DYNAMIC INTERACTIONS BETWEEN COMMODITY PRICES AND AUSTRALIAN MACROECONOMIC VARIABLES

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To my beloved spouse Farhana Rabbi and three of our angels: Nabiha, Nazifa and Nashwan.

‘Read! And your lord is the Most Generous, who has taught (writing) by the pen. He has taught man that which he knew not.’

(Surat Al-‘Alaq-96, 3-5).

DECLARATION

I hereby declare that the discussion provided in this research is only my own study and that to the best of my knowledge the research is unique apart from where otherwise specified by references to other authors or studies. No section of this dissertation has been submitted for any other degree or diploma.

[redacted]

(FAZLE RABBI)

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ABSTRACT

Price swings of commodities affect the economies of commodity exporting nations worldwide and these fluctuations are a major concern for Australian policy makers. Australia is one of the major commodity exporting countries in the global market; therefore, the main focus of this thesis was to shed light on the influence of various fundamental macroeconomic variables on Australian commodity prices. First, emphasis was placed on what magnitude changes in real interest rates and fluctuations of the real exchange rate account for volatility in commodity prices and whether commodity prices tend to show overshooting phenomena (J. Frankel, 1986; J. Frankel, 2006) in reaction to interest rate changes.

The possible contribution of global real economic activity to Australian commodities prices was then assessed, which can lead to both higher interest rates and volatile commodity prices (Akram, 2009; Svensson, 2008) within Australia. Similarly, the current slowdown in world economic growth after several years of high growth might clarify the sharp drop in real interest rates and commodity prices. In addition, the present study explored whether Australian resources stock prices had significant predictive ability for the future global commodity price index as suggested by Rossi (2012).

Johansen's (1988, 1991) cointegration technique was utilised to attain the above research objectives and to examine the long-run relationship of the considered variables. This thesis utilised seasonally adjusted monthly time series for real interest rate, real exchange rate, industrial production and

resources stock price from January 2000 to December 2015 after considering an appropriate structural break.

The study found significant long-run relationships among the variables; therefore, the vector error correction model was applied to judge the short-run dynamic relationship among variables. Then, the forecast ability of all variables was assessed by employing vector error correction Granger causality or block exogeneity tests. Single equation models do not allow the examination of dynamic relations between commodity prices and other macroeconomic variables over different time horizons (Akram, 2009); therefore, the study applied the impulse response technique as well as forecast error variance decomposition to assess the comparative influences of diverse shocks to the variations in key variables of the proposed commodity price model.

The research found significant negative relationships between real interest rates and commodity prices. However, the impulse response results did not show any immediate responses of commodity prices because of an impulse in the real interest rate. This showed a significant negative response of commodity prices after six months of the initial shock and the importance of interest rate information to predict the commodity prices in the long run. In two years' time, approximately one third of the commodity price changes will be explained by the shocks in real interest rate. The shocks from opposite directions showed a significant negative response for real interest rate after having shocks from Australian commodity prices in the medium term.

The results of the present study also suggested an immediate fall in Australian commodity prices and thereafter increases at a higher rate significantly in response to the real exchange rate shock, consistent with Frankel's (1986) overshooting model of commodity prices. This finding raised the question as to whether real exchange rate shocks are a significant factor of Australian macroeconomic instability as commodity export plays an important role in its economy. Results of the present study revealed the response to this query as being in the negative, especially in the long run.

The interaction of these two variables from opposite directions showed interesting results. Separate commodity-related drivers of exchange rates results showed that Australian real exchange rate movements were not purely random. Vector error correction-based Granger causality tests indicated a strong support of causality from commodity prices to real exchange rate in the short run.

The impulse response results showed the most noteworthy results. The shocks from Australian commodity prices showed immediate significant depreciation in real exchange rates and the index remained depreciated significantly in all horizons, which shows the complete opposite results to many studies (Connolly & Orsmond, 2011; Minifie, Cherastidtham, Mullerworth, & Savage, 2013; Plumb, Kent, & Bishop, 2013; Sheehan & Gregory, 2013). However, this finding is consistent with the theoretical explanation provided by Dumrongrittikul (2012) to explain the puzzle of the Chinese real exchange rate, which is supported by the theoretical explanation of S. Edwards' (1989) real exchange rate model.

The results of the present study also showed that the shock to industrial production had a negative effect on Australian commodity prices and the effect remained significant during all time horizons. It also showed that the commodity price fluctuation had predictive ability of the Australian resources stock prices.

After considering these above findings, several policy recommendations for relevant Australian authorities are suggested and limitations are discussed including the pathway for future research.

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Chapter 1 DYNAMICS OF COMMODITY PRICES

1.1 Introduction

1.1.1 Background, Context and Rationale for Research

Commodity price swings affect worldwide commodity exporting nations and these fluctuations are a major concern for policy makers. Australia is no exception to this. Australia noted its 25th year of uninterrupted economic growth in 2015–16. After considering the uncertain economic and political condition presently, this achievement in Australia is definitely significant. Australia is the only commodity exporting nation after the Netherlands that has the longest record of economic growth (Office of the Chief Economist [OCE], 2016).

Increasing commodity export prices were a positive contributor to Australian economic growth at the beginning of the twenty first century. During that time, Australian terms of trade reached their highest level since the Korean War boom. The difference between the growth of export and import prices was believed to be the reason for the favourable conditions. However, there is argument over whether these gains are purely cyclical or whether they show a structural shift to an eternally higher level of national income. Some researchers point towards the historical experiences of Australia, which suggests that this country is well placed to weather any downturn in commodity prices. These researchers argue that commodity production and exports are not as important to the overall Australian economy as commonly assumed (Kirchner, 2009).

The above view is not supported by many academics and policy making circles of commodity exporting nations because fluctuations in commodity prices are responsible for countries' external and internal balances as well as their particular fiscal and monetary policies (Byrne, Fazio, & Fiess, 2013). Moreover, Australia has experienced both the upward and downward swings in its commodity prices over the last two decades. Commodity prices increased to their highest peak in real terms during the global financial crisis (GFC) of 2007–2008 and former historical highs reached in the 1970s. The commodity price index has had a steady, decreasing trend since 2011 until now. The surge in commodity prices is partially, if not primarily, attributed to the drop in interest rates and exchange rates and vice versa (Akram, 2009; Krichene, 2008).

Strong growth in China and India also influenced Australia's commodity export before the GFC, by improving Australia's terms of trade and attracting huge business investment. The general assessment of the net macroeconomic policy in this small open country is vigilantly optimistic, with Australia experiencing clear benefits from the commodity boom period.

However, the Asian-driven commodity boom now appears to be over for Australia. Global economic uncertainty is adding more fear for the future of this natural resource export dependent economy. All these events are affecting Australian iron ore, coal and natural gas exports. All these factors are decreasing business confidence along with the export earnings of this economy. Therefore, an effective and efficient macroeconomic policy is required to predict the commodity price movement of such a commodity dependent economy such as Australia to maintain sustainable commodity export-led growth. The findings of the present research should provide the authorities with effective macroeconomic management policies for resource rich countries.

1.1.2 Objectives and Methodology of the Research

In the present study, the main focus was given to the influence of various fundamental macroeconomic variables on Australian commodity prices. First, the author emphasises what magnitude changes in real interest rates and fluctuations in real exchange rates can account for volatility in commodity prices and whether commodity prices tend to show overshooting phenomena in reaction to interest rate changes. Frankel (1986, 2006) described this argument in his model whereby commodity prices tend to overshoot in response to interest rate fluctuation. This same mechanism was presented earlier in Dornbusch's (1976) model for exchange rates.

