_t} \\ e_{y_{r_t}} \\ e_{y_{a_t}} \\ e_{y_{n_t}} \\ e_{r_t} \\ e_{y_{m_t}} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 & 0 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & 0 & 0 \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 & 0 \\ a_{81} & a_{82} & a_{83} & a_{84} & a_{85} & a_{86} & a_{87} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{y^*_{F,t}} \\ \varepsilon_{p^*_t} \\ \varepsilon_{tot_t} \\ \varepsilon_{y_{R_t}} \\ \varepsilon_{y_{a_t}} \\ \varepsilon_{y_{n_t}} \\ \varepsilon_{r_t} \\ \varepsilon_{y_{m_t}} \end{bmatrix}$$

According to Dungey, Fry-McKibbin and Linehan (2014), we placed restrictions on the contemporaneous impact of world economic activity on domestic inflation and interest rate in the extended model. The inflation and monetary policy variable do not react immediately due to the change in world demand. The similar argument applies while restricting the Australian resource and non-resource export. The inflation and interest rate react to change in foreign demand, resource export and non-resource export with lag structure. The last variable exchange rate is assumed to be impacted by all other variables contemporaneously. The contemporaneous impact matrix after restriction takes the following form

$$A_0 X_t = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ a^0_{21} & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a^0_{31} & a^0_{32} & 1 & 0 & 0 & 0 & 0 & 0 \\ a^0_{41} & a^0_{42} & a^0_{43} & 1 & 0 & 0 & 0 & 0 \\ a^0_{51} & a^0_{52} & a^0_{53} & a^0_{54} & 1 & 0 & 0 & 0 \\ 0 & a^0_{62} & 0 & 0 & a^0_{65} & 1 & 0 & 0 \\ 0 & a^0_{72} & 0 & 0 & a^0_{75} & a^0_{76} & 1 & 0 \\ a^0_{81} & a^0_{82} & a^0_{83} & a^0_{84} & a^0_{85} & a^0_{86} & a^0_{87} & 1 \end{bmatrix} \begin{bmatrix} y^*_t \\ p^*_t \\ z^x_t \\ m^x_t \\ y_{j_t} \\ \pi_t \\ i_t \\ r_t \end{bmatrix}$$

where $y_j = \{y_a, y_z, y_m, y_n\}$

Chapter 6

Results

6.1 Results from the empirical model

The structural analysis presented through the structural impulse response function analysis, variance decomposition, and historical decomposition.

6.1.1 Structural analysis of Impulse response function

The impulse response functions are displayed from figure 9 to 14. The results from the impulse response functions show the dynamic behaviour of the variables to one-standard deviation shocks to the error that is Cholesky two-standard error innovation with degrees of freedom adjusted.

I. The foreign demand shock

In chapter two, we discussed the importance of incorporating international demand shock. In a small open economy, global economic conditions and policies affect home countries macroeconomic conditions. The propagation of one standard deviation shock to the foreign demand showed in figure 9. The foreign demand shock increases the MTP's real GDP from 2.6 per cent in the first quarter to 3.8 per cent in the third quarter, and the impulses started to decline after quarter three.

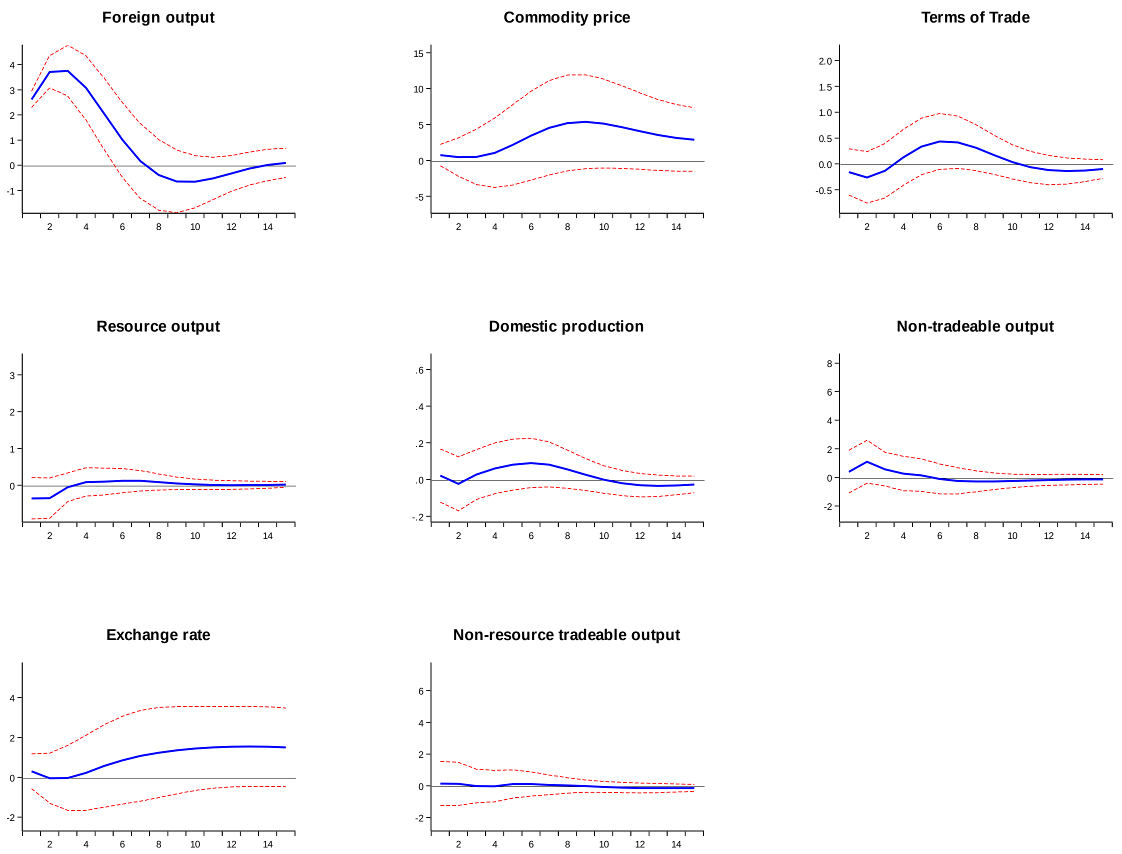


Figure 9: Impulse responses to shock to the foreign demand

The foreign demand shock contributed to upsurge the commodity price from period three. The price reached a maximum of 5.4 per cent in period nine and remained higher for around four years. The terms of trade raised from quarter four, and it was higher until quarter ten, then the impulse dies out. The real exchange rate also increased from quarter four due to the shock. The real exchange rate rose to 1.5 per cent and remained high 1.4 per cent till the entire horizon. The resource output started to grow from quarter four and went back to equilibrium at quarter ten. The shock barely impacted the non-mining tradeable output. Conversely, the non-tradeable production raised to 1.1 percentage point. However, the output became negative from quarter six and remained negative till year four. The aggregate GDP increase 0.06 percentage point from quarter three to quarter six but falls below the baseline from after year three.

II. The commodity price shock

The effect of one standard deviation shock to the commodity price presented in the following figure 10.

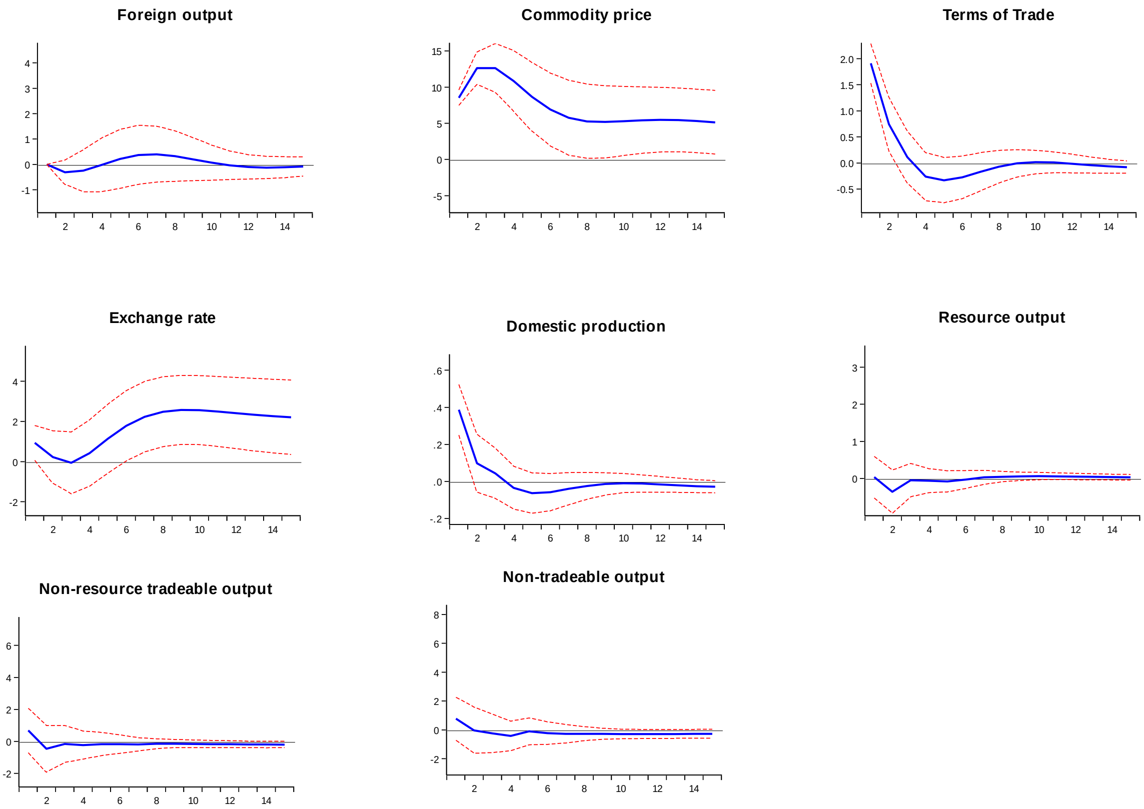


Figure 10: Impulse responses to shock to the commodity prices

The commodity price shock immediately uplifts the commodity price, terms of trade, aggregate real GDP and real exchange rate. The resource output initially drops after the shock hit the economy, but there was a sharp rise in aggregate GDP, the non-resource sector's production and non-tradeable sector's output. The shock caused the commodity price to escalate a maximum of 12.6 per cent in the second quarter. The price showed a steady decline after one year but remained high till the end of the horizon. The terms of trade rose to 1.91 per cent in the first quarter and fall to - 0.12% in the third quarter and went back to equilibrium at quarter ten. The real exchange rate showed a persistent rise after the third quarter and remained high through the entire horizon. The aggregate real GDP increased up to 0.4 percentage point after the shock hit the economy. But we saw the response function falls below the baseline level from quarter four to the end of quarter fifteen. The analysis of structural impulse response showed that there were significant fluctuations of aggregate GDP compared to sectoral output. But impulse responses of the aggregate GDP, non-resource sector output, and non-tradeable sector's production fall below the baseline in the longer horizon, except the resource output.

III. The terms of trade shock

The exchange rate, real domestic GDP and non-resource output boost immediately due to positive terms of trade shock, which is presented in figure 11. The commodity price started to rise after the first quarter and reach a maximum of 4.7 per cent at quarter five, and real exchange rate increases 2.4 per cent at quarter two. Both variables were above the baseline for more than five years. The resource output and non-tradeable output declines at first quarter, but our model revealed that all the sectoral output were quite stable due to the terms of trade shock. The non-mining sectors GVA increased up to 0.9% and from around fourth quarter began to decline. Resource GVA initially declines but remained positive between quarter two to quarter six. For the first two quarters the GVA of the non-tradeable sector was negative, reach minimum point -0.6 percentage, then gradually shock dies out.

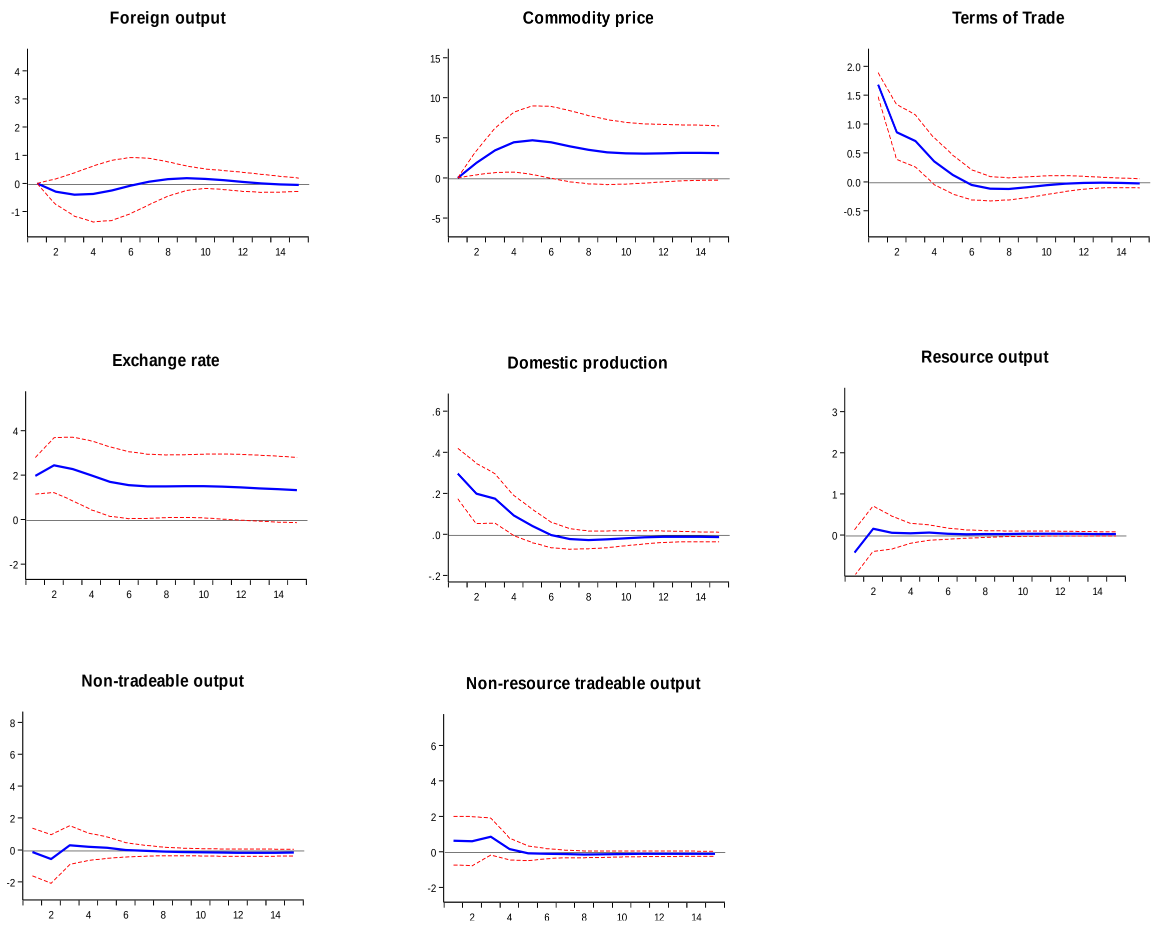


Figure 11: Impulse responses to shock to the terms of trade

IV. The exchange rate shock

The propagation of two standard error shock to the exchange rate presented in figure 12. The commodity prices, terms of trade, domestic output, resource output and non-resource output initially upsurge due to the exchange rate shock. The terms of trade and the real GDP began to rise from period one. The terms of trade rise sharply and reached a peak of 0.78 per cent at quarter two. Similarly, the real GDP reached a maximum of 0.11 per cent at quarter three. Both variables gradually fall down from around quarter five. The resource GVA respond positively from quarter three to quarter fifteen. However, the non-resource tradeable GVA remained below the baseline level from quarter three and non-tradeable GVA from quarter two for the entire horizon.