This research also examined the possible contribution of global real economic activity to prices of Australian commodities. There are various measures of global real economic activity popular among empirical researchers and we considered industrial production for our research, which has been widely utilised as a measure of real economic activity at both the country and global level (Kilian, 2009). Greater effort is required to assess the influence of global real economic activity because this variable may lead to both higher interest rates and to volatile commodity prices (Akram, 2009; Svensson, 2008). Similarly, the current slowdown in world economic growth after some years of high growth may clarify the sharp drop in real interest rates as well as commodity prices.

In addition, this research explores the linkage between equity and commodity markets, focusing in particular on Australian resources stock prices. One of the objectives was to explore whether Australian resources have significant predictive ability for the future global commodity price index as suggested by Rossi (2012).

To attain the above research objectives as well as to assess the dynamic interactions between commodity price and other Australian macroeconomic variables, the author decided to first determine the long-run relationship among the variables. Johansen's (1988, 1991) cointegration technique was utilised for this purpose along with seasonally adjusted monthly time series for considered variables from January 2000 to December 2015.

Because the study discovered significant long-run relationships among the variables, then there exists an error correction mechanism. This system takes the long-run relationship with the short-run dynamic adjustments of the variables in the model. Since the study dealt with a multivariate vector autoregression (VAR) system, the vector error correction model (VECM) was applied to judge the dynamics of the variables in the short run.

To assess the forecast ability of each and every variable of our model, this study employed VEC Granger causality or block exogeneity tests. Because the present study found one cointegrating vector for presenting the relationship among the variables, a VAR-based Granger causality would be misleading (Enders, 2008; C. W. Granger, 1988; Parsva & Lean, 2011). This particular test does not show a cause-effect relationship, but rather is based only on ‘predictibility’ or ‘forecastability’ of the variables involved (C. W. J. Granger, 1969).

One of the disadvantages of single equation models is that they do not allow for the examination of dynamic relations between commodity prices and other macroeconomic variables over different time horizons (Akram, 2009). Furthermore, they do not assist with the differentiation between effects of anticipated and unanticipated shocks to probable determinants of commodity prices. Impulse response technique founded on the structural VAR models allows for the assessment of the effects of shocks to diverse variables over time while taking into account relations between the financial and real macroeconomic variables and the commodity prices of Australia. This study assessed the comparative influences of diverse shocks to variations in the key variables by forecast error variance decomposition.

All the above econometric techniques are utilised in the present study to assess the dynamic interactions between commodity prices and other Australian macroeconomic variables.

1.1.3 Organisation of the Research

The present study is separated into seven chapters. Chapter 1 is the preliminary chapter, showing the circumstances, background, context and justification of conducting the study. This section also deliberates on the objectives of the research including a brief summary of the methodology and data utilised during the study.

Chapter 2 presents an overview of the Australian economy. It provides a snapshot of Australian commodity export-led growth in the present century including the exchange rate as well as terms of trade situation. This chapter also describes the Australian monetary policy and its influence on investment as well as overall productivity in the tradable and non-tradable sector. Issues related to Australian industrial production and the interaction between equity markets and commodity markets are also discussed.

Chapter 3 analyses both the theoretical and empirical works relating to the Australian commodity price model. After the introductory notes, this chapter describes the theoretical literature related to commodity price followed by empirical literature on determinants of commodity prices. The very last part of this chapter summarises the literature on determinants of Australian commodity price.

The purpose of Chapter 4 is to establish an analytical framework to evaluate the dynamic interactions between commodity prices and other Australian macroeconomic variables. It also describes the required data sources and their respective definition. This chapter also reveals the expected sign of variables utilised in the model from the existing literature and shows a few estimation techniques applied in the research.

Chapter 5 is one of the main result sections of the present study. It represents all the empirical findings including the dynamic behaviour of the VECM. The assessment techniques that are incorporated in this chapter include Johansen (1988, 1991) cointegration, VEC, Granger causality, impulse response functions (IRFs) and VECM forecast error variance decomposition. This chapter reveals the long run relationship among the variables including their short run dynamics. This chapter also shows the short- and long-run forecastability or predictability of the variables involved in the commodity price model. The impulse response technique is utilised in this chapter, which allows for the assessment of the effects of shocks to diverse variables over time while taking into account relations between the financial and real macroeconomic variables and the commodity prices in Australia. Finally, the chapter assesses the comparative influences of diverse shocks to variations in the key variables by the econometric technique of forecast error variance decomposition.

Chapter 6 is another results chapter, which mainly reveals the responses of macro variables to the Australian commodity price shock. Impulse response functions as well as forecast error variance decomposition techniques are utilised to assess these interactions.

Chapter 7 presents the foremost outcomes of the thesis and draws lessons for Australia in understanding the dynamic interactions between commodity prices and macroeconomic variables. It suggests policies for responsible authorities to obtain the maximum benefits from resource booms and escape the possible adversative consequences for both short-run steadiness and long-term growth. Practical and sensible policies are essential to counteract the adverse consequences of commodity price volatilities. This chapter also indicates some limitations of the research and makes suggestions for additional research on the subject.

1.2 Concluding Remarks

The present research continues its assessment after considering the objectives according to the procedures stated above. This would assist policy makers to understand the dynamic interactions of commodity prices and other

Australian macroeconomic variables to propose and implement policies in a knowledgeable way.

Chapter 2 AUSTRALIAN MACROECONOMY AND COMMODITY PRICES

2.1 Introduction

2.1.1 Australian Commodity Export-led Growth in the Twentieth Century

The Australian economy is characterised by enormous swings in commodity prices and, together with huge mining investment, these have been performing as vital forces affecting the economy since the mid-2000s. Although the economic and political situation in the majority of countries worldwide has been volatile in recent years, Australia recorded its 25th year of continuous growth in 2015–16 (OCE, 2016). This is an extraordinary success for the Australian economy, which is now only second to the Netherlands that has the lengthiest record of economic growth.

Many advanced economies such as the United States and Japan are still striving to reach to their pre-GFC growth rate level. Developing countries such as China and India have been growing strongly for many years. However, countries worldwide have been observing some structural changes in their growth patterns recently. China recently transformed from investment-led growth to consumption-led growth. Moreover, the Brexit vote that saw Britain vote to leave the European Union has added to global uncertainty. All of these events combined are causing uncertainty amongst the international community. These issues are, in turn, affecting demand for three of the four top Australian exports, i.e. iron ore, coal and natural gas. These developments are also influencing domestic business confidence, which, while increasing, is still comparatively weak in light of constant global uncertainty (OCE, 2016).

Historically, commodity exports have been a vital source of income for the Australian economy. Over the past decade, commodity exports have, on average, accounted for greater than 55 per cent of total export values and 11 per cent of gross domestic product (GDP), well above the levels over the previous decade (Robinson & Wang, 2013). Figure 2.1 clearly shows this fact.

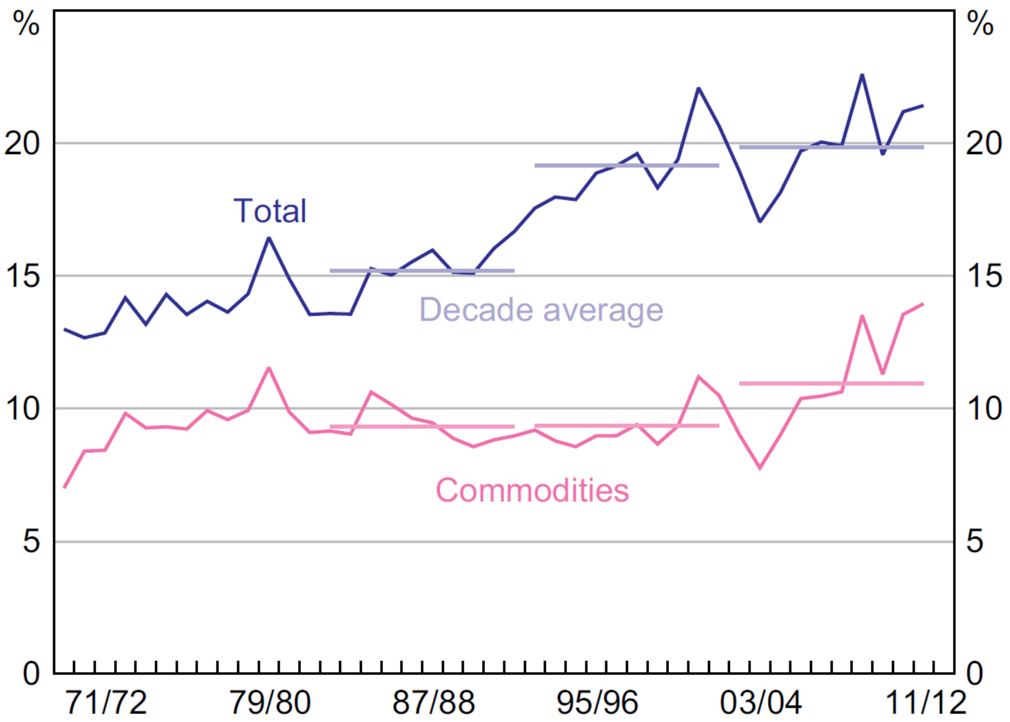


Figure 2.1 Export share of Australian GDP (at current price)

Source: Robinson and Wang. (2013).

The Reserve Bank of Australia (RBA) Index of Commodity Prices (ICP) indicates the prices received by Australian commodity exporters. The ICP is a Laspeyres index and represents a weighted average of recent changes in commodity prices (Robinson & Wang, 2013). The weights are provided to each commodity to reflect its importance in commodity export values during a base period. The RBA updates the base period and weights to retain their applicability. The recent updates were performed on 01 April, 2013 (Appendix 01 & 02). This updated ICP included 21 major commodities presently exported by Australia, which indicates Australia's commodity export earnings more accurately.

Australia's commodity prices, on average, have fallen from the highs related to the mining boom as indicated by the updated ICP. At the same time, the position of the Australian currency suggests this would increase to surge its exports as they become cheaper to other countries. Resources and energy export earnings are the most significant component of Australia's total exports as shown by Figure 2.2.

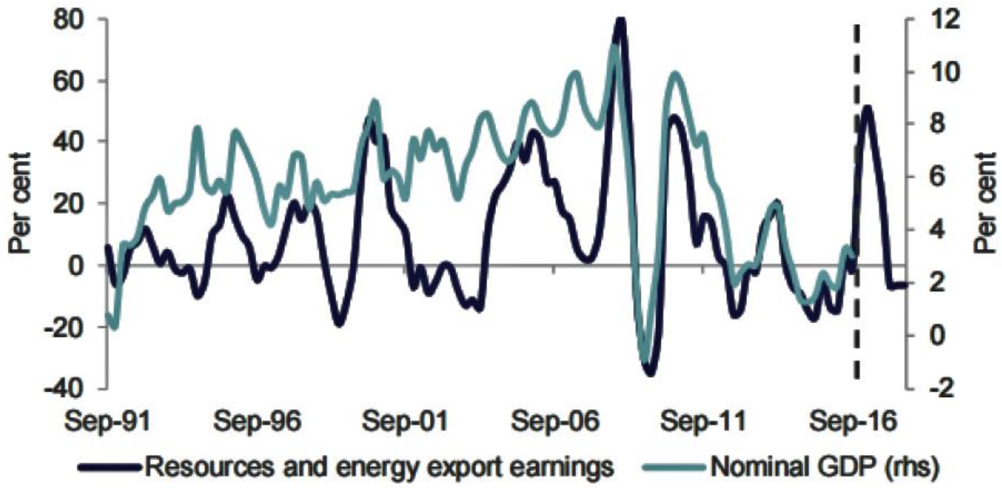


Figure 2.2 Australia's nominal GDP vs resource and energy export earnings, year-on-year change

Source: Australian Bureau of Statistics (2016) National Accounts, 5206.0

The lower worldwide growth for commodities outlook, high debt levels of various developed as well as developing economies and amplified protectionist actions have softened demand, and contributed to a reduction in the value of Australia’s exports. During the last financial year (2016–17), Australia’s export values declined to $312 billion from $318 billion in 2014–15. That was approximately a 2 per cent decrease and was generated mainly by weakening in the export values of three of Australia’s top four exports, i.e. iron ore, coal and natural gas.

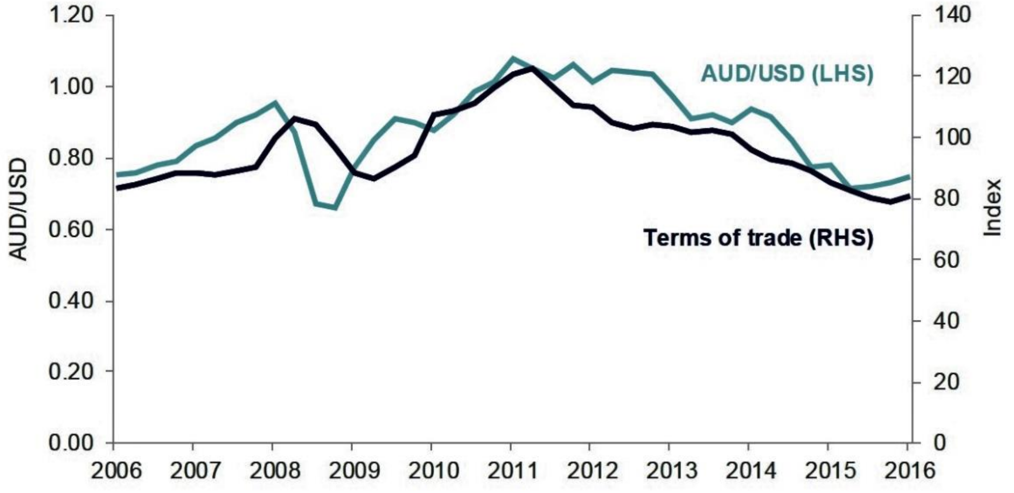
In 2015–16, the value of our top export (iron ore) fell 12.4 per cent to $47.7 billion, while the value of our second largest export (coal) fell 9.4 per cent to $34.3 billion. Values for our fourth largest export (natural gas) fell 2.1 per cent to $16.5 billion (OCE, 2016).

Australia’s third largest export is international education, which is not a part of the resources and energy sector. There is no evidence of the slowing Chinese economy having an impact on Australia’s international education sector. This particular sector continued to grow, with annual growth in international education in 2015–16 being 9.4 per cent. The Department of Education and Training data reveals that Chinese students were Australia’s major international student group during 2016. This particular Australian sector could provide necessary support for its economy during unfavourable periods of its commodity led growth.

2.1.2 Australian Exchange Rate and Terms of Trade Episodes

Australia’s resource boom was the key power behind its latest economic strength. However, that boom period is now transitioning into a production stage, which can be detected from the commodity production volumes of the Australian resource sector in 2016. The volume of iron ore and concentrates production increased by 66.3 per cent in 2012–13 and 2015–16 than 2008–09 and 2011–12.

However, during the mining investment boom Australia experienced a reversal in the appreciation of the Australian dollar. The increase in commodity volumes and lower international demand might have contributed to this. The value of the Australian dollar was at its peak of $1.08 USD in June 2011 and from there it fell to $0.71 USD in January 2016 (Figure 2.3). Economic theory suggests that a fall in the exchange rate should make Australian exports inexpensive overseas and imports costlier here at home, and hence boost the comparative competitiveness of Australian exports as well as firms challenging in the domestic market against imports. Recently, the bilateral exchange rate of Australia is again showing an increasing tendency.



Notes: Terms of trade data is quarterly, seasonally adjusted data. Exchange rate data is an average of each quarter.