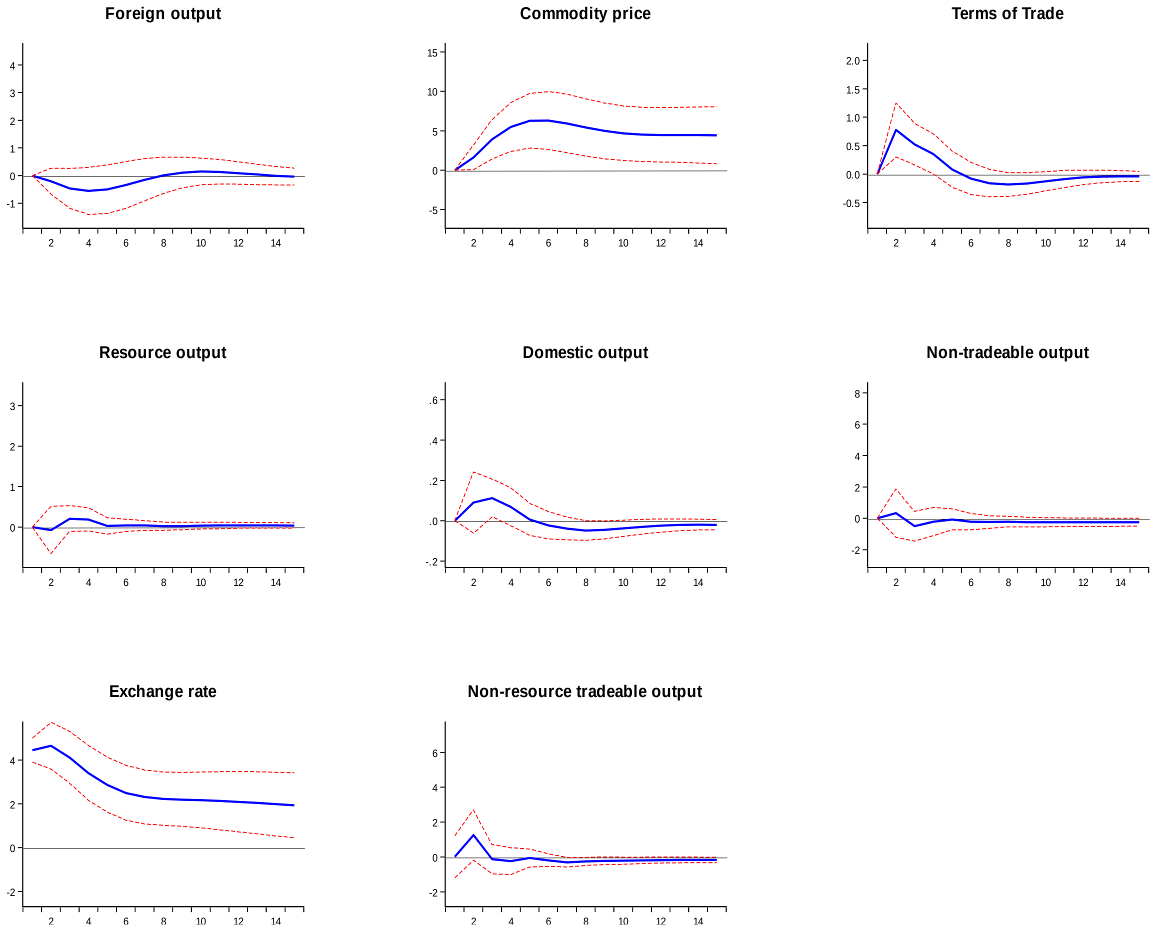


Figure 12: Impulse responses to shock to the exchange rate

V. The resource activity shock

As a commodity-rich economy, Australia's resource activity linked to extract and export of minerals. Here, we analysed how a positive shock to resource activity affect the other sector's output. We already know from the literatures that the growth in resource output has a positive spillover on aggregate production and service sector. Corden (1984) mentioned that if the manufacturing sector is capital intensive, then other non-mining industries might also experience growth through the spending effect. Our model showed that one standard deviation positive shock to the resource sector output increases real GDP by 0.27 per cent at quarter one. Then it sharply falls below the baseline level from quarter two and remains negative till quarter four. The real GDP became positive from quarter five to quarter eleven before the shock dies out.

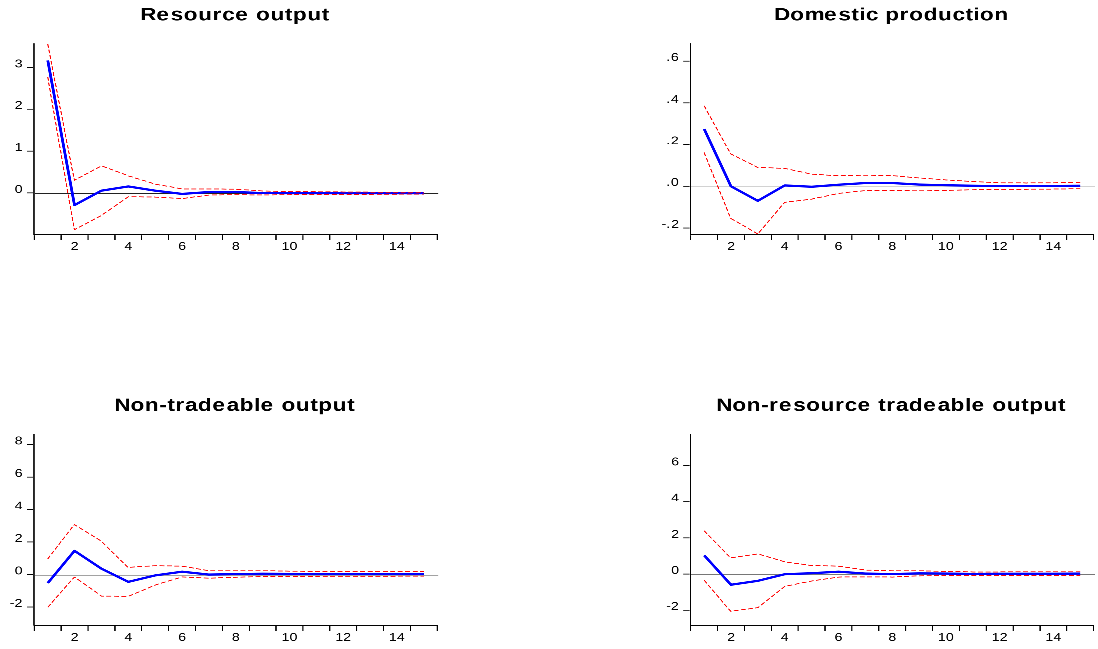


Figure 13: Impulse responses to shock to the resource output

The non-resource output rises 1% initially, and the non-mining tradeable GVA falls to -0.6 per cent at quarter two, then the shock dies out at quarter four. On the other hand, the spending effect positively impacted the non-tradeable output by increasing its GVA to 1.5 per cent at quarter two, then the impulse gradually declines and reach baseline at quarter seven. Our results consistent with the theory that resource activity has positive spillover on the service sector, but not on the non-mining tradeable industries, as it falls from quarter two.

VI. The domestic demand shock

Below we showed the impulse response functions of two standard error shock to domestic demand.

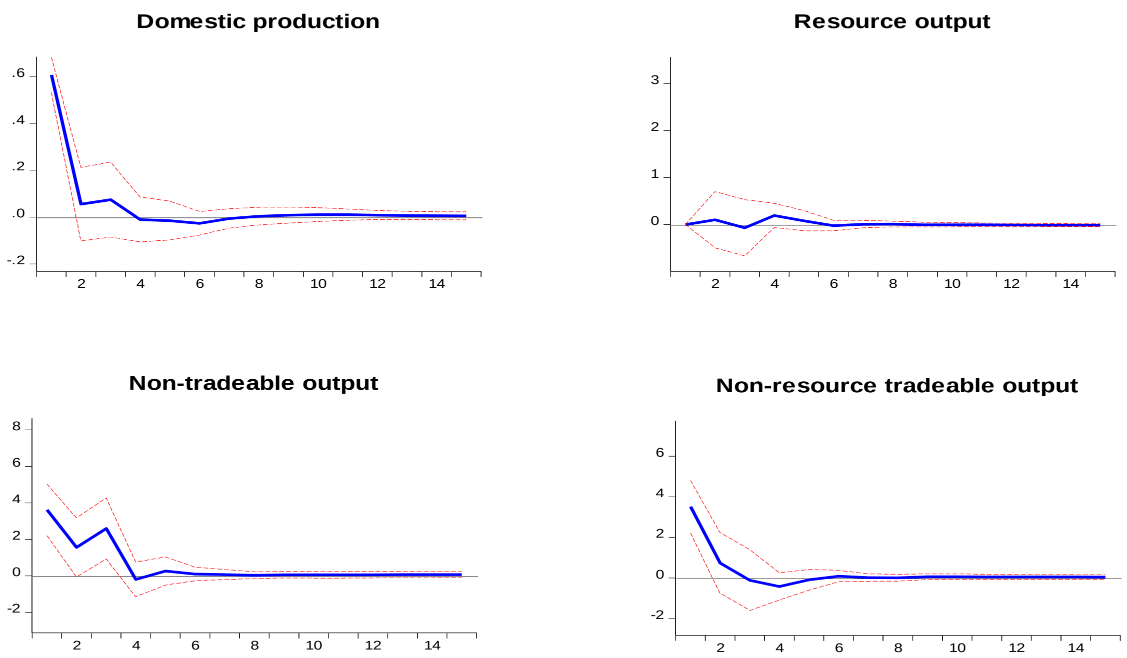


Figure 14: Impulse responses to shock to the domestic demand

A positive shock to real GDP increase the non-tradeable GVA 3.6% in the first quarter but sharply drops down to 1.6 % in the second quarter. Nonetheless, again rise to 2.6 % in quarter three, and falls to -0.2 % in quarter four, once again grows 0.3% in quarter five, and remain positive for more than three years. The non-resource sector rises 3.5% in quarter one and falls to -0.4% in quarter four, shock die out in quarter six.

Our results reveal that income effect has a positive impact on the non-tradeable sector, but not on the non-resource tradeable sector.

6.1.2 Structural analysis of Forecast error variance decomposition

The knowledge of forecast error is useful to understand the relationships among endogenous variables. In a sequence of movements of a variable, the forecast error variance decomposition demonstrates the proportion of those movements due to shocks to itself and shocks to other variables. According to the construction of the recursive method, the forecast errors take on a recursive ordering. That is, there is a sequential change of the variables. If we assume that there is a timeline of events, then all of the one period ahead forecast-error variance of the variable is due to itself. At longer time horizons, the explanatory share of shocks to variables diminish, and the variance of forecast errors should rise, as there is more uncertainty the further ahead of the forecast.

For our empirical model, we estimated the forecast error variance up to quarter 24, and the detailed results of the forecast error variance decomposition presented in appendix D for the forecast horizon 2, 4, 12 and 24 quarters.

VII. The foreign demand shock

The foreign demand shock explains the percentage of the variance of the 24 periods ahead forecast error for commodity price is 11.65 %, for real exchange rate is 9.50 %, for the terms of trade is 6.95%. In the longer horizon, the shock explains the forecast error for real GDP is 3.94% real GDP, for resource output is 2.78%, the non-tradeable output is 2.57%. The shock only attributed to the forecast error variance for non-mining tradeable output is 0.37%. So, we can say that the world event or foreign demand influence the fluctuation of commodity prices and relative prices (the real exchange rate and terms of trade).

VIII. The commodity price shock

The 24 periods ahead forecast showed that the commodity price shock attributed 39.25% variation of the terms of trade, 25.69% variation of real exchange rate and 19.40% variation of the aggregate output. The contribution of the commodity price shock to sectoral output is much smaller compared to the aggregate GDP. In the model, the shock only explains 2.27% variation of the non-tradeable output and accounts for less than 2% variation of resource output (1.51%) and non-resource output (1.85%).

IX. The terms of trade shock

The model's 24 periods ahead forecast error variance of the terms of trade shock contributes a large proportion of variations of the real GDP (18.47%), commodity price (10.65%) and real exchange rate (15.48%). The shock is found to attribute less for the variation of sectoral output.

X. The exchange rate shock

The 24 periods ahead of forecast error showed the exchange rate shock contributed 21.39% variation of commodity prices, terms of trade by 10.02% and real exchange rate by 42.36%. The shock attributed 4.33% variation of aggregate output, and 3.16% variation of the non-resource production, but only explains less than 1% (0.91%) variation of resource output and 1.50% variation of the non-tradeable sector. Our results found that in the longer horizon, the real exchange rate shocks contribute to most for the variation of GVA of the non-resource tradeable sector, compared to the other sectors. In other words, the total variations of GVA of all sectors are 5.57% due to real exchange rate shock in which non-mining tradeable sector accounts for 3.16% variation.

The theory of Dutch disease portrays the fact that the rise in the real exchange rate has a negative impact on the non-resource tradeable sector, and the results from forecast error variance show that the real exchange rate contributes more volatility to the growth rate in value-added in the non-mining sector more than other sectors growth rate in value-added.

6.1.3 Structural analysis of Historical decomposition

The historical decompositions (HD) provides an interpretation of the historical fluctuations of each variable in the model due to the identified structural shock in the system. Dungey and Pagan (2000) provided a historical decomposition analysis of the growth rate in real GDP over the sample period from 1980 to 1997. They explained that international activity plays a substantial role to home countries, such as the Asian crisis and recession in the 1990s have a negative influence on Australia's export and growth of real GDP. Dungey et al., (2017) applied the generalised historical decomposition method which showed that the domestic and international shocks caused the variable to move from steady-state; however, the steady-state gap disappears by 2015.

In our linear VAR model, the historical decompositions explain the relative importance of the shocks to each of the variables for causing the fluctuations over the past fifteen years. We plotted the historical decomposition graphs for the sample period from 2002: Q1 to 2016: Q4. The reason behind to truncate the sample size is to focus on the growth cycle of variables just before and after the mining boom period. The results from the historical decomposition presented in figure 15 to figure 24. In the graphs, the zero lines correspond to the steady-state or trend value of the variables, so at that level (zero lines), no fluctuation is achieved or no steady-state gap. The positive value means the specific shock is causing the variables to move above the trend, and the negative value means the movement below the steady-state.