Figure 2.3 Australia's exchange rate and terms of trade

Source: OCE (2016)

Australia’s terms of trade move by the influence of its exchange rate because of its relationship between exports and imports. Massive increases in Australia’s terms of trade occurred at the beginning of the 21st century. The historical increase in Australia’s terms of trade led to increases in the national income, government revenue and the income of ordinary Australians. However, its decreases have also been observed. Thus, decreases in the exchange rate can again be linked to decreases in Australia’s terms of trade, which continued into 2016. Australia’s terms of trade reached its lowest level in a decade during the June quarter of 2016.

The true magnitude of the changes in the exchange rate of a country relative to its trading partners can be represented by the nominal effective exchange rate (NEER) of a country, which is also known as the trade-weighted index. The bilateral exchange rate is not appropriate in this regard because it does not provide the information about the purchasing power of a particular currency (Kurilenko, 1998). However, theoretically the most common measure of changes in a country’s international competitiveness is not the NEER, but the real exchange rate (RER). Fazle (2011) stated that the various definitions of RER can be categorised under two main headings:

- The nominal exchange rate adjusted for price level differences between countries and
- The ratio of the domestic price of tradable to non-tradable goods within a single country.

The first definition is made in line with purchasing power parity (PPP) and the second definition is based on the dissimilarity between tradable and the non-tradable goods. This is also known as the Salter ratio (Chowdhury, 1998).

The Australian RER shows clear volatility between late 2008 and 2015; however, setting it against the scale of the real appreciation it looks fairly modest (Figure 2.4). This phase of the Australian RER occurred between December 2002 and March 2003. However, we can observe clear favour for Australian exporters from March 2003 when the RER began to depreciate (Figure 2.4).

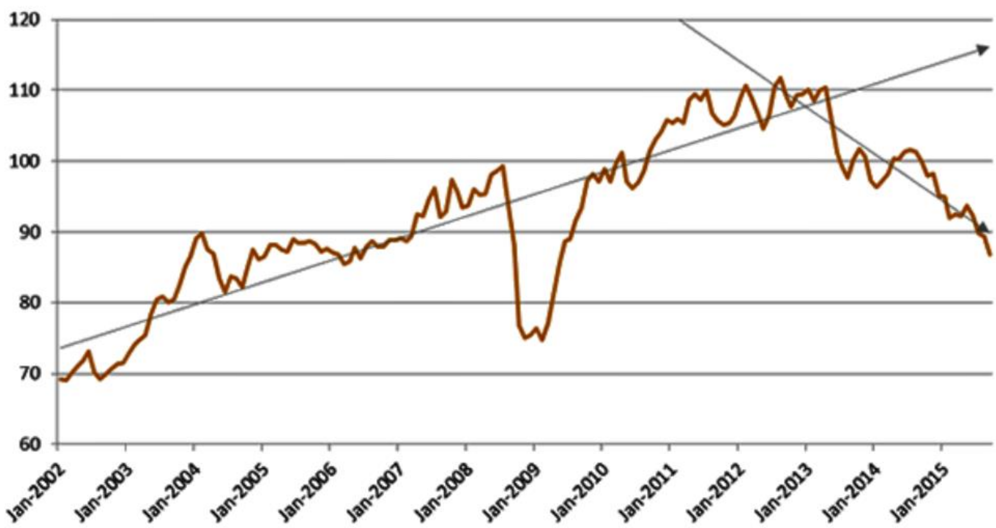


Figure 2.4 Real exchange rate index of Australia (Index, 2010 = 100)

Source: Bank for International Settlements (BIS) and Austrade, 2016

These swings on other Australian macroeconomic variables should be analysed carefully to develop the correct policy strategies at the appropriate time by policymakers.

2.1.3 Australian Monetary Policy, Investment and Productivity

Australian monetary policy choices are stated in terms of a target for the cash rate, which is the overnight interbank loan rate. This cash rate influences various macroeconomic variables in various ways: sometimes directly and occasionally indirectly (Figure 2.5).

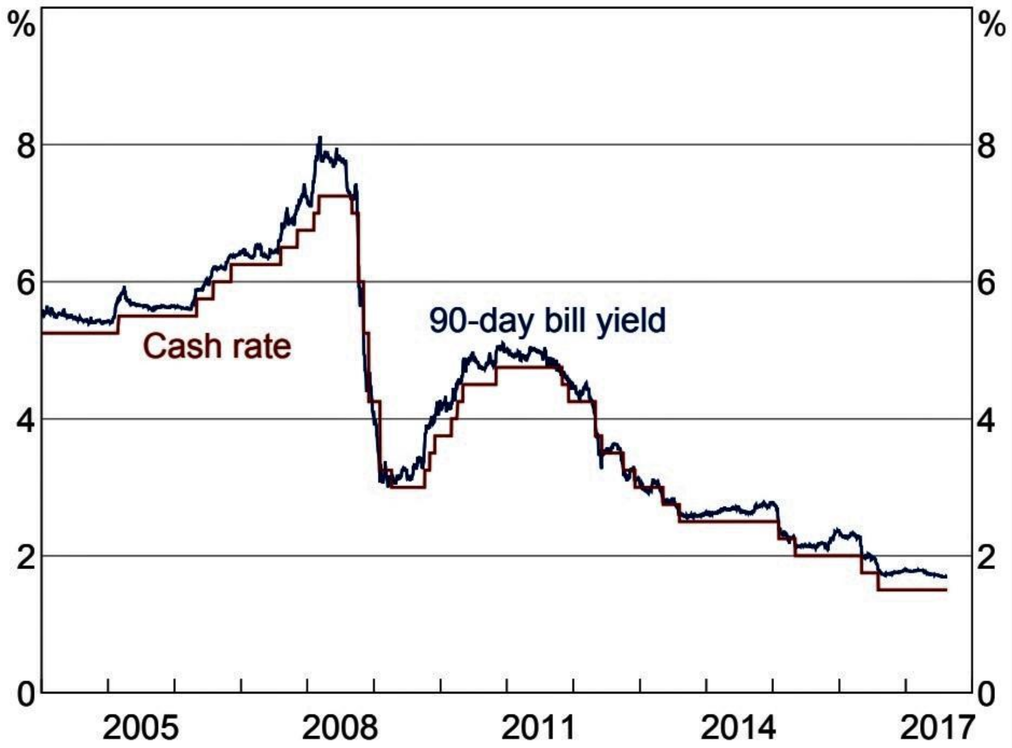


Figure 2.5 Australian Cash Rate and 90 - day Bill Yield

Source: Australian Stock Exchange (ASX) and RBA, 2017.

Economic theory advises that the cash rate moves the cost of capital and influences the investment judgements immediately based on standard approaches applied to assess investment opportunity. Researchers have shown various causes to describe the ongoing weakness in business investment both in Australia and overseas. In addition to low interest rates, these include weak demand, intensified uncertainty and reduced business confidence. It has also been reported that low interest rates do not directly encourage investment (Lane & Rosewall, 2015).

Based on a study by Lane and Rosewall (2015), irrespective of whether fluctuations in interest rates have a direct influence on investment choices or not, interest rates will still have a dominant indirect effect on firms' investment results via other passages, including their effect on aggregate demand (Figure 2.6).