In figure 15, we see that the foreign demand shock contributed to the persistent rise in Australian bulk commodity prices and real exchange rate from 2004 till 2015. We mentioned in chapter two that the commodity price started to rise around the period 2004 due to a rise in Australian commodity demand from Asian economies and the exchange rate appreciated around the same period as the commodity price. The foreign demand shock plays a relatively small role for the variation of the terms of trade.

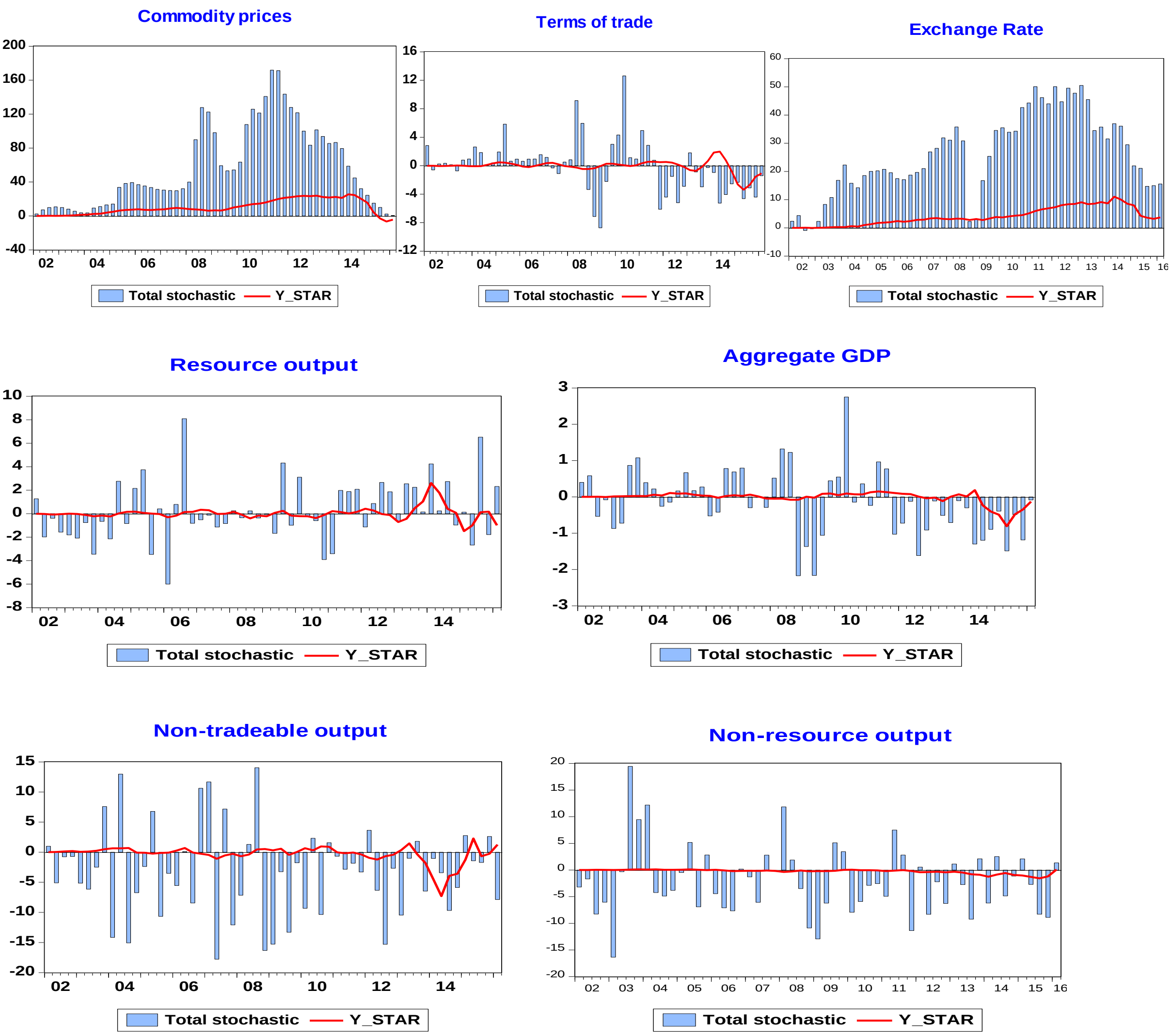


Figure 15: Historical decomposition of the MTP's real GDP

The foreign demand shock contributed a sudden growth in resource output around 2012 to 2014, on the contrary, non-resource production becomes negative after 2011 to 2016, aggregate GDP falls from 2014 to the end of the sample period, and non-tradeable GVA was negative from 2012 to 2015.

XI. The terms of trade shock

Figure 16 shows the growth cycle of the variables caused by the terms of trade shock.

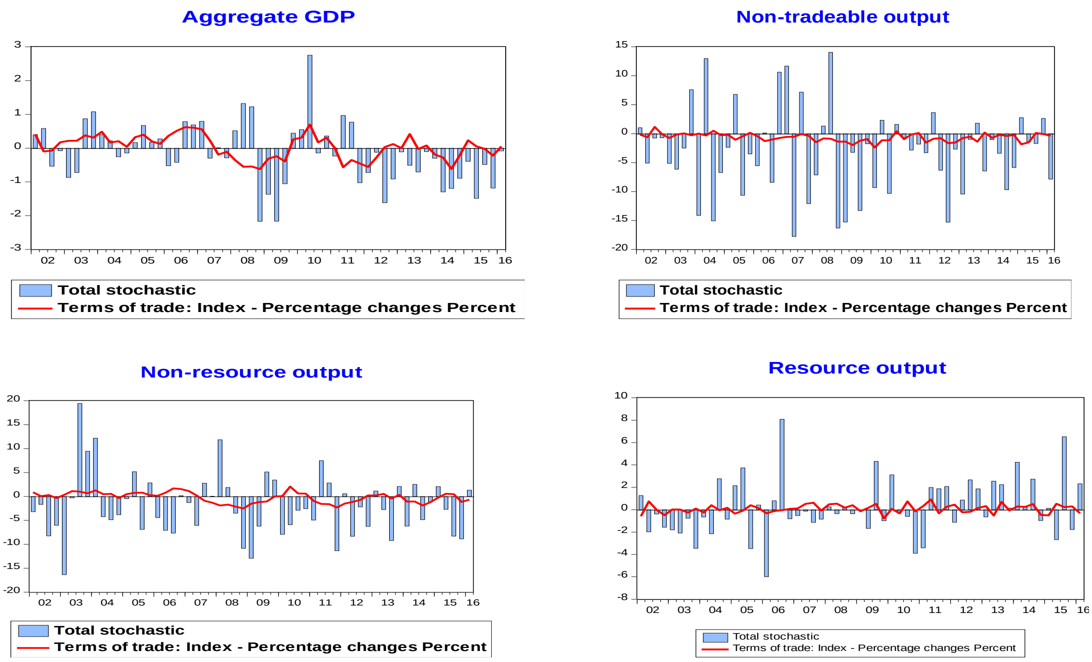


Figure 16: Historical decomposition of the terms of trade

The terms of trade contributed more fluctuations to aggregate real GDP and non-mining tradeable sector's output compared to non-tradeable and resource sector output. The growth rate of the non-mining GVA is below the steady-state level from around 2005 to 2015. There was a significant negative output gap in the non-tradeable sector from 2007 to 2009, mostly because of the global financial crisis. However, the growth cycle of mining output was almost positive throughout the sample period.

XII. The commodity price shock

The results from figure 17 demonstrated that the commodity price shock has a significant influence on the terms of trade, real exchange rate and aggregate domestic production.

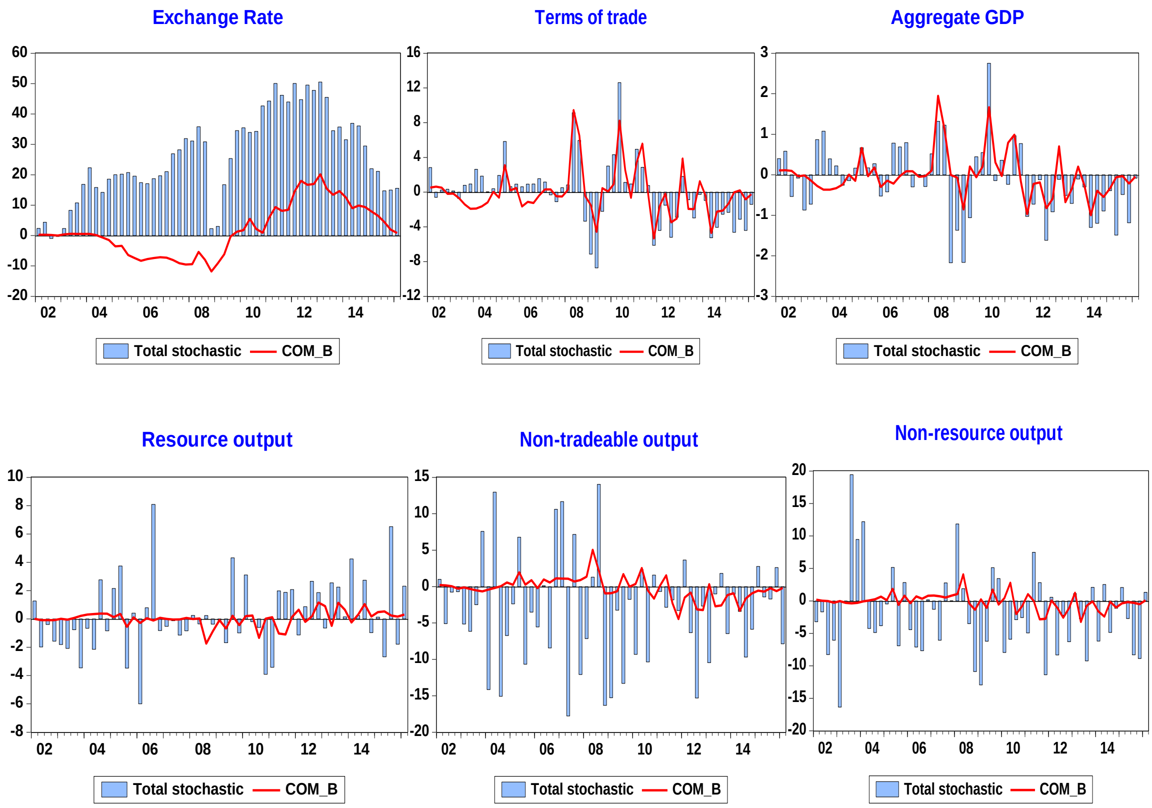


Figure 17: Historical decomposition of the commodity price shock

The positive shock to resource commodity price caused the real exchange rate to appreciate from 2009. The interesting feature is that the relative importance of the commodity price shock on the fluctuation of terms of trade and aggregate real GDP is almost similar. The shock causes a significant positive impact on terms of trade and aggregate GDP from period 2007 to around the last quarter of 2011, except a slowdown in 2009. Our results found a negative output gap of the non-tradeable sector and the non-resource output from 2011. On the contrary, the gross value added to the resource sector showed a positive output gap from

2011. The reason for the fall of non-tradeable and non-resource sectors production could be the appreciation of the real exchange rate from 2009, which cause the non-resource sector to become less competitive and reduces the relative import price.

XIII. The exchange rate shock

In figure 18, we showed how much aggregate GDP and sectoral output fluctuate around the steady-state due to exchange rate shock. The shock contributed to a negative gap in the growth rate of aggregate GDP from around 2011. The shock contributed positive growth to resource output, but output growth of the non-tradeable sector was below the steady-state from 2005, and the non-mining tradeable sector output falls mostly during the global financial crisis period, and again reduces from 2011 to 2015.

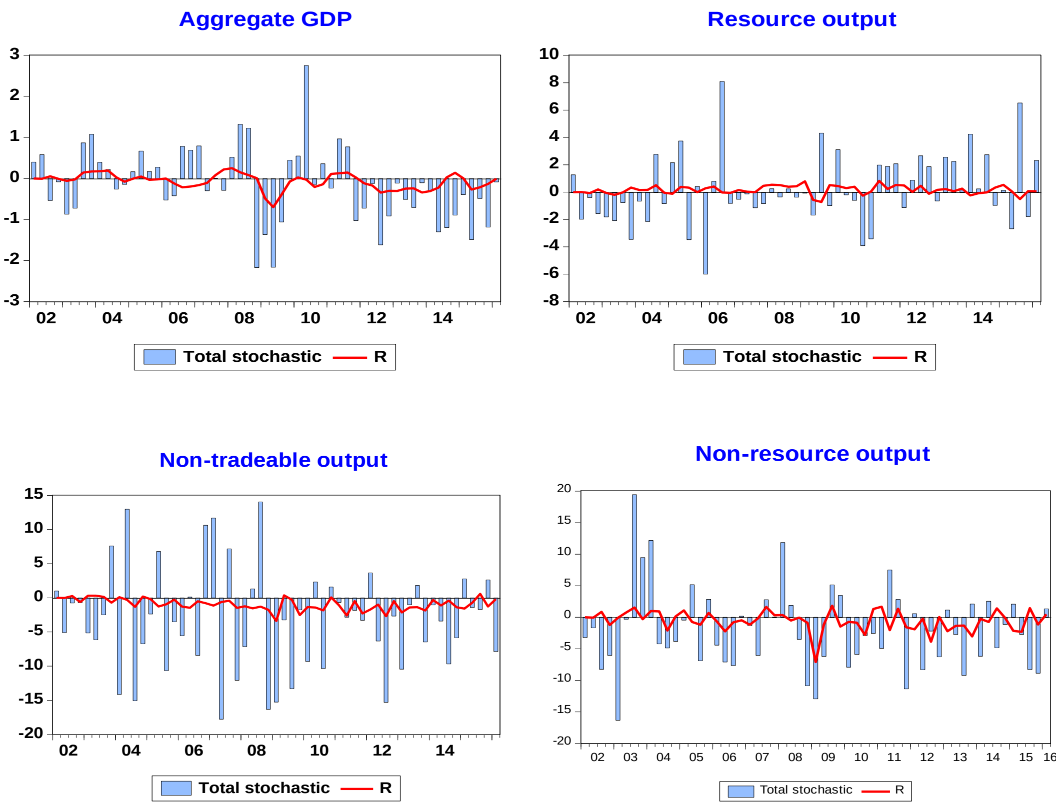


Figure 18: Historical decomposition of the real exchange rate

XIV. The domestic demand shock

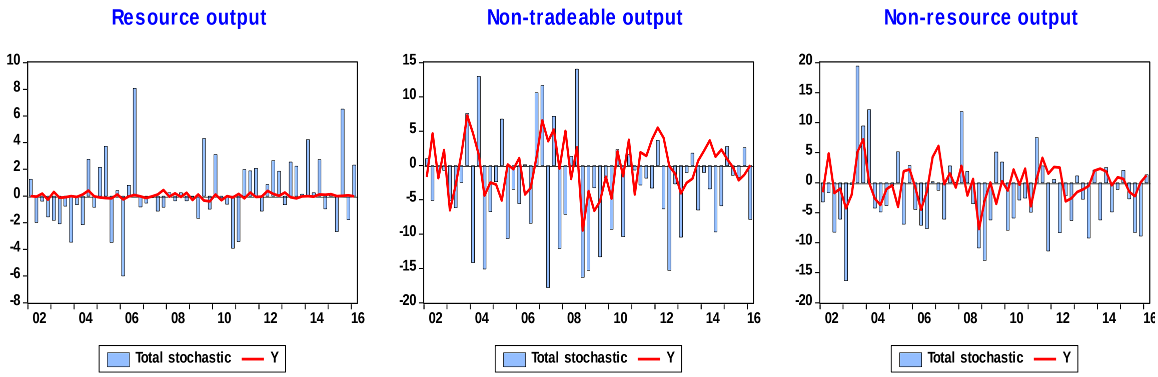


Figure 19: Historical decomposition of the domestic output

Comparing the relative importance of the domestic demand shock on sectoral output, our model showed that the shock attributes more to the non-tradeable sector, compared to the non-resource sector, it has almost no effect on the mining sector.