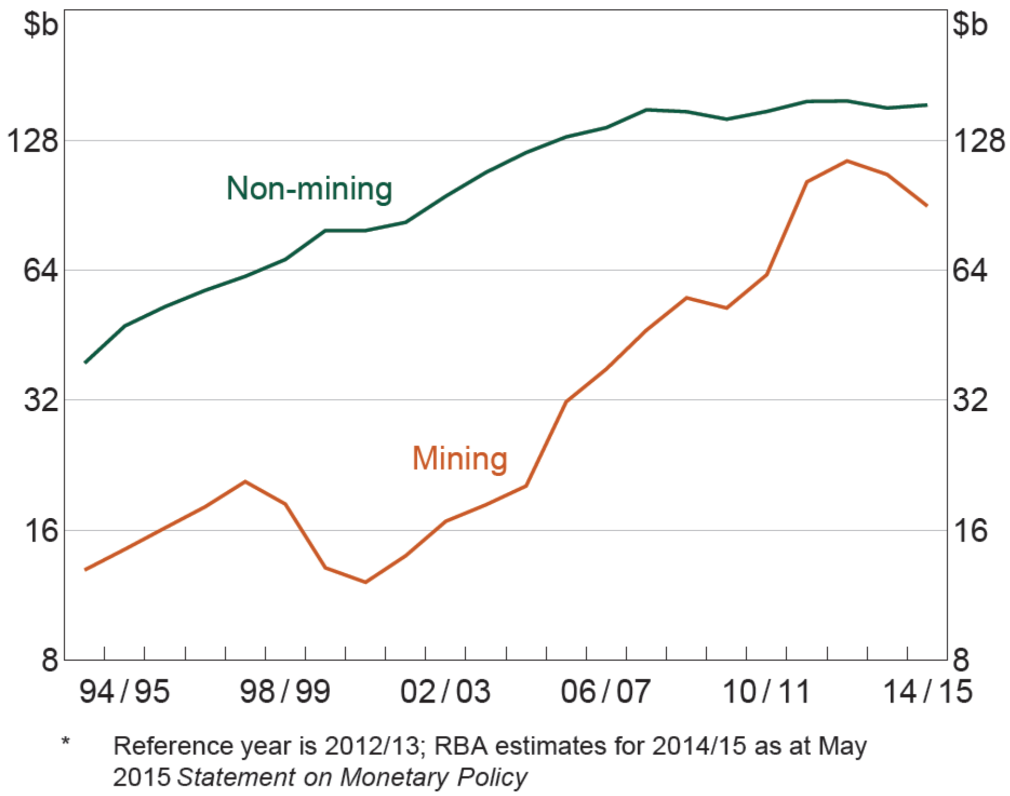


Figure 2.6 Private Business Investment (Chain volume, log scale)*

Source: Lane and Rosewall (2015)

The present study investigates the influence of interest rates on different macroeconomic variables via various channels. Even if the cash rate does not have a direct effect on investment decisions, overall investment in the economy can be influenced by commodity prices. In particular, investment in the mining sector grew strongly (Figure 2.6) as businesses responded to the historically high level of commodity prices (Carr, Fernandes, & Rosewall, 2017).

Tradable and non-tradable commodities respond differently to international competitiveness via their own price determination mechanisms. Both supply and demand powers describe the relative rise in the price of non-tradable items. On the supply side, there is the Balassa-Samuelson effect that explains productivity in the tradable sector tends to increase more rapidly than in the non-tradable sector (Balassa, 1964; Samuelson, 1964). The tradable sector generates more demand for labour owing to productivity growth and consequently the wage rates increase across the economy. This wage growth in turn increases prices of non-tradable items. However, the price of the tradable items is determined in the international markets.

Jacobs and Williams (2014) showed the above effect by analysing 20 years of Australia data, which is shown in Figure 2.7. The graphs do not fully explain the shift in relative prices and suggests to integrate China as an additional supply side factor into the global trading system to explain the price movement of tradable sector. However, the labour productivity gap shown in this research can explain S. Edwards' (1989) RER model, which predicted that productivity growth in traded sectors compared to non-traded sectors would push the RER to depreciate. However, further research and analysis is required after considering the other determinants of the RER in an Australian context such as is explained in the case of China by Dumrongrittikul (2012).

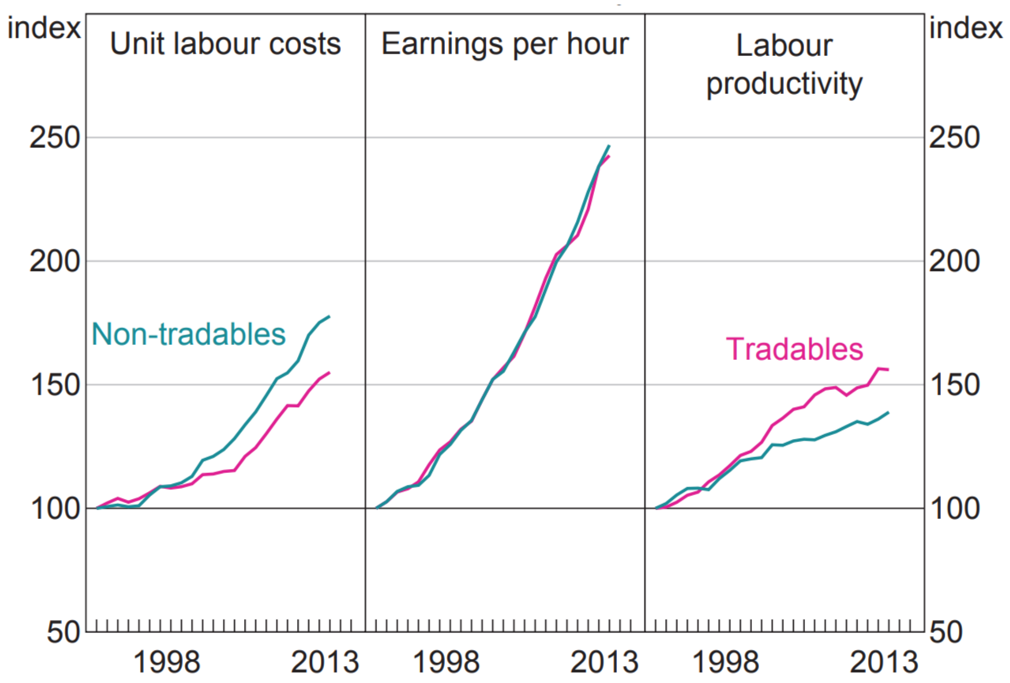


Figure 2.7 Labour Costs and Productivity Growth in Australia (1991 = 100, Financial Years)

Source: Jacobs and Williams (2014)

2.1.4 Australian Industrial Production Episodes

In Australia, industrial production measures the output of businesses integrated in the industrial sector of the economy such as manufacturing, mining and utilities. Australia's industrial production averaged 2.21 per cent from 1975 to 2017, reaching an all-time high of 12.40 per cent during the fourth quarter of 1987 and a record low of -7.80 per cent during the first quarter of 1983 (Figure 2.8).

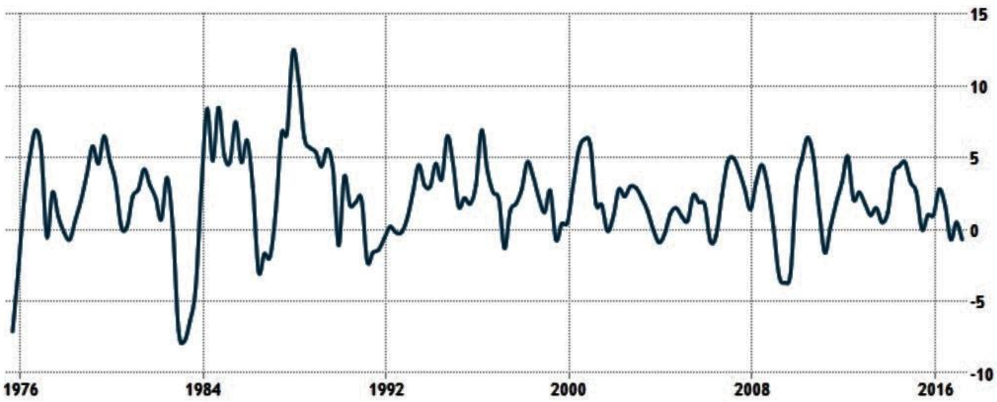


Figure 2.8 Australian Industrial Production Growth

Source: ABS, 2017

During 2016, Australia's industry sector and manufacturing sector experienced massive changes. Ford stopped its Australian production site in October and Adelaide declared the commencement of its Future Submarine Program. The tourism industry set new records during 2016 and Australian tourism related services grew by 11.2 per cent in 2015–16. Although the Australian economy crossed the resources investment boom, its production activities were still strong during this time.