XV. Historical decomposition: the resource output

Comparing all the contribution of each shock on the resource sector in the following figure 20, our model explains that the shock in the growth rate of the resource sector explains mostly the volatility of resource sector. The foreign demand shock contributes growth in resource sector around 2011 to 2014. The shock to commodity price, real exchange rate, and non-resource sector also explain the fluctuation of the growth rate of the resource sector.

Figure 20: Contribution of shocks to the growth rate of the resource output

XVI. Historical decomposition: the non-resource tradeable output

In figure 21, comparing the contributions of each shock to the non-resource sector, our model provides the interpretation that the fluctuation of the non-mining sector comes from mostly growth rate of real GDP shock, the shock to the real exchange rate, and commodity price. The terms of trade shock and non-tradeable sector explain mild volatility in that sector. The shock to foreign demand sector contributes nothing to the sector.

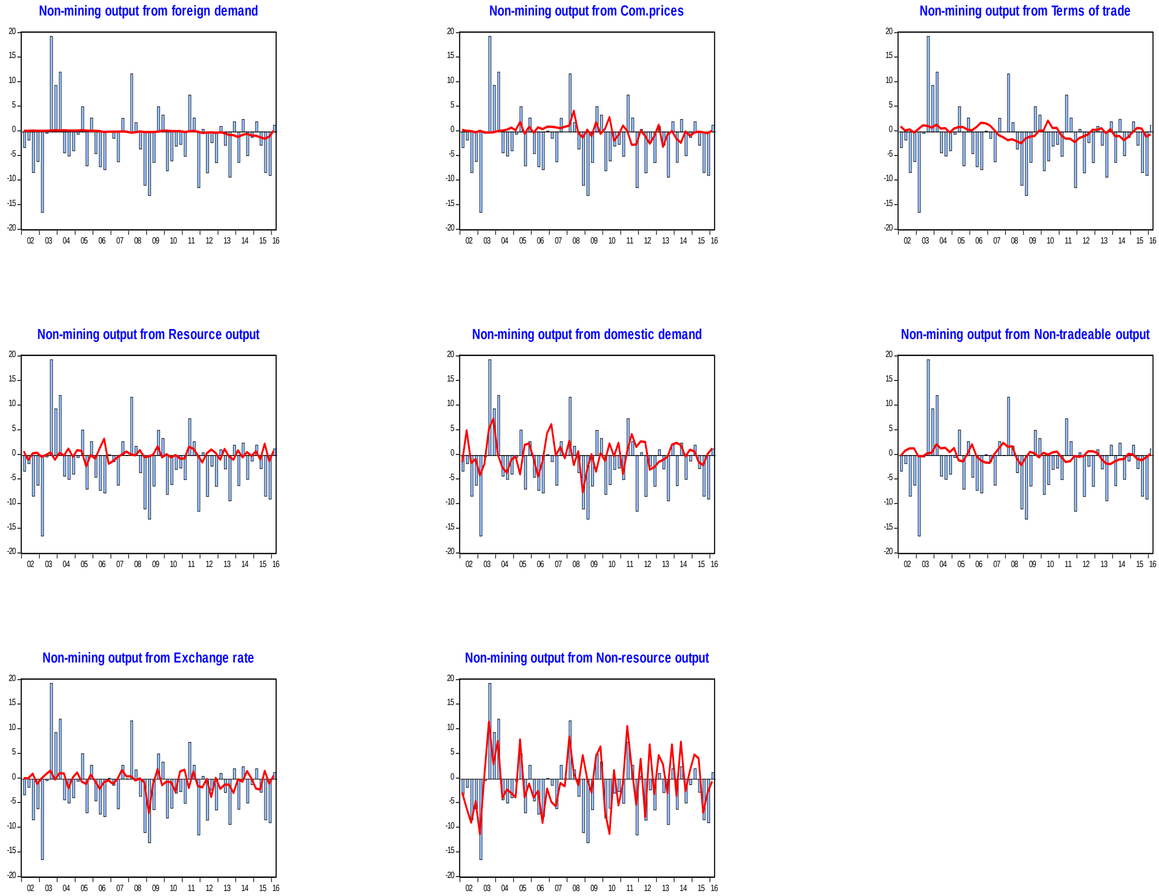


Figure 21: Contribution of shocks to the growth rate of the non-resource output

XVII. Historical decomposition: the non-tradeable output

The historical decomposition of the non-tradeable sector's output presented in figure 22. The foreign demand shock contributed to a fall in the non-tradeable output from 2012 to 2014. The non-resource sector production shock and terms of trade shock did not provide much importance to the fluctuation in non-tradeable sector production. The domestic demand shock is the major contributor to the volatility of non-tradeable sector output. The resource sector production shock, commodity price and real exchange rate shock contributed a mild fluctuation in non-tradeable sector output.

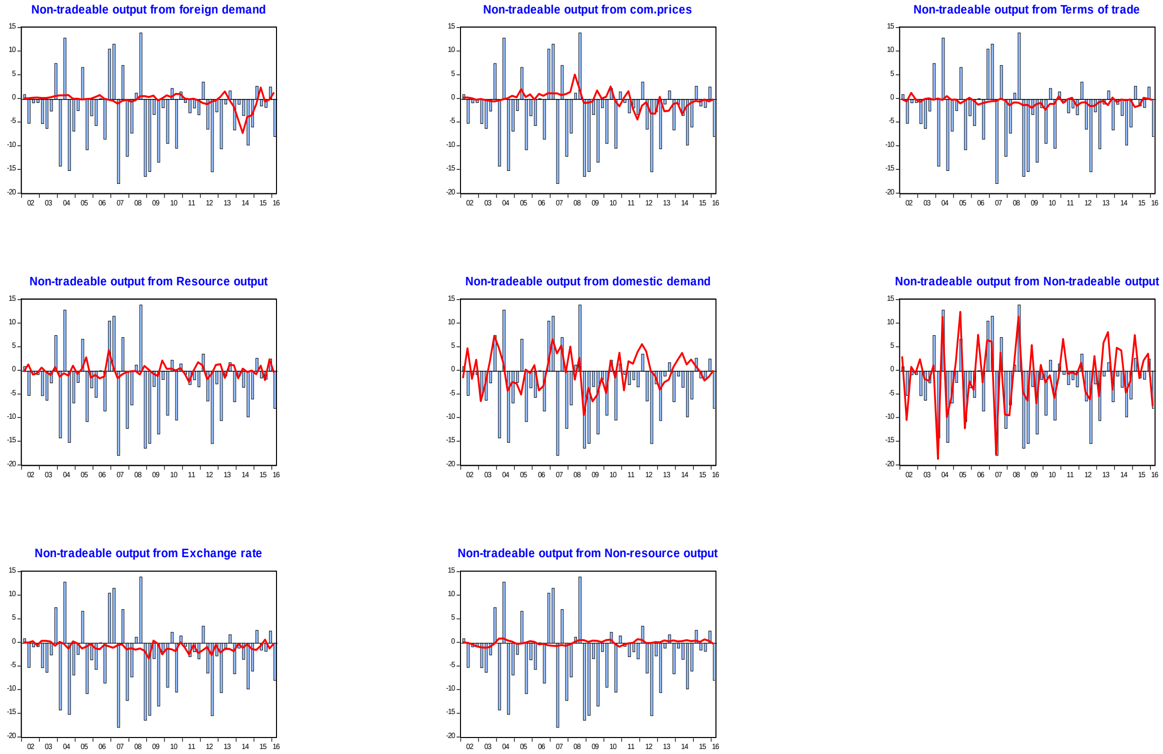


Figure 22: Contribution of shocks to the growth rate of the non-tradeable output

XVIII. Historical decomposition: the domestic output

A positive commodity price shock stands out as the primary contributor to the growth rate of real GDP. After the commodity price shock, the terms of trade shock provide a significant effect on the fluctuation of domestic production. The exchange rate shock and resource output shock caused for mild fluctuations.

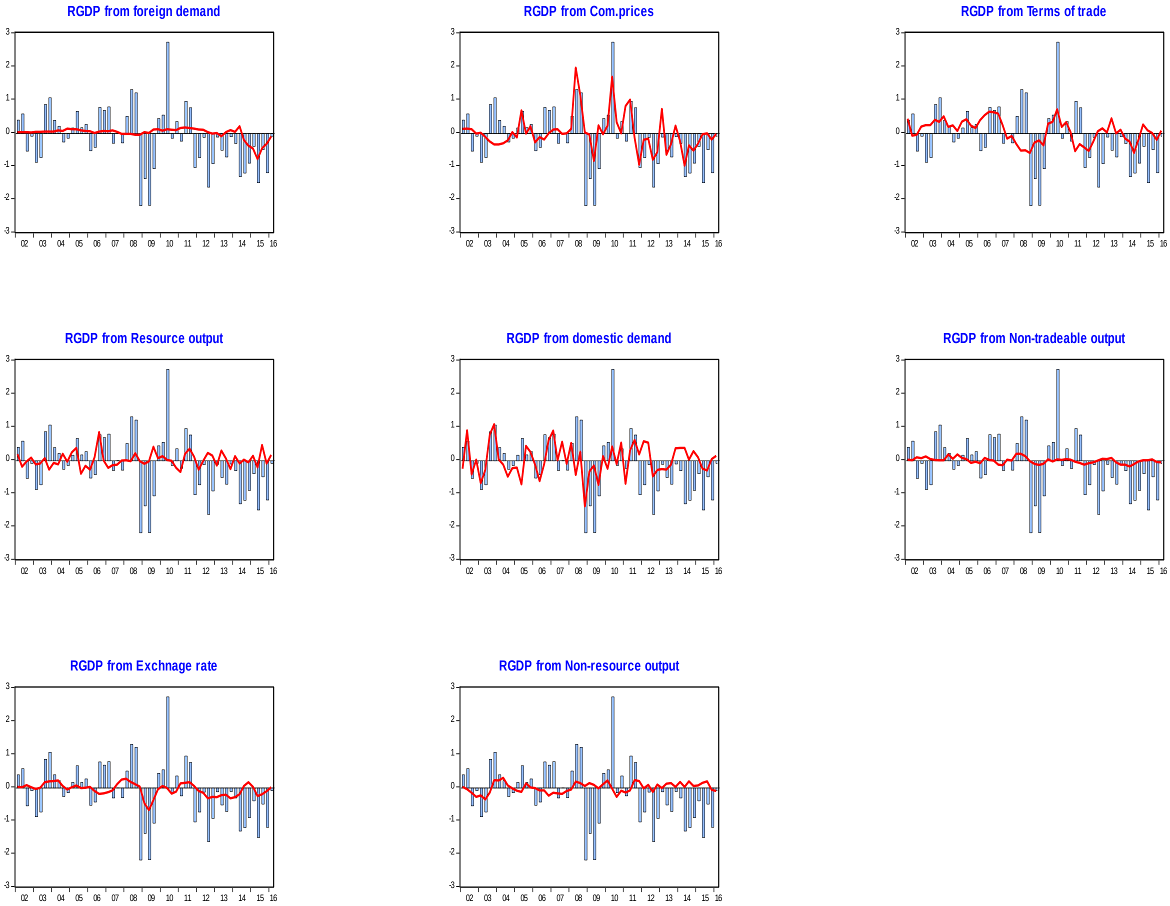


Figure 23: Contribution of shocks to the growth rate of the domestic output

XIX. Historical decomposition: the exchange rate

The theory of Dutch disease explains that when the economy will experience a boom either due to rise in commodity price, or discovery of mineral, the expansion of mineral sector will not immediately cause the exchange rate to rise. From the historical decomposition of the exchange rate in our model showed that commodity price shock contributed to raising the exchange rate from around 2009. However, the terms of trade shock attributed to appreciate the exchange rate around 2003, and non-tradeable sector production shock is vital for the exchange rate to appreciate. The model showed that the monetary policy shock and inflation shock didn't provide any contribution for exchange rate volatility.

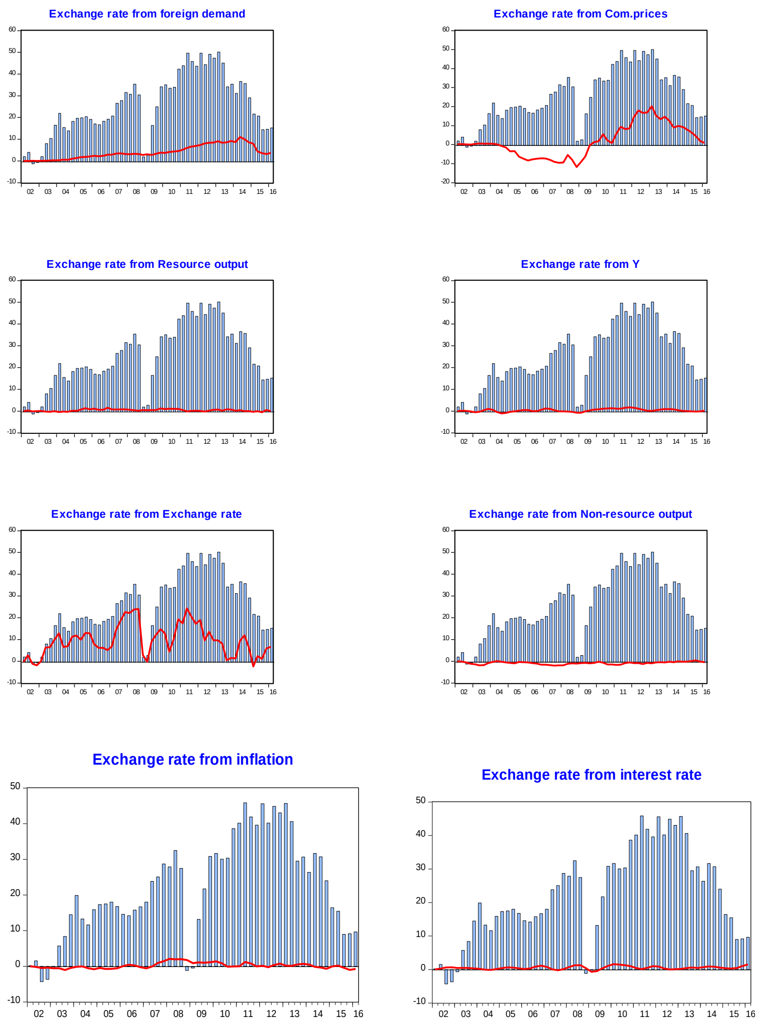


Figure 24: Contribution of shocks to the real exchange rate

6.2 Results of the Extended Model

We computed the impulse response functions over 20 quarters or five years in our extended model. The figures 25, 26 and 27 presented the dynamic response of all the endogenous variables when an exogenous shock to MTP's RGDP, commodity price and real exchange rate hits the economy. The estimated figures of impulse responses included asympototic standard errors of one standard deviation. In the pictures, the solid line depicts the point estimates, and dotted lines are confidence bands at two standard errors. The forecast error variance decomposition of the endogenous variables was calculated for forecast horizon 2, 4, 12 and 24 quarters ahead. The estimation of contemporaneous A_0 matrix and covariance matrix of structural innovations (aggregate and sectoral) are reported in appendix E.