The OCE Australian Industry Report (2016) indicated that, at 6.2 per cent, mining was the strongest performer in terms of output growth, compared to a relatively low employment growth of 1.0 per cent (Table 2.1). The taper in mining investment did not adversely affect demand for construction, with overall construction output and employment growing by 2.8 per cent and 1.8 per cent, respectively, in 2015 and 2016. Moreover, Australia experienced mixed results for the agriculture and manufacturing sectors recently. While both experienced a fall in output, agriculture gained a small increase in employment from a low base and manufacturing exports continued to grow (OCE, 2016, Table 2.1).

Table 2.1 Output and Employment by Industry in Australia, 2015 – 2016

Industry	Output ($ billion)	Share of GDP (per cent)	Employment (million)	Share of all industry (per cent)
Services	1,015.1	61.1	9.4	79.2
Mining	114.9	6.9	0.2	1.9
Construction	134.2	8.1	1.1	8.8
Manufacturing	99.4	6.0	0.9	7.4
Agriculture	36.7	2.2	0.3	2.7
All industries	**1,400**	**84.3**	**11.9**	**100**

Source: OCE (2016).

Notes: Output calculations applied original, chain volume measures data. Employment data utilised original data and averaged all quarters in 2015–16.

2.1.5 Australian Stock Market in 21st Century

The ASX is one of the world's top financial market exchanges. With a total market capitalisation of approximately $1.5 trillion, ASX is home to some of the world's prominent resource, finance and technology companies. The present study utilises the S&P/ASX 200 resources index. This index provides investors with sector exposure to the resources sector of the Australian equity market, which is classified as a member of the Global Industry Classification Standard (GICS) resources sector (Figure 2.9). The academic community has been interested in the connection between the financial markets and the economy for a long time; therefore, the present study attempts to determine some of the links between these two major sectors in an Australian context.

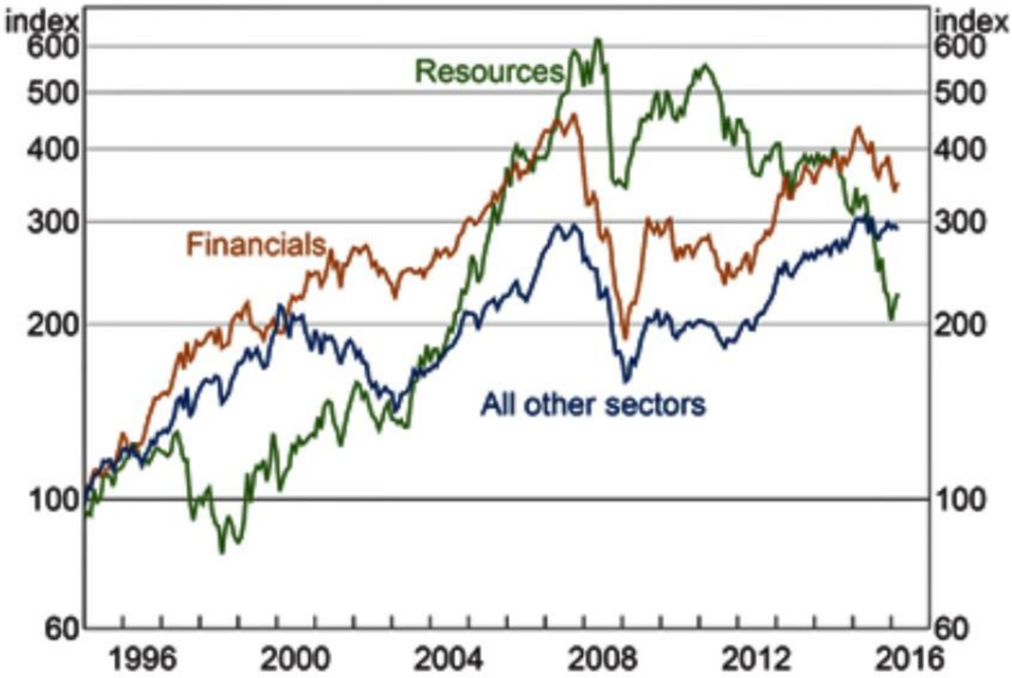


Figure 2.9 Australian Share Price Indices (Log scale, end December 1994 = 100)*

Source: RBA. * ASX 200 companies, 2017.

The present study considered the dynamic interaction between commodity prices and other macroeconomic variables and for that reason it only considered the resources share price. The Australian resource rich economy has experienced an upward trend in the share price index of resources. However, over the last few years this segment of the financial market has experienced a decreasing trend. ASX 300 resources index (capital only) shed 25.2 per cent in value during the 2015 calendar year (Lennox, 2016). The author discussed the China factor and the increasing US dollar as the reasons behind this negative return. The China story is still a dominating factor in investors' sentiment and many of them fear a sharp decline in the economy.

The Australian economy has been experiencing continuous economic growth with low unemployment rate. These positive achievement demonstrates that Australia is successfully transitioning away from the mining investment boom (OCE, 2016), which may definitely influence the stock prices, especially the resources stock. However, to obtain a better understanding of these dynamic effects, one needs to consider the influences of other macroeconomic variables also.

2.2 Concluding Remarks

Australia had stable real GDP growth of 2.8 per cent during 2015–16 with a very low unemployment rate of 5.6 per cent in September 2016. These indicate that Australians are in good position for their economic future. Nonetheless, other economic indicators represent Australia in a more mixed state, i.e. poor business investment quantities with low confidence and slow wage growth. Part-time employment has also increased in the Australian job market including underemployment status. The economy has experienced mixed performance in the manufacturing and agricultural industries. Stock prices, especially in the resources sector, are experiencing a volatile condition along with the Australian RER.

Therefore, this resource dependent economy needs to carefully analyse and manage its commodity-led growth pattern. Because the resource investment peaks have already been crossed, demand for labour in the resource sector is anticipated to decrease and the influence of resource investment to output growth can be retreated. Policies related to increasing export of resources and amplified production in this sector can switch part of this problem. Commodity prices will definitely play a vital role including the exchange rate movements resulting from price arrangements. Monetary policy makers toned to consider all the interacting factors cautiously to influence the commodity producing sector efficiently.

Australia may face challenges if the Asian demand for Australian commodities changes during the near future because of their consumption pattern and demand shift from the goods to the services sector. This transformation might appear to be detrimental for economies such as Australia as pointed out by Plumb, Kent, & Bishop (2013). However, this potential demand shift for household, business and financial services in Asia can be advantageous for the Australian economy because it has a well advanced and comparatively open services sector.

Chapter 3 LITERATURE REVIEW ON THE DYNAMICES OF COMMODITY PRICES

3.1 Introduction

The literature review in this section illustrates the latest variations in Australian commodity prices. Fluctuations in commodity prices have a dramatic impact on the Australian economy. Based on a study by Frankel and Rose (2010), every aspect of the determination of the commodity prices have fallen predominantly in the province of microeconomics. However, it becomes difficult to ignore the influence of macroeconomic phenomena when almost every type of commodity price begins to move in the same direction. It cannot be a concurrence that nearly all commodity prices worldwide increased together during much of the past decade, and peaked sharply and equally during mid-2008.

The increased commodity prices boosted Australia's mining exports, with the value of mining exports more than tripling over the past decade, whereas investment spending by the mining sector increased from 2 per cent to 8 per cent of GDP (Downes, Hanslow, & Tulip, 2014). The Australian mining boom has substantially increased Australian living standards; however, it has also led to a large appreciation of the Australian dollar. These effects had some influence on other industries exposed to trade. Thus, the stimulus of various macroeconomic variables cannot be ignored. It is very important to understand the influence of macroeconomic variables as determinants of the commodity prices for appropriate economic policy responses.