6.2.1 Results from Impulse response functions

The results of the impulse response functions of the extended model analysed in the following figure 25, 26 and 27.

XX. Shock to the foreign output

The GDP of a foreign country might impact on Australia's real exchange rate through the uncovered interest rate parity (UIP) condition. During the period of the recent boom, the world has faced the North-Atlantic financial crisis, which affected the trade and the GDP growth rate of Australia's major trading partner and mining investment. Connolly and Orsmond, (2011) mentioned that Australia had projected around $35 billion worth of iron ore investment projects, which were expected to increase the export capacity further 50% between the periods of 2011 to 2015, but many investors ceased production in 2009. Sheehan and Gregory (2012) analysed the Bureau of Resource and Energy Economics (BREE) data and concluded that much less advanced resource investment had cancelled. They argued that Australia has extensive integration into the global economy, with an around 80 per cent of foreign mining industry ownership and 100 per cent ownership of many new projects. The revenue earning from mining have a less domestic impact as the income was distributed to foreign owners. They indicated that though the resource export increased 8 per cent of GDP, due to this foreign transfer of income, the impact on GDP is about 3 per cent.

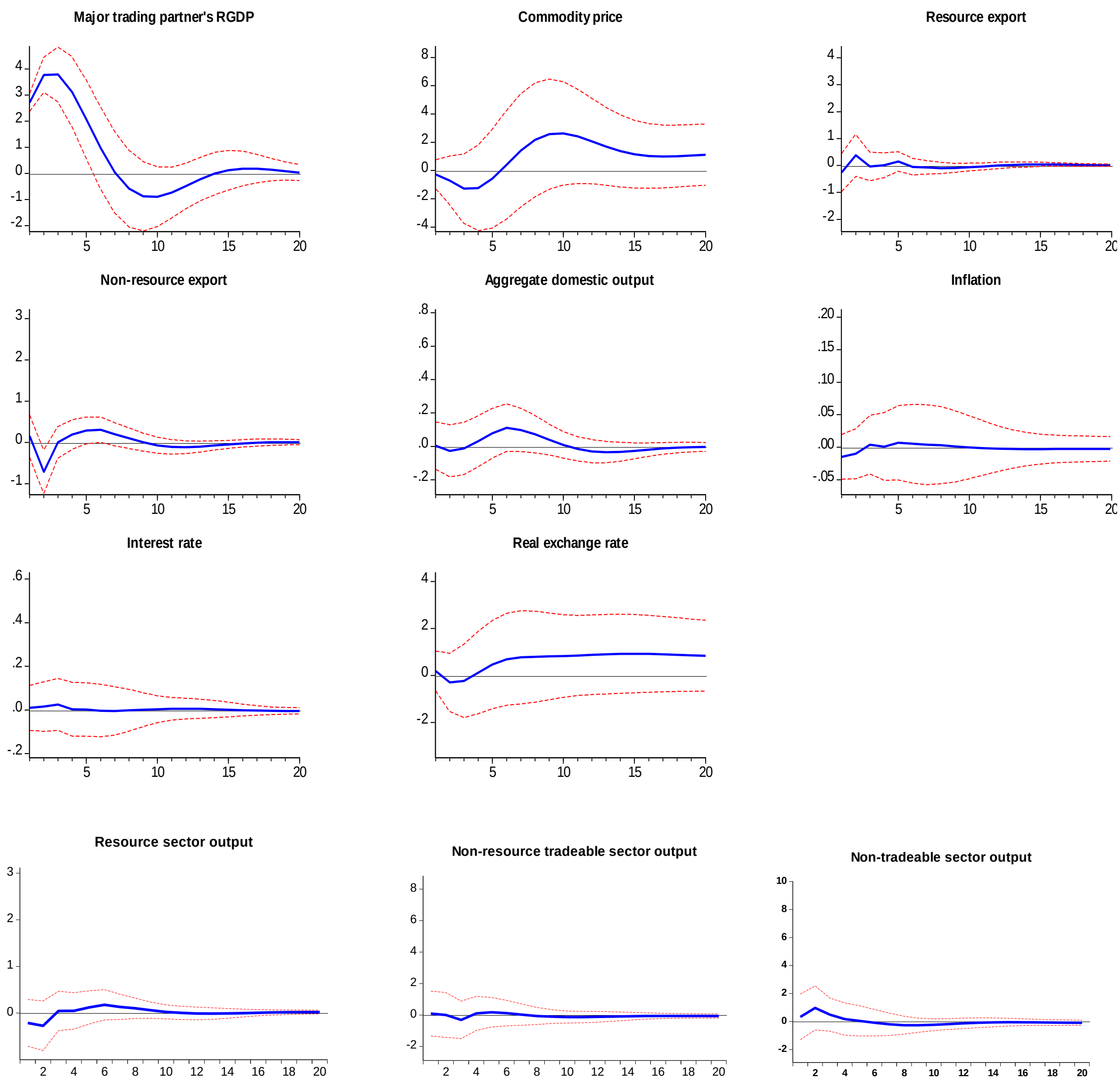


Figure 25: Impulse responses to shock to the foreign output

The impulse response functions of the variables due to a shock to foreign demand showed that the shock first affects MTP real GDP, then raises the commodity price, real domestic GDP, non-tradeable sector output, real exchange rate, resource export, and non-resource export. The foreign demand shock has less influence on the overnight cash rate and CPI inflation. The non-tradeable output rises more compared to the real GDP, and the non-resource tradeable output.

Due to one SD innovations to a foreign demand shock, the point estimates suggest that Australia's major trading partner's RGDP has increased by 3.8% in quarter three and gradually falls to –0.9% in quarter ten. Then the impulse response function goes back to baseline level in quarter twenty. The impulse response function of the Australian non-rural commodity price initially falls to -1.3% in quarter three, however, peaking 2.6% above the baseline at quarter ten, and remain high 1.1% till five years.

The resource export surged around 0.4% in quarter two. The response of the resource export volume becomes negative -0.2% from quarter five to quarter eleven, and the shock dies out at quarter thirteen. The non-resource exports fall sharply -0.7% in quarter two after the foreign demand shock hit the economy. The non-resource export volume rose 0.3% in quarter five, and again falls below the baseline level -0.1 from quarter ten to fourteen, then the shock dies out in quarter twenty. The higher external demand for the mineral, high resource commodity price and appreciation of real exchange rate results in a reduction of resource export and affected the non-resource export by reducing the competitiveness of the manufacturing sector and construction and accommodation (Dungey et al., 2014).

The foreign demand shock results in the domestic output to rise 0.11% at quarter six. Before the shock dies out in quarter twenty, and it decreases -0.03% in quarter fifteen. Unlike domestic production, the sectoral output reacts differently due to the foreign demand shock. The resource sector output and the non-resource tradeable sector output growth both remain -0.3% below the baseline level till quarter two and quarter three, respectively. The resource sector output growth shows a positive trend between quarter three to quarter eight, reaches a maximum of 0.2% at quarter six, the shock dies out at quarter ten. The non-resource sector output remains positive at 0.1% before output growth become negative -0.3%

at quarter three; however, shows positive response 0.2% at quarter five and remains positive 0.1% till quarter six. On the other hand, the non-tradeable sector remains above the baseline till quarter five, the response rises a maximum of 1.0% at quarter two, but the impulse response decreases -0.1% at quarter six, -0.3% at quarter three, -0.2% at quarter ten and eleven and from quarter twelve to twenty remain -0.1% below the baseline level. The CPI inflation and overnight cash rate do not respond much to the foreign demand shock. The inflation goes below -0.01% at quarter one, and the interest rate remains 0.03% till quarter three and then almost remain at the baseline level over the horizon. The foreign demand results in depreciation of the real exchange rate -0.3% to quarter two and reaches a maximum of 0.8% at quarter seven and remains higher at 0.8% more than five years.

XXI. Shock to the commodity prices

Figure 26 displayed the dynamic behaviour of the variables in the system due to one SD innovation shock to the commodity prices.

The shock does not affect contemporaneously foreign output but with lags in the system. Due to the commodity price shock, the Australian MTP's real GDP raised 0.2% after quarter four, but at quarter ten it goes below -0.1% and goes back to the initial level at quarter thirteen. The result is consistent with Dungey et al., (2014) and Jääskelä and Smith (2011) that the rise in resource commodity prices, increases the cost of production of those industries, which uses resources as input, results fall in foreign output.

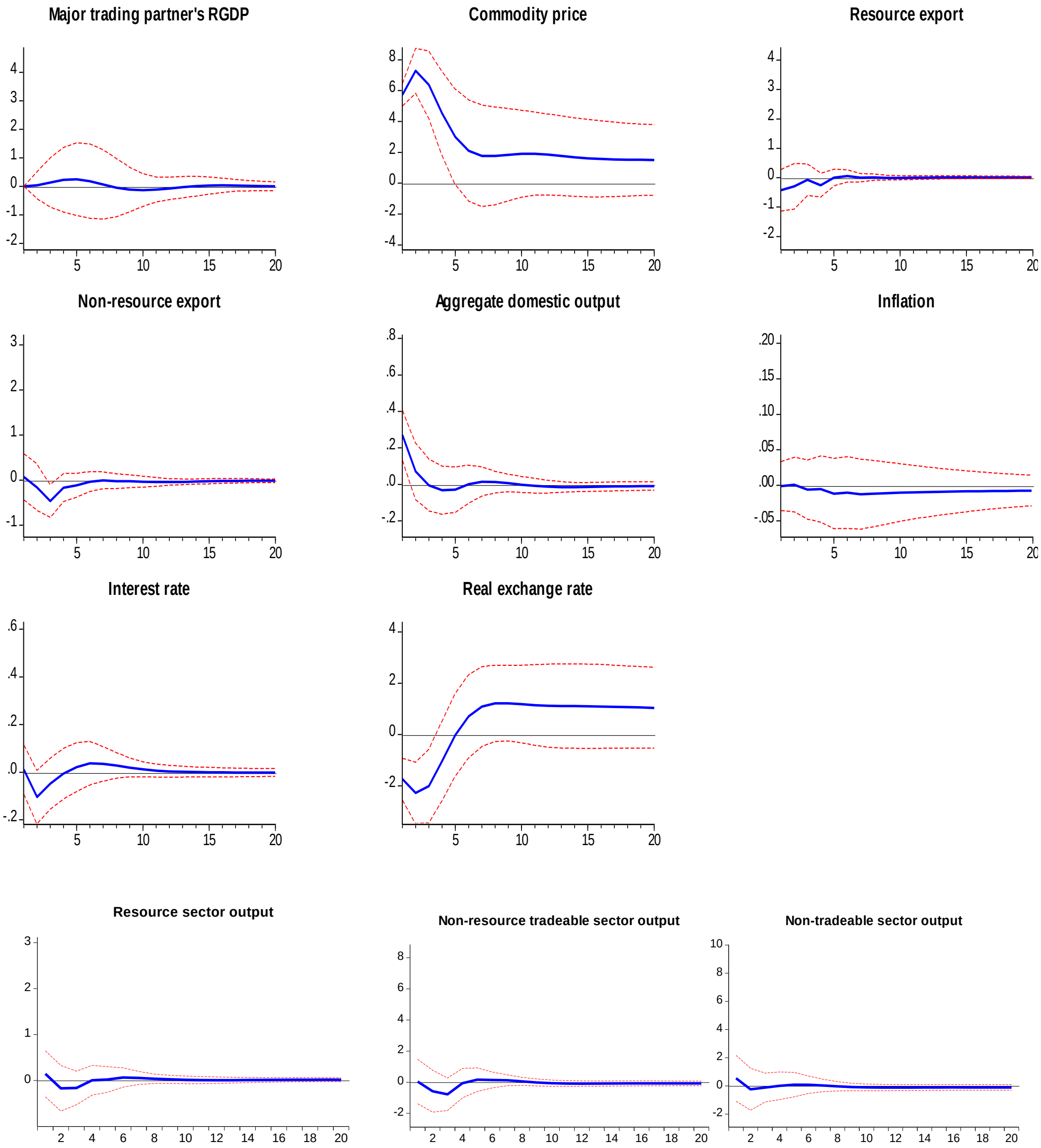


Figure 26: Impulse responses to shock to the commodity prices (Aggregate model and Multi-sector model)

The commodity price reached 7.3% higher above the baseline after quarter one, then falls 1.8% at quarter seven, and remain higher 1.5% more than five years. The shock to commodity prices reduced the export volume -0.4% below the baseline at quarter one and quarter four goes to a minimum -0.3%, the response goes to steady state at quarter five. The commodity price shock also reduces the non-resource export volume -0.5% at quarter three, then goes back to the initial level at quarter six. The higher prices increase the input cost. The higher input cost negatively affect the production of goods which use commodities as intermediate goods. However, the increase in mining investment stabilise the price hike, but with lag.

There was a sharp rise in aggregate domestic output of 0.27% at quarter one due to the non-rural commodity prices. However, aggregate GDP drops off -0.03% at quarter four, and goes slightly above the baseline 0.02% at seven quarter, then remain below -0.01% up to five years. The sectoral decomposition shows that, at quarter one, the commodity price shock raised the resource sector output and the non-tradeable sector output 0.1% and 0.5% respectively, [28] and at quarter three the response of the resource sector output, non-resource sector output, and non-tradeable sector output drops off -0.2 percentage point, -0.8 percentage point and -0.1 percentage point respectively. At quarter seven, the resource sector output rises 0.1% and goes back to equilibrium at quarter nine. The non-resource sector output also increases 0.2% at quarter five, the response of non-resource sector output remains constant at point 0.1% during quarter six to eight and does not move from baseline from quarter nine to onwards. The response of non-tradeable sector output reached 0.1% between quarter five and six, however, the non-tradeable output falls below -0.1% from the baseline at quarter nine and remain at that point more than five years. The results suggest that the high commodity prices reduce the demand for the products of the non-resource sector and the non-tradeable sector.

The commodity price shock caused inflation to fall (-0.01%) from quarter five to more than five years. According to the literature, due to the adoption of a floating exchange rate, this recent boom does not end up with higher inflation (Plumb et al., 2013, Downes et al.,

[28] Downes, Hanslow and Tulip (2014) estimated that, the mining boom, raised Australian per capita income by 13% and manufacturing benefit from its higher demand as input to the mining industries.