3.2 Theoretical Literature

Movements in commodity prices are very important for a country's external and internal balances as well as the fiscal and monetary policies of that particular country. For these reasons, policy makers are keen to identify the nature of these movements and simultaneously they have been trying to categorise the determinants of various commodity prices to suggest appropriate economic policies for their own economies.

3.2.1 Determinants of Commodity Prices in International Markets

The volatile behaviour of commodity prices is critical for both developed and developing countries. Therefore, both researchers and policy makers are interested in discovering the determinants of commodity prices. Frankel (1984) initially identified seven conceptions that were noticeable in the literature on the determination of commodity prices. These are discussed in the following sub-sections.

3.2.1.1 The Neutrality of Money

In the literature of commodity price determination, there is an established and clear contrast between the determination of relative prices of goods and the determination of the general price level of an economy. Money neutrality is regarded by many economists as a good guesstimate for an economy's long run behaviour. They believe that the real supply and demand factors for money, such as climate, tastes, and so on, of an economy determines the relative prices of goods within the system. On the other hand, the supply and demand for money without the concern of relative goods prices determine the general price level (Figure 3.1).

Frankel (1984) stated that a doubling of the money supply in an economy results in a doubling of all nominal prices. This sudden effect can also change relative prices and an attribute referred to as the homogeneity of the system helps keep relative prices unchanged. If we consider international trade in the system, then a doubling of a country's nominal prices would double the exchange rate, which would affect the relative prices of domestic and foreign goods if they are expressed in a common currency. PPP keeps these relative prices unchanged. In short, the neutrality of money exists with respect to the relative prices of goods.

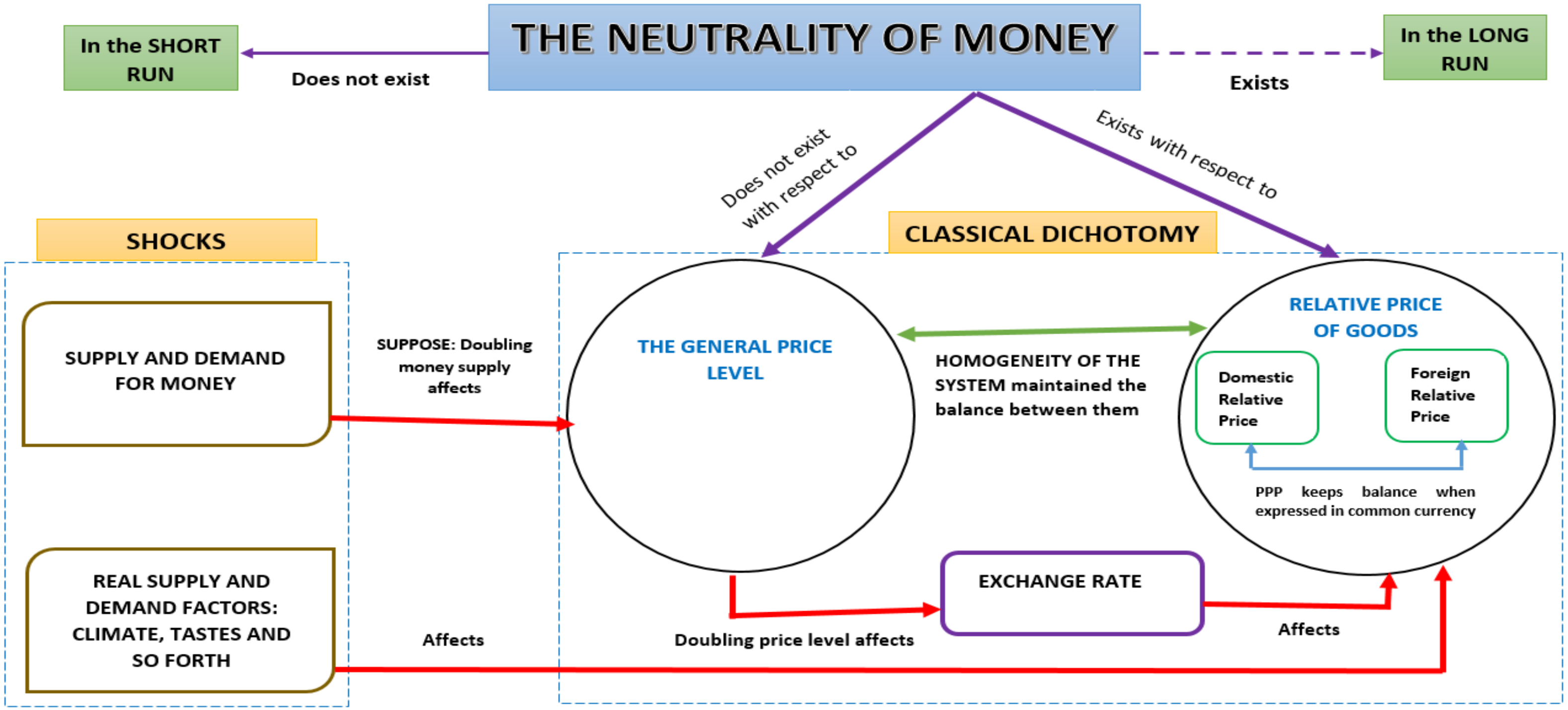


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Figure 3.1 The Neutrality of Money

3.2.1.2 Interest Rate Parity

The second concept that has become prominent in the literature on the determination of commodity prices is interest rate parity. Because of globalisation, world economies are interconnected. Therefore, economic variabilities in one area influence investors throughout the world. Features such as interest rates play a large role in influencing returns as do some other domestic factors. Thus, interest rate parity is definitely an important parameter to determine commodity prices internationally.

Speculators or investors mainly choose their investment opportunities to maximise expected return. If an investor wants to hold an asset willingly, there must be an expectation on the part of the investor for future increases in the dollar price of the asset. Interest rates provide information on this expected rate of appreciation. Interest rate parity can tell investors this information and there can be an extra term representing direct costs or returns obtained from holding the asset beyond the expectation of an appreciation of the alternative asset. If the asset in question is a foreign currency, the expected rate of appreciation is the expected rate of change in the dollar exchange rate and the extra term is the foreign interest rate. In other words, the expected rate of appreciation of the foreign currency against the dollar is equal to their own country's interest rate minus the foreign interest rate. Frankel (1984) also stated that if the asset in question is a storable commodity such as gold or wheat, the extra term is any utility derived directly from holding that minus the cost of storage including insurance, spoilage and so on.

3.2.1.3 Rational Expectations

The third concept determining commodity prices is the rational expectations. This concept was first formally introduced by Muth (1961) who clarified how expectations were shaped with the help of the analysis of the hog cycle. Muth's (1961) explanation advanced the hypothesis that expectations are fundamentally the same as the forecasts of the applicable economic theory. Especially, this hypothesis states that the economy usually does not waste information and that expectations depend precisely on the arrangement of the complete system (Figure 3.2).

Frankel (1984) stated that when we add rational expectations schemes to the proposition that there are no large transaction costs or government controls to detach investors from the assets they desire to hold, we obtain the proposition that the market is competent and all available information is mirrored in market prices. If we consider the monetary economic system, rational expectations suggest that today's market prices of the commodities will respond according to the known predictions of probable future money supply. Investors' believe that rapid monetary growth during the coming period will generate the expectations of price increments and thus the value of money will fall. This will cause investors today to shift out of money. In this way, the demand for money will increase. Therefore, the prices of alternative assets and commodities will increase immediately.