2014). The interest rate decreased by -0.10% at quarter two, but there is an interest rate rise maximum of 0.04% at quarter six and reached the baseline from quarter twelve to quarter twenty. The interest rate increased due to the appreciation of exchange rate and higher demand for finance from the resource sector. The real exchange rate depreciated to -2.3% just after the commodity price shock hits the economy. The response of real exchange rate gradually raises, and it appreciated to a maximum 1.2% at quarter eight and remained higher at 1.0% more than five years.[29]

XXII. Shock to the real exchange rate

The responses of the variables due to one SD innovations shock to the real exchange rate captured in figure 27. A positive shock to real exchange rate results in -0.6% decrease of MTP's RGDP at quarter four, the impulse response of the foreign output increases to 0.1% between period quarter eight and eleven, and the shock die out at quarter nine.

[29] Connolly and Orsmond (2011), Plumb, Kent and Bishop (2013), Downes, Hanslow and Tulip (2014) mentioned that the 2000s mining boom caused exchange rate to appreciate but Australia has managed it macroeconomic perfermance better through floating exchange rate and inflation was under control.

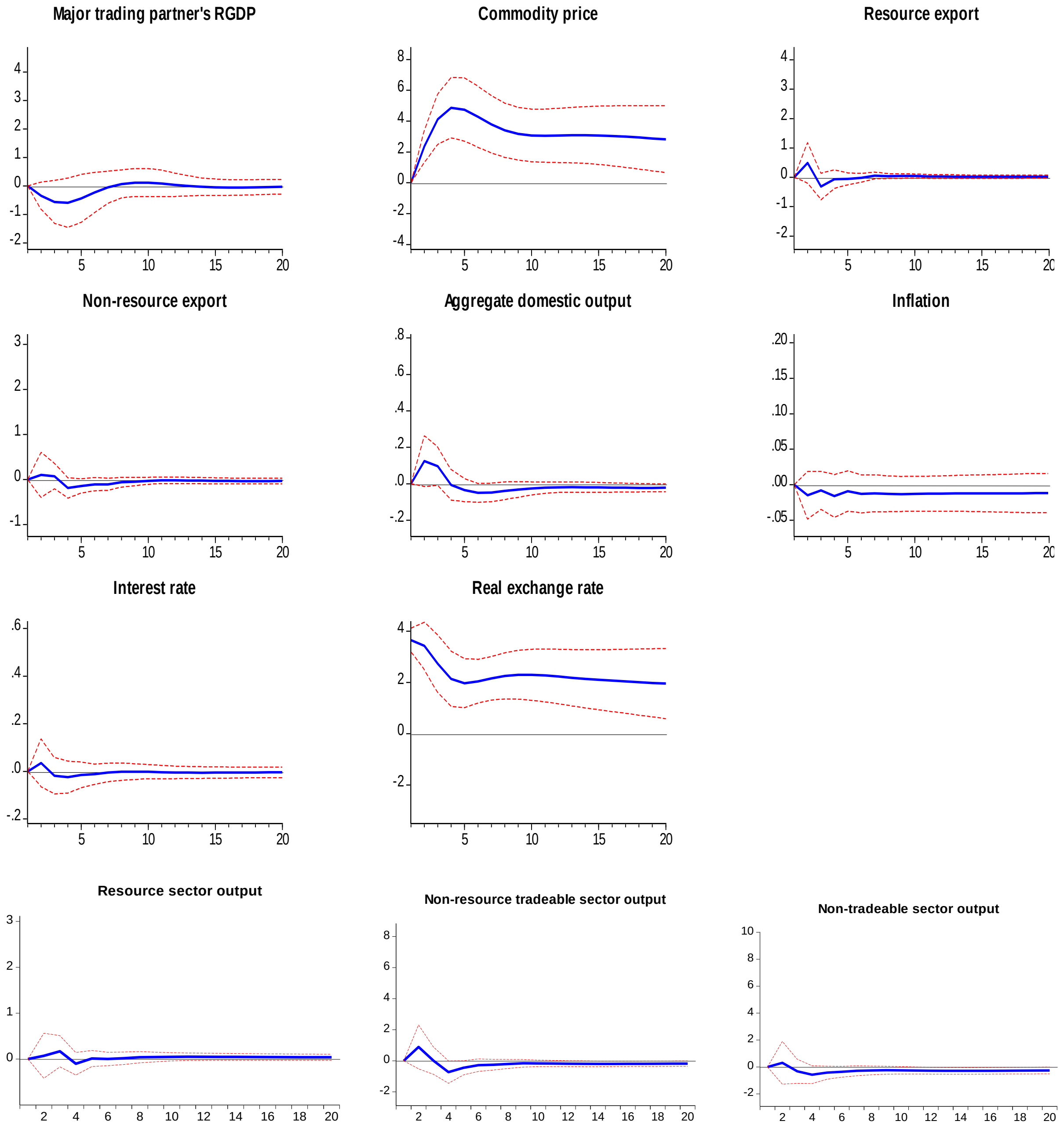


Figure 27: Impulse responses to shock to the real exchange rate (Aggregate model and Multi-sector model)

The shock to real exchange rate raises the commodity price 4.9% at quarter four, and the response drops off to 3.4% at quarter eight and stays 2.8% above the baseline over twenty quarters. The resource export increased immediately by 0.5%, but the response becomes negative -0.3% at quarter three and returns to baseline at quarter five. The non-resource export volume also increased 0.1% at quarter two and decreased -0.2% at quarter four, again drops off -0.1% in period five and goes back to baseline at quarter seven.

The aggregate domestic real GDP increased 0.12% at quarter two, due to revenue gain from resource and non-resource export. The response of the domestic output falls below the baseline -0.04% at quarter five, fall more -0.05% at quarter seven and -0.02% at quarter eleven and the goes back to baseline at quarter thirteen. The reason behind the decline in domestic output from quarter five would be the reduction of resource export volume and non-resource export volume from quarter three and two, respectively. The impulse response of the sectoral decomposition shows that the non-resource sector output and non-tradable sector output increased 0.9% and 0.3% respectively at quarter two after the real exchange rate shock. The resource sector output also increased by 0.2% at quarter three. All the three sectors output drops at quarter four. The resource sector output drops to -0.1%, the non-resource sector falls -0.7%, and non-tradeable sector output reduces to -0.6%. The resource sector output goes back to baseline at quarter five. However, the non-resource sector output decreases -0.4% in quarter five, -0.3% in quarter six and remain lower -0.2% from quarter eight to twenty. The similar response we observe for the non-tradeable sector output, it stays below the baseline -0.3% from quarter seven to twenty.

The impulse response function of CPI inflation shows deflation -0.01% from period two to the next 20 quarters and the interest rate increase 0.04% at quarter two, then decline -0.02% at quarter four, and die out from quarter seven. According to macroeconomic principles, there is a positive relationship between the interest rate and exchange rate, and an increase in interest rate usually reduces inflation.[30]

6.2.2 Results from Forecast error variance decomposition

We estimated the forecast error variance for the forecast horizon 2, 4, 12 and 24 quarters ahead, and the detailed results are presented in Appendix E.

The results show that over the longer horizons, the percentage of the variance of the 24 periods ahead forecast for Australia's MTP real GDP explained by the orthogonal shock to itself is 98.97% and only 4.36% is explained by domestic output (1.14%), inflation (1.29%) and real exchange rate (1.93%). For the commodity price in the second quarter, 90.46% the forecast error variance is attributable by shock to itself, 5.87% by the real exchange rate, and only 2.37% by domestic real GDP. However, over the longer horizon at 24 quarters, 27.87% the forecast error variance of variable commodity price is attributable by shock to itself, 33.51% by the exchange rate, 20.55% by domestic demand shock, 6.88% is contributable by foreign demand, 6.50% by non-resource tradeable sector and 4.36% by non-tradeable sector.

The percentage of the variance of the 24 periods ahead forecast error for the real exchange rate explained by the orthogonal commodity price shock in the system is 12.74%, by domestic demand shock is 24.48%, 5.02% by foreign demand shock, 7.13% by non-resource export, 6.56% and 4.36% by non-resource sector output and non-tradeable sector output respectively and 44.60% by shock to itself. The estimated results of the forecast error

[30] Amano and Van Norden (1995), Beine, Bos, and Coulombe (2012), Rapach and Wohar (2002) and Balazs (2012) and the literature on the monetary model of exchange rate determination have shown that bilateral exchange rates are influnced by interest rate differentials.

variance decomposition of commodity price and real exchange rate suggest that there is a strong relationship between non-rural commodity price and real exchange rate.

Focussing on the aggregate domestic output and sectoral outputs, the contribution of a percentage of the variance of the 24 periods ahead forecast error for domestic demand, resource output, non-resource tradeable output and non-tradeable output by real exchange rate shock in the system are 4.25%, 0.74%, 2.98%, and 2.30% respectively. The results showed that non-resource tradeable sector output is about 3% volatile due to real exchange rate shock compared to resource sector output (less than 1%). On the other hand, over the longer horizon, the orthogonal commodity price shock attributed to forecast error variance for domestic demand, resource output, non-resource tradeable output, and non-tradeable output is 8.81%, 0.89%, 1.46%, and 0.63% respectively. Therefore, commodity price shock is important for explaining the aggregate output. The percentage of the variance of the forecast error for real domestic GDP is explained by 69.08% by shock to itself, the 77.13% variance for resource output is attributed by itself, the 84.31% variance for non-resource output is contributed by itself, and the 87.89% variance for non-tradeable output is contributed by itself. The orthogonal resource export shock attributed to forecast error variance for domestic demand, resource output, non-resource tradeable output, and non-tradeable output is 8.17%, 12.28%, 4.34%, and 3.15% respectively. The orthogonal non-resource export shock attributed to forecast error variance for domestic demand, resource output, non-resource tradeable output, and non-tradeable output is 2.33%, 1.20%, 4.03%, and 2.45% respectively. The orthogonal monetary policy shock contributed to the forecast error variance for domestic demand, resource output, non-resource tradeable output, and non-tradeable output are 2.47%, 3.96%, 1.93%, and 1.40% respectively. From the sectoral output decomposition, it is evident that the mining boom has a significant effect on the output of the non-resource tradeable and non-tradeable sectors.

At the 24 quarters, the variance of resource exports is dominated by shock to itself 82.56%, by 9% interest rate shock and by 5.44% non-tradeable sector output shock. However, 80.65% of the forecast error variance for non-resource export is explained by itself, 7.83% by foreign demand shock, 4.62% by domestic real GDP and 2.64% by resource sector output. The percentage of the forecast error variance for inflation is attributable mostly by shock to itself 85.58%, by the monetary policy shock (interest rate) 5.85%, by the resource output shock 3.58%, by non-resource export shock 3.31%, by non-tradeable sector output 2.53% and 2.47% is explained by the real exchange rate.

The percentage variance of the 24 periods ahead forecast error for the monetary policy variable explained by own shock is 77.01%, by the domestic demand shock is 12.95%, by the non-resource tradeable output is 4.57%, by the inflationary shock is 3.75% and by the commodity price shock is 3.55%.

6.3 Sensitivity Analysis

We included the federal funds rate as a proxy for foreign interest rate (i^*) and US inflation as foreign inflation (π^*), in the foreign block following Manalo, Perera, and Rees (2015). However, considering the parsimony of the model, we dropped those variables. In the first estimation, the percentage change of U.S Real Gross domestic product was used as a proxy for the foreign real GDP. But, to capture the major trading partners GDP growth on the Australian economy, the foreign output is calculated manually from Australia's major trading partner countries. The Reserve Bank of Australia produces the time series of the index of commodity prices measured in $AUD, SDR and $U.S. While estimating our empirical model, and we considered all three measurements of index of commodity prices, and results did not differ.

We initially estimated the extended model with nine variables with the order of lag two. That is, we assessed the VAR(2) with nine variables, including the inflation rate and interest rate in the model. The ordering of the variables and the contemporaneous impact matrix took the following form.

$$A_0X_t = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 & 0 & 0 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & 0 & 0 & 0 \\ 0 & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 & 0 & 0 \\ 0 & a_{82} & a_{83} & a_{84} & a_{85} & a_{86} & a_{87} & 1 & 0 \\ a_{91} & a_{92} & a_{93} & a_{94} & a_{95} & a_{96} & a_{97} & a_{98} & 1 \end{bmatrix} \begin{bmatrix} y^* \\ p^* \\ y_a \\ y_z \\ y_m \\ y_n \\ \pi \\ i \\ r \end{bmatrix}$$

However, we kept the vector of variables are essential for explaining the mechanism of Dutch disease. We estimated the extended model by changing the order of the real exchange rate in the system, but results did not vary due to that.

We examined a set of unit-root tests, including the Augmented Dickey-Fuller (ADF), Phillip-Perron and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests to assess whether or not the series is $I(1)$ when first differenced and transformed the $I(1)$ series to their first differences. For sensitivity analysis, all the series again examined with addition unit root test, called 'breakpoint unit root', to check the structural break in the series. The breakpoint unit root corrects the structural break and allows the series to consider as stationary if Augmented

Dickey-Fuller (ADF), Phillip-Perron and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test considered those series as non-stationary. We estimated the VAR(1) with the quarterly data from the period 1980: Q1 to 2017: Q4. As Australia has adopted a flexible exchange rate since 1983, therefore, the SVAR estimated with quarterly data observed from the period 1984: Q1 to 2016: Q4 (with VAR of order 2).

Chapter 7

Conclusion

This thesis empirically investigates the evidence of Dutch disease in Australia due to the early 2000s mining boom. We applied a Structural Vector Autoregressions (SVAR) model on the Australian economy by incorporating multiple production sectors, such as the resource sector, non-resource tradeable sector, and non-tradeable sector. The recursive method of identification has applied to identify exogenous shocks based on economic theory and institutional knowledge. Our first contribution of this thesis is to provide a macro-econometric analysis of the mining boom and Dutch disease for a small open economy, and also to complement the existing literature on the structural VAR model. Our second contribution to this study is the sectoral analysis of the economy, and the third contribution is creating a broader measure of the foreign real GDP variable, which includes almost all the countries, Australia has a trading relationship.

The results showed that overseas activity influenced Australian resource commodity price, the volume of export, and the volume of import. The prolonged rise in resource commodity price caused a persistent appreciation of the real exchange rate. The higher commodity price temporarily increased aggregate demand, but in the long-run, the aggregate real GDP, gross value-added of the non-resource tradeable sector and non-tradeable sectors declined.

The results from the extended model found that Australia has experienced a negative CPI inflation. Additionally, the shock to the exchange rate lowered the inflation rate of imported goods. The results showed that the appreciation of the real exchange rate and increase in interest rate contracted the activity of the non-mining tradeable sector and non-tradeable sector in the long-run. The reason behind this contraction was due to the investment was concentrated in the mining sector, and making non-mining industries less competitive in the world market due to appreciation of the real exchange rate. And also, according to the Fisher equation, deflation causes real interest to rise, which causes an increase in firms borrowing cost.

The results from historical decomposition found that the growth cycle of Australian real GDP sustained from 2003 except a slow down during the North Atlantic financial crisis, and in 2010, 2013 and 2014. The period after the global financial crisis, the higher resource price and investment contributed to the positive growth in aggregate real GDP, and appreciation of the real exchange rate. The exchange rate shock contributed negative output gap of the aggregate real GDP, non-resource sector and non-tradeable sector and deflationary effect. However, a fall in the commodity price after 2012 caused the real exchange rate to depreciate.

Reasoning from these results, we can claim that our model demonstrates a plausible explanation for the evidence of Dutch disease in Australia. Our results are robust because we identified the structural shocks using economic theory and consistent with the literature. We included a set of variables in the model, which we found necessary to empirically examine the classical theory of Dutch disease. The inclusion of a broader measure of Australian major trading partner's GDP validates the result to capture the recent changes in Australia's international trade flow. Our results from the extended model are also robust because we found that the impulse responses of the endogenous variables (except for each sectoral output and aggregate GDP) is nearly identical across models.

In conclusion, we would like to say that the challenge posed from the Australian mining boom is not only associated with the structural changes but expansionary fiscal policy, negative productivity, and investment shock in the non-tradeable sector. The economy requires proper policies for smooth structural adjustment and retain the gain from resource income and policies to remove regulation or policy-related impediments for industries facing increased competitive pressure.

Banks, G (2011) mentioned that appropriate fiscal policy, such as discipline in public financing via smoothing consumption in an intertemporal dimension or a Sovereign Fund. He mentioned that it is the government decision for making a prudent decision about how resource revenue should be utilised. He also mentioned that investing abroad the resource revenue would increase the demand for foreign currency and might reduce the appreciation of the real exchange rate. Other monetary policy could be sterilised flows of foreign exchange which might limit the rise in the nominal exchange rate. Wills, S. (2015) discussed few policy options for reducing the volatility of resource revenue, such as investment to stabilise the real exchange rate, smoothing consumption via Future Generation Fund, build a volatility fund soon after the mining boom.

Our future work could be to empirically examine the effect of fiscal policy shock during the booming period, to find out how resource windfall has managed, and also we may consider developing a dynamic macro-economic model, such as the dynamic general equilibrium model to compare our SVAR model results.

Appendix A

Description of the data and their sources

The data are seasonally adjusted at quarterly frequencies for the period 1984:Q1 to 2016:Q4. The variables are observed for a total of 130 quarters.

1. **Foreign GDP:** Percentage change of United States Real Gross domestic product. Quarterly seasonally adjusted.

Source: Federal Reserve Bank of St. Louis, Economic Research Division.

2. **MTP RGDP:** Percentage change of Australia's major trading partners RGDP. The variable MTP RGDP calculated manually by aggregating the RGDP of Australia's major trading partners. MTP's RGDP has collected from Penn World Table 9.0 and weights have used from https://www.rba.gov.au/statistics/frequency/twi/twi-20171130.html.

3. **Foreign Interest rate**: Monthly and not seasonally adjusted Effective Federal Funds rate.

Source: Federal Reserve Bank of St. Louis, Economic Research Division.

4. **Foreign Inflation:** Trimmed Mean PCE inflation rate of United States, monthly and seasonally adjusted.

Source: Federal Reserve Bank of St. Louis, Economic Research Division.

5. **Resource prices:** Percentage change in the RBA non-rural commodity price index measured in Special Drawing Rights.

Source: Reserve Bank of Australia, Statistical Table: I2 Commodity prices.

6. **Resource exports:** Percentage change in resource export volumes.

Source: Reserve Bank of Australia, Statistical table I1, International Trade and Balance of Payments.

7. **Non-resource export:** Percentage change in non-resource export volumes. It is calculated as the difference between total exports volumes and resource export volumes.

Source: Reserve Bank of Australia, Statistical table I1, International Trade and Balance of Payments.

8. **Australian Real GDP:** Percentage change in the real gross domestic product.

Source: Australian Bureau of Statistics, Cat. No. 5206.0, 'Australian National Accounts: National Income, Expenditure, and Product.

9. **Resource Value added:** Quarterly growth rate of value-added production in the mining industry.

Source: Australian Bureau of Statistics, Cat. No. 5206.0, 'Australian National Accounts: National Income, Expenditure, and Product.

10. **Non-resource tradeable value-added:** Quarterly growth rate of value-added production in the non-resource tradeable sector. The non-resource sector consists of agriculture, forestry and fishing industry, the manufacturing industry, the transport industry, the wholesale trade industry, the accommodation, and the food and service industry. The growth rate of this series has calculated by summing the growth rates of each industry weighted by that industry's share of non-resource tradeable value-added.

Source: Australian Bureau of Statistics, Cat. Nos. 5204.0 and 5206.0.

11. **Non-tradeable value-added:** Quarterly growth rate of value-added production in the non-tradeable sector. The non-tradeable sector includes the gas, electricity, water and waste industry, the construction industry, the retail trade industry, the information, media and telecommunications industry, the finance and insurance industry, the real estate industry, the professional services industry, the administrative service industry, the public administration industry, the education industry, the healthcare industry, the arts and recreation industry,

the other service industry and ownership of dwellings. The growth rate of this series has calculated by summing the growth rates of each industry weighted by that industry's share of non-tradeable value-added.

Source: Australian Bureau of Statistics, Cat. Nos. 5204.0 and 5206.0.

12. **Inflation:** Quarterly trimmed mean inflation, excluding interest and tax changes.

Source: Reserve Bank of Australia, Statistical table G1: Consumer Price Inflation.

13. **Cash rate:** Quarterly average interbank overnight cash rate.

Source: Reserve Bank of Australia, Statistical table F1.1, Interest Rates, and Yields – Money Market.

14. **Real Exchange rate:** Quarterly average (original) Australian dollar trade-weighted exchange rate index, adjusted for relative consumer price levels.

Source: Reserve Bank of Australia, Statistical table F15, Real Exchange Rate Measures.

Quarterly percentage change in the average nominal exchange rate.

Appendix B

Table 1: Descriptive statistics of the Data

Variables	N	Mean	Median	Maximum	Minimum	Std. Dev.
MTP RGDP	132	3.15	3.17	20.67	-17.93	6.00
Domestic RGDP	132	0.88	0.80	3.70	-1.60	0.90
Resource GVA	132	1.4	1.05	15.70	-8.00	3.17
Non-resource GVA	132	3.55	2.50	24.60	-15.40	7.99
Non-tradeable GVA	132	13.13	12.50	44.20	-12.50	9.19
Resource Export	126	1.34	1.22	24.64	-10.82	4.45
Non-resource Export	132	1.11	1.48	13.00	-52.49	5.59
Bulk-commodity price	132	65.47	37.93	226.41	28.44	49.92
Commodity price	132	66.94	47.02	161.61	36.34	32.32
Cash rate	132	7.11	5.41	18.25	1.50	4.40
Inflation	132	0.88	0.70	2.40	0.20	0.50
Real Trade weighted Index	132	120.49	115.30	166.91	90.81	20.82
Terms of Trade	132	0.368	0.250	13.20	-8.10	3.07

Table 2(a): Major OECD Country's annual GDP growth rate (percentage)

	1993	2003	2007	2012	2017
Australia	4.0	4.1	3.7	2.6	2.8
Canada	2.7	1.8	2.1	1.8	3.0
Germany	-1.0	-0.7	3.3	0.5	2.2
Japan	-0.5	1.5	1.7	1.5	1.9
France	-0.6	0.8	2.4	0.3	1.5
UK	2.5	3.3	2.5	1.4	1.8
US	2.8	2.9	1.9	2.2	2.2
Korea	6.8	2.9	5.5	2.3	3.1

Source: https//stats.oecd.org/ (tables 0119, 0801)

Table 2(b): Non-OECD Countries annual GDP growth rate (percentage)

	1993	2003	2007	2012	2017
Peoples Republic of China	13.9	10.0	14.2	7.9	6.7
India	4.8	7.9	9.8	5.5	6.7

Source: https//stats.oecd.org/ (tables 0119, 0801)

Table 3(a): An average percentage change in growth rate in value-added in all sectors (every five years) in Australia

	GVA of Mining sector	GVA of Non-mining tradable sector (Manufacturing and Agriculture)	GVA of Non-tradeable sectors
Year			
1980-1985	1.41	2.662	15.354
1986-1990	1.81	3.805	15.285
1991-1995	0.895	4.24	12.965
1996-2000	1.105	5.35	14.495
2001-2005	0.375	4.665	13.32
2006-2010	1.115	1.62	10.51
2011-2015	2.225	0.92	10.255
2016-2017	0.875	3.55	8.0
2011-2017	1.84	1.67	9.610

Source: 5206.0 Australian National Accounts: National Income, Expenditure and Product

Table 3(b): An average percentage change in growth rate in value-added in all sectors (every ten years) in Australia

	GVA of Mining sector	GVA of Non-mining tradable sector (Manufacturing and Agriculture)	GVA of Non-tradeable sectors
Year			
1981-1990	1.847	3.645	14.77
1991-2000	1.0	4.795	13.73
2001-2010	0.745	3.142	11.915
2011-2017	1.839	1.671	9.610

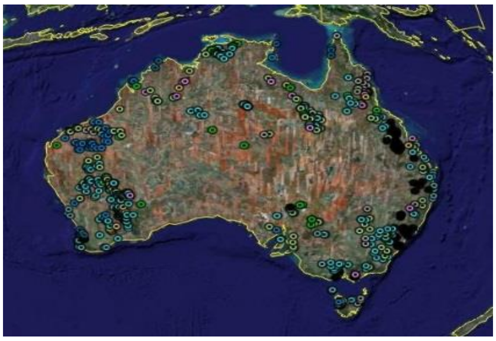
Source: 5206.0 Australian National Accounts: National Income, Expenditure and Product

Mines in 1855

Mines in 1900

Mines in 1950

Mines in 1980



Mines in 2000

Figure 28: History of Australian Mineral industry
Source: Geoscience Australi

Appendix C

Table 4: Unit Root Test Results

Variables	ADF unit-root test	PP unit root test	KPSS unit root test	Decision
y^*	-4.701***	-3.63***	0.089	$I(0)$
$p^*{}_B$	-1.42	-1.52	0.84***	$I(1)$
P*	-1.28	-1.123	1.064***	$I(1)$
tot	-5.923***	-5.65***	0.128	$I(0)$
$infl^*$	0.22	0.23	0.23**	$I(1)$
i^*	0.15	0.076	0.132	$I(0)$
z_x	-15.37***	-16.65***	0.108	$I(0)$
m_x	-13.31***	-13.56***	0.089	$I(0)$
y	-7.99***	-8.06***	0.107	$I(0)$
y_z	-11.96***	-12.23***	0.196	$I(0)$
y_m	-11.06***	-11.05***	0.213	$I(0)$
y_n	-10.80***	-10.97***	0.803	$I(0)$
$infl$	-1.803	-2.10	0.732***	$I(1)$
i	-6.97***	-8.62***	0.075	$I(0)$
r	-1.38	-1.49	8.33***	$I(1)$

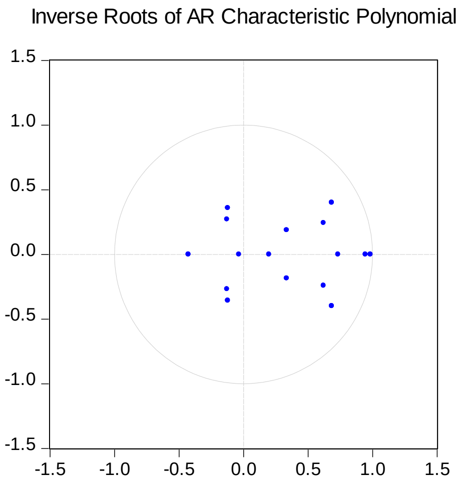
Null hypothesis: variable has a unit root (Augmented Dickey-Fuller test and Phillips–Perron test)
Null hypothesis: variable is stationary (Kwiatkowski–Phillips–Schmidt–Shin test)
Lag length is 2, and the only intercept is included in the test equation.
***, **, * denotes rejection of the null hypothesis at the 1%, 5% and 10% level.

Table 5: Breakpoint Unit root Test Results

Variables	Zivot-Andrews test P-value	Calculated t-stat	Decision
y^*	0.062*	-6.58	$I(0)$
$p^*{}_B$	0.0005***	-4.55	$I(0)$
tot	0.0006***	-6.6703	$I(0)$
$infl^*$	0.05*	-4.99	$I(0)$
z_x	0.0127**	-9.605	$I(0)$
m_x	0.064*	-13.537	$I(0)$

y	0.003**	-8.416	$I(0)$
y_z	0.097*	-12.32	$I(0)$
y_m	0.014**	-9.560	$I(0)$
y_n	0.0004***	-12.97	$I(0)$
$infl$	0.0005***	-5.891	$I(0)$
i	0.002***	-7.147	$I(0)$
r	0.0003***	-4.240	$I(0)$

Null hypothesis: variable has a unit root with a structural break in both the intercept and trend (Zivot-Andrews unit root test)
Lag length is 2, and
***, **, * denotes rejection of the null hypothesis at the 1%, 5% and 10% level.
Probability values are calculated from a standard t-distribution.



No root lies outside the unit circle.
VAR satisfies the stability condition.

Table 6: VAR Lag Order Selection Criteria

Lag	LR	AIC	SC	HQ	FPE
0	NA	50.37570	50.55765	50.44961	1.04e+12
1	948.6014	43.15925	44.79683*	43.82447*	7.67e+08
2	119.6125*	43.07363*	46.16685	44.33017	7.13e+08*
3	81.76936	43.27994	47.82878	45.12778	9.03e+08
4	76.44620	43.47213	49.47660	45.91129	1.16e+09
5	59.39790	43.78875	51.24885	46.81922	1.77e+09
6	58.03956	44.04715	52.96288	47.66892	2.68e+09

*indicates lag order selected by the criterion
LR: Sequential modified LR test statistics (each test at 5% level)
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion
FPE: Final prediction error

Appendix D

Estimation from the Baseline Model

Table 7: Variance Decompositions

Table 7.A: Variance decomposition of aggregate and sectoral output

		Horizon (quarters)		
Variable	**Shocks**	**4**	**12**	**24**
Real GDP	Resource output	9.34	8.83	8.63
	Non-resource output	3.49	3.29	3.21
	Non-tradeable output	1.16	1.43	1.50
	Aggregate output	44.00	41.45	40.48
Resource sector GVA	Resource output	90.72	89.85	89.52
	Non-resource output	0.72	0.74	0.74
	Non-tradeable output	1.95	1.98	1.99
	Aggregate output	0.46	0.52	0.53
Non-Resource sector GVA	Resource output	2.19	2.19	2.17
	Non-resource output	70.61	69.77	68.77
	Non-tradeable output	3.09	3.17	3.20
	Aggregate output	18.50	18.28	18.05
Non-tradeable sector GVA	Resource output	3.03	3.02	2.97
	Non-resource output	0.31	0.33	0.33
	Non-tradeable output	67.98	66.78	65.42
	Aggregate output	24.82	24.46	23.97

Table 7.B: Per cent of variance explained by foreign demand shocks

	Horizon (quarters)		
Variable	4	12	24
Real GDP	0.62	3.48	3.94
Resource sector GVA	2.31	2.74	2.78
Non-resource GVA	0.05	0.14	0.37
Non-tradeable GVA	1.93	2.33	2.57
Commodity price	0.33	10.53	11.65
Terms of trade	1.23	6.55	6.95
Exchange rate	0.15	5.68	9.50
MTP real GDP	95.99	93.97	93.84

Table 7.C: Per cent of variance explained by terms of trade shocks

	Horizon (quarters)		
Variable	**4**	**12**	**24**
Real GDP	19.37	18.65	18.47
Resource sector GVA	1.87	1.94	1.98
Non-resource GVA	2.11	2.25	2.40
Non-tradeable GVA	0.52	0.65	0.94
Commodity price	5.59	9.45	10.65
Terms of trade	40.75	37.16	36.74
Exchange rate	19.94	17.12	15.48
MTP real GDP	0.86	1.05	1.07

Table 7.D: Per cent of variance explained by Commodity price shocks

	Horizon (quarters)		
Variable	4	12	24
Real GDP	19.04	19.00	19.40
Resource sector GVA	1.19	1.39	1.51
Non-resource GVA	1.07	1.35	1.85
Non-tradeable GVA	0.93	1.50	2.27
Commodity price	81.03	53.38	47.99
Terms of trade	41.68	39.36	39.25
Exchange rate	1.16	19.21	25.69
MTP real GDP	0.35	1.23	1.31

Table 7.E: Per cent of variance explained by exchange rate shocks

	Horizon (quarters)		
Variable	4	12	24
Real GDP	2.94	3.82	4.33
Resource sector GVA	0.74	0.81	0.91
Non-resource GVA	2.35	2.81	3.16
Non-tradeable GVA	0.44	0.88	1.50
Commodity price	7.65	18.40	21.39
Terms of trade	9.75	9.88	10.02
Exchange rate	73.96	51.93	42.36
MTP real GDP	1.23	1.87	1.89

Table 7.F: Contemporaneous Coefficient (Baseline model)

	Coefficient	Std. Error	z-Statistics	P-value
C(1)	-0.284	0.286	-0.993	0.320
C(2)	0.123**	0.056	2.185	0.028
C(3)	0.168	0.108	1.551	0.120
C(4)	-0.031	0.020	-1.498	0.134
C(5)	0.099	0.267	0.372	0.709
C(6)	-0.211	0.155	-1.357	0.174
C(7)	0.059	0.241	0.248	0.804
C(8)	-0.223***	0.017	-12.95	0.000
C(9)	-0.061	0.049	-1.243	0.213
C(10)	-0.000	0.009	-0.066	0.946
C(11)	-0.114	0.119	-0.952	0.340
C(12)	0.143**	0.069	2.054	0.039
C(13)	0.012	0.109	0.115	0.908
C(14)	0.253	0.165	1.535	0.124
C(15)	-0.198***	0.031	-6.212	0.000
C(16)	1.304***	0.459	2.841	0.004
C(17)	-1.031***	0.275	-3.749	0.000
C(18)	0.848**	0.446	1.899	0.057
C(19)	-0.086***	0.016	-5.149	0.000
C(20)	0.684***	0.233	2.937	0.003
C(21)	0.088	0.139	0.636	0.524
C(22)	0.253	0.216	1.173	0.240
C(23)	-5.974***	1.108	-5.391	0.000
C(24)	-0.614	0.712	-0.863	0.388
C(25)	-6.465***	1.101	-5.868	0.000
C(26)	0.060	0.050	1.195	0.232
C(27)	0.113	0.079	1.441	0.149
C(28)	-0.003	0.135	-0.028	0.977
C(29)	2.614	0.162	16.124	0.000

C(30)	8.534	0.529	16.124	0.000
C(31)	1.681	0.104	16.124	0.000
C(32)	3.164	0.196	16.124	0.000
C(33)	0.606	0.037	16.124	0.000
C(34)	7.663	0.475	16.124	0.000
C(35)	4.452	0.276	16.124	0.000
C(36)	6.867	0.425	16.124	0.000

Appendix E

Estimation from the Extended Model

Table 8: Variance decomposition

Variable	Shock	2	4	12	24	Variable	Shock	2	4	12	24
$\boldsymbol{y}^*$	y^*	98.98	96.76	94.73	94.27	$\boldsymbol{p}^*$	y^*	0.61	1.60	6.76	6.87
	p^*	.006	0.15	0.38	0.39		p^*	90.46	62.65	35.39	27.87
	z^x	0.09	0.15	0.14	0.14		z^x	0.12	0.92	2.32	2.68
	m^x	0.09	0.41	0.64	0.68		m^x	0.42	2.83	5.20	5.80
	y	0.33	0.76	1.03	1.14		y	2.37	10.35	17.86	20.55
	y_z	0.06	0.19	0.50	0.50		y_z	1.05	1.77	1.01	0.70
	y_m	0.20	0.44	0.47	0.48		y_m	0.87	4.35	6.18	6.50
	y_n	0.57	0.70	0.91	0.92		y_n	0.19	1.78	3.91	4.36
	π	0.02	0.08	1.09	1.29		π	0.00	0.13	0.17	0.16
	i	1.01	0.00	0.06	0.14		i	0.13	1.80	2.69	2.54
	r	0.55	1.69	1.91	1.93		r	5.87	19.71	29.60	33.51

Variable	Shock	2	4	12	24	Variable	Shock	2	4	12	24
$\boldsymbol{z^x}$	y^*	1.06	0.97	1.21	1.24	$\boldsymbol{m^x}$	y^*	5.64	5.52	7.69	7.83
	p^*	1.36	1.57	1.58	1.58		p^*	0.33	2.67	2.72	2.76
	z^x	91.00	83.44	82.70	82.56		z^x	0.19	0.52	0.76	0.77
	m^x	0.10	0.87	1.09	1.10		m^x	92.69	84.88	80.97	80.65
	y	1.03	1.82	1.85	1.87		y	0.12	3.84	4.58	4.62
	y_z	0.02	0.46	0.64	0.64		y_z	1.43	2.64	2.66	2.64
	y_m	0.63	0.67	0.68	0.69		y_m	0.23	0.39	0.62	0.64
	y_n	1.05	5.41	5.45	5.44		y_n	0.56	0.97	1.07	1.08
	π	0.01	0.78	0.93	0.98		π	0.70	1.14	1.12	1.13
	i	4.21	8.60	9.00	9.00		i	0.20	0.94	1.20	1.20
	r	1.20	1.56	1.61	1.63		r	0.11	0.50	0.94	1.02

Variable	Shock	2	4	12	24	Variable	Shock	2	4	12	24
$\boldsymbol{y}$	y^*	0.09	0.21	4.14	4.47	$\boldsymbol{y_z}$	y^*	1.27	1.26	2.00	2.02
	p^*	9.90	9.20	8.81	8.81		p^*	0.54	0.78	0.86	0.89
	z^x	7.23	8.78	8.28	8.17		z^x	13.03	12.53	12.32	12.28

	m^x	2.02	2.17	2.18	2.33		m^x	1.53	1.78	1.96	1.20
	y	77.03	74.29	70.07	69.08		y_z	82.63	78.96	77.50	77.13
	π	0.002	0.01	0.29	0.40		π	0.08	0.43	0.87	0.97
	i	1.75	2.46	2.43	2.47		i	0.84	3.80	3.90	3.96
	r	1.94	2.85	3.77	4.25		r	0.05	0.45	0.55	0.74

Variable	**Shock**	**2**	**4**	**12**	**24**	**Variable**	**Shock**	**2**	**4**	**12**	**24**
$\boldsymbol{y_m}$	y^*	0.01	0.16	0.29	0.36	$\boldsymbol{y_n}$	y^*	1.23	1.52	1.81	1.87
	p^*	0.49	1.29	1.38	1.46		p^*	0.41	0.42	0.48	0.63
	z^x	3.72	4.18	4.36	4.34		z^x	2.75	3.17	3.15	3.15
	m^x	2.55	3.77	3.97	4.03		m^x	2.27	2.24	2.34	2.45
	y_m	90.39	86.77	85.17	84.31		y_n	92.25	90.64	89.27	87.89
	π	0.01	0.21	0.50	0.57		π	0.04	0.19	0.27	0.29
	i	1.62	1.77	1.84	1.93		i	0.91	1.22	1.27	1.40
	r	1.17	1.82	2.47	2.98		r	0.11	0.60	1.39	2.30

Variable	Shock	2	4	12	24	Variable	Shock	2	4	12	24
$\boldsymbol{\pi}$	y^*	0.67	0.44	0.36	0.38	$\boldsymbol{i}$	y^*	0.07	0.20	0.22	0.24
	p^*	0.00	0.08	0.81	1.25		p^*	2.64	2.81	3.59	3.55
	z^x	0.88	1.00	0.62	0.60		z^x	0.07	0.25	0.25	0.25
	m^x	4.50	4.07	3.63	3.31		m^x	1.06	1.34	1.59	1.66
	y	0.90	0.65	0.43	0.53		y	7.99	12.92	13.02	12.95
	y_z	3.55	3.81	3.69	3.58		y_z	0.43	1.86	1.99	2.00
	y_m	0.19	0.23	0.22	0.21		y_m	2.48	4.80	4.60	4.57
	y_n	0.12	0.92	2.12	2.53		y_n	1.57	1.57	1.66	1.65
	π	89.91	88.72	86.89	85.58		π	0.90	1.03	2.99	3.75
	i	2.65	4.29	5.83	5.85		i	86.94	80.97	77.80	77.01
	r	0.46	0.71	1.41	2.47		r	0.30	0.46	0.52	0.57

Variable	Shock	2	4	12	24	Variable	Shock	2	4	12	24
$\boldsymbol{r}$	y^*	0.25	0.26	3.10	5.02	$\boldsymbol{r}$	y_z	0.47	0.62	0.39	0.24
	p^*	16.76	17.60	13.66	12.74		y_m	4.28	5.01	6.05	6.56
	z^x	0.65	2.00	2.73	3.05		y_n	1.52	3.77	3.97	4.36
	m^x	5.00	5.18	6.75	7.13		π	0.89	1.05	0.98	0.60
	y	23.24	22.59	23.49	24.48		i	1.70	2.02	2.16	2.35
							r	51.48	49.28	47.12	44.60

Table 9: Estimates of the parameters of matrix A_0 and Covariance matrix of structural shocks

- The estimates of the strucural parameters of the contemporaneous matrix A_0 for Aggregate model.

$$A_0 Z_t = \begin{bmatrix} 1.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.100 & 1.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.103 & 0.074 & 1.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ -0.062 & -0.015 & -0.031 & 1.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ -0.005 & -0.046 & 0.024 & 0.038 & 1.000 & 0.000 & 0.000 & 0.000 \\ 0.004 & 0.000 & -0.006 & 0.011 & -0.016 & 1.000 & 0.000 & 0.000 \\ -0.004 & 0.005 & -0.000 & -0.002 & -0.168 & -0.326 & 1.000 & 0.000 \\ -0.049 & 0.428 & -0.072 & 0.231 & -2.790 & -0.953 & -0.574 & 1.000 \end{bmatrix} \begin{bmatrix} y^* \\ p^* \\ z^* \\ m^* \\ y \\ \pi \\ i \\ r \end{bmatrix}$$

Non-unit symetric, positive diagonal covariance martix (B) of structural disturbances from aggregate SVAR model.

$$B = \begin{bmatrix} 2.713 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 5.722 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 3.907 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 2.847 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.723 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.187 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.556 & 0.000 \\ 0.000 & 0.00 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 3.656 \end{bmatrix}$$

- The estimates of the strucural parameters of the contemporaneous matrix A_0 for Resource sector.

$$A_0 Z_t = \begin{bmatrix} 1.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.088 & 1.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.103 & 0.075 & 1.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ -0.063 & -0.007 & -0.054 & 1.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.066 & -0.027 & -0.014 & 0.128 & 1.000 & 0.000 & 0.000 & 0.000 \\ 0.003 & 0.000 & -0.006 & 0.013 & 0.005 & 1.000 & 0.000 & 0.000 \\ -0.006 & -0.000 & 0.008 & 0.008 & -0.008 & -0.280 & 1.000 & 0.000 \\ -0.043 & 0.285 & -0.023 & 0.270 & 0.058 & -1.730 & -1.332 & 1.000 \end{bmatrix} \begin{bmatrix} y^* \\ p^* \\ z^x \\ dm \\ y_z \\ \pi \\ i \\ r \end{bmatrix}$$

Non-unit symetric, positive diagonal covariance martix (B) of structural disturbances from Resource sector SVAR model.

$$B = \begin{bmatrix} 2.713 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 5.642 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 3.994 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 2.867 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 & 2.760 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.183 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.574 & 0.000 \\ 0.000 & 0.00 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 4.217 \end{bmatrix}$$

- The estimates of the strucural parameters of the contemporaneous matrix A_0 for Non-resource tradeable sector.

$$A_0 Z_t = \begin{bmatrix} 1.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.094 & 1.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.110 & 0.068 & 1.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ -0.063 & -0.019 & -0.062 & 1.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.012 & 0.016 & 0.294 & -0.262 & 1.000 & 0.000 & 0.000 & 0.000 \\ 0.003 & -0.000 & -0.006 & 0.011 & -0.000 & 1.000 & 0.000 & 0.000 \\ -0.005 & -0.000 & 0.006 & 0.013 & -0.007 & -0.300 & 1.000 & 0.000 \\ -0.069 & 0.300 & -0.063 & 0.299 & -0.082 & -1.194 & -1.005 & 1.000 \end{bmatrix} \begin{bmatrix} y^* \\ p^* \\ z^x \\ dm \\ y_m \\ \pi \\ i \\ r \end{bmatrix}$$

Non-unit symetric, positive diagonal covariance martix (B) of structural disturbances from Non-resource tradeable sector SVAR model.

$$B = \begin{bmatrix} 2.710 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 5.708 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 3.985 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 2.915 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 & 7.825 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.188 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.570 & 0.000 \\ 0.000 & 0.00 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 4.164 \end{bmatrix}$$

- The estimates of the strucural parameters of the contemporaneous matrix A_0 for Non-tradeable sector.

$$A_0 Z_t = \begin{bmatrix} 1.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.166 & 1.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.151 & 0.100 & 1.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ -0.072 & -0.024 & -0.066 & 1.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ -0.119 & -0.074 & 0.300 & 0.435 & 1.000 & 0.000 & 0.000 & 0.000 \\ 0.003 & -0.001 & -0.007 & 0.010 & -0.000 & 1.000 & 0.000 & 0.000 \\ -0.000 & 0.000 & 0.013 & 0.008 & 0.003 & -0.342 & 1.000 & 0.000 \\ -0.062 & 0.302 & -0.019 & 0.299 & 0.017 & -1.465 & -1.365 & 1.000 \end{bmatrix} \begin{bmatrix} y^* \\ p^* \\ z^x \\ dm \\ y_n \\ \pi \\ i \\ r \end{bmatrix}$$

Non-unit symetric, positive diagonal covariance martix (B) of structural disturbances from Non-tradeable sector SVAR model.

$$B = \begin{bmatrix} 2.682 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 5.601 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 3.923 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 2.901 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 & 8.874 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.188 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.570 & 0.000 \\ 0.000 & 0.00 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 4.146 \end{bmatrix}$$

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