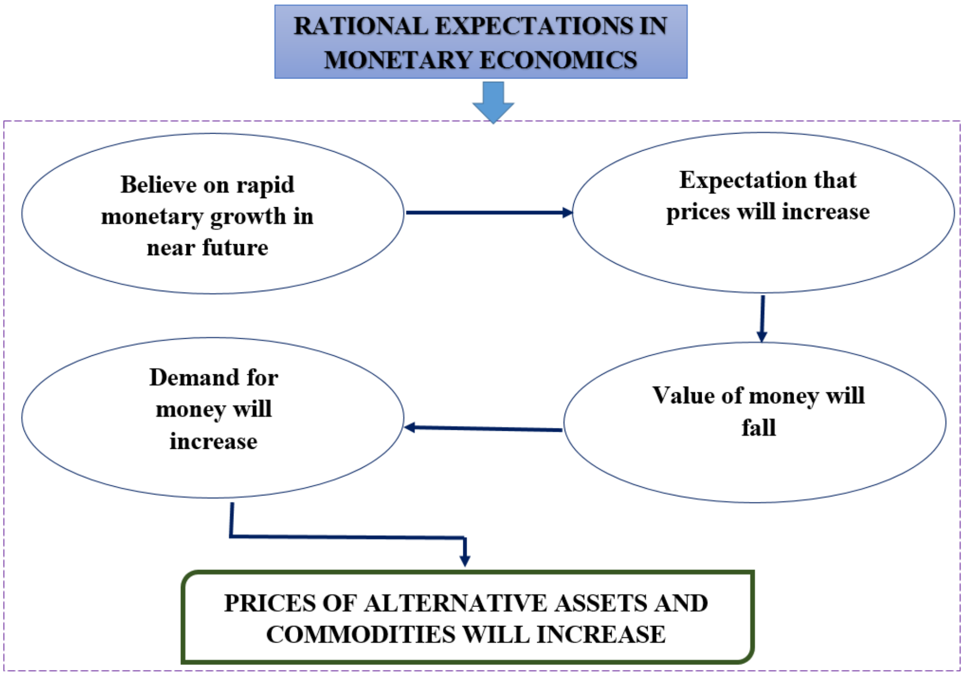

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Figure 3.2 Rational Expectations in Monetary Economics

Frankel (1984) stated that even if the money supply does not increase until a few years in the future, under rational expectations there will still be an increased influence on prices today. In fact, investors will see that today's market prices reflect a present discounted sum of the entire expected future path of the money supply.

3.2.1.4 The Magnification Effect

The magnification effect is the fourth concept in the literature on determination of commodity prices. This concept can be described with the help of rational expectations. Normally, an investor's expectations about the future path of the money supply can be described very simply. It can be seen as a trend in growth rate and a temporary present deviation around this trend. If the trend in money growth shows a random walk and if the money supply is detected to increase more than that projected, then rational investors will guess some positive probability of the chance that the trend growth rate has increased, as opposed to the possibility of a purely temporary deviation from the previously prevailing trend rate.

Under the above circumstances, Frankel (1984) stated that prices of foreign exchange and commodities might increase more than proportionately to the observed increase in the money supply. The cause for this is that the price levels would have to rise proportionately merely to maintain the real money balance from fluctuating. However, there will be a lower demand for real money balances because of higher expected rates of future money growth, inflation and exchange depreciation. Thus, based on the international finance context, the more than proportionate effect of the increase in the money supply on the exchange rate has been called the magnification effect (Figure 3.3).

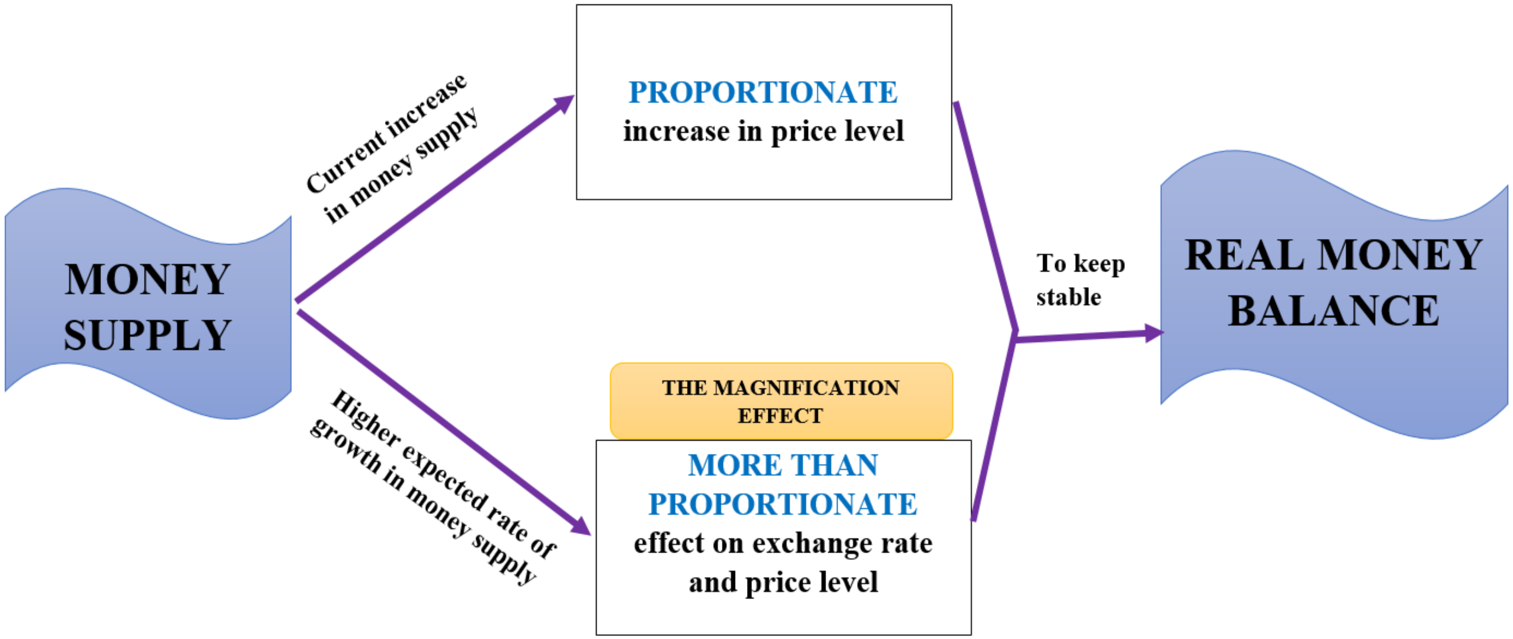

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Figure 3.3 The Magnification Effect

3.2.1.5 Overshooting

The overshooting model was initially developed by Dornbusch (1976) to explain the market for foreign exchange and was formally transformed to the framework of commodity prices in the study by Frankel (1986).

Frankel (1984) explained that decreases in the money supply is, in the long run, reflected in a proportionate decrease in the prices of storable commodities and services. Because a one per cent decrease in the money supply that is likely to be long-lasting can cause the price of commodities to fall in the long run by one per cent in the absence of new shocks. However, the prices of commodities are fixed in the short run. Thus, the decrease in the nominal money supply is a drop in the real money supply. In this situation, interest rates also rise to equilibrate money demand. However, the arbitrage condition of the commodity market must hold, i.e. since commodities are storable, the rate of return on domestic bonds can be no greater than the expected rate of increase of commodity prices plus storage costs. This means that the spot price of commodities must fall today and must fall by greater than the one per cent that it is expected to fall in the long run. In other words, commodities prices must overshoot their long-run value. When commodities are sufficiently undervalued to make the investors rationally expect a future rate of appreciation back toward long-run equilibrium, then investors become willing to hold the commodities. At this point, investors expect a future rate of appreciation in the commodity prices to offset the higher interest rate and, thus, the interest rate parity condition is met (Figure 3.4).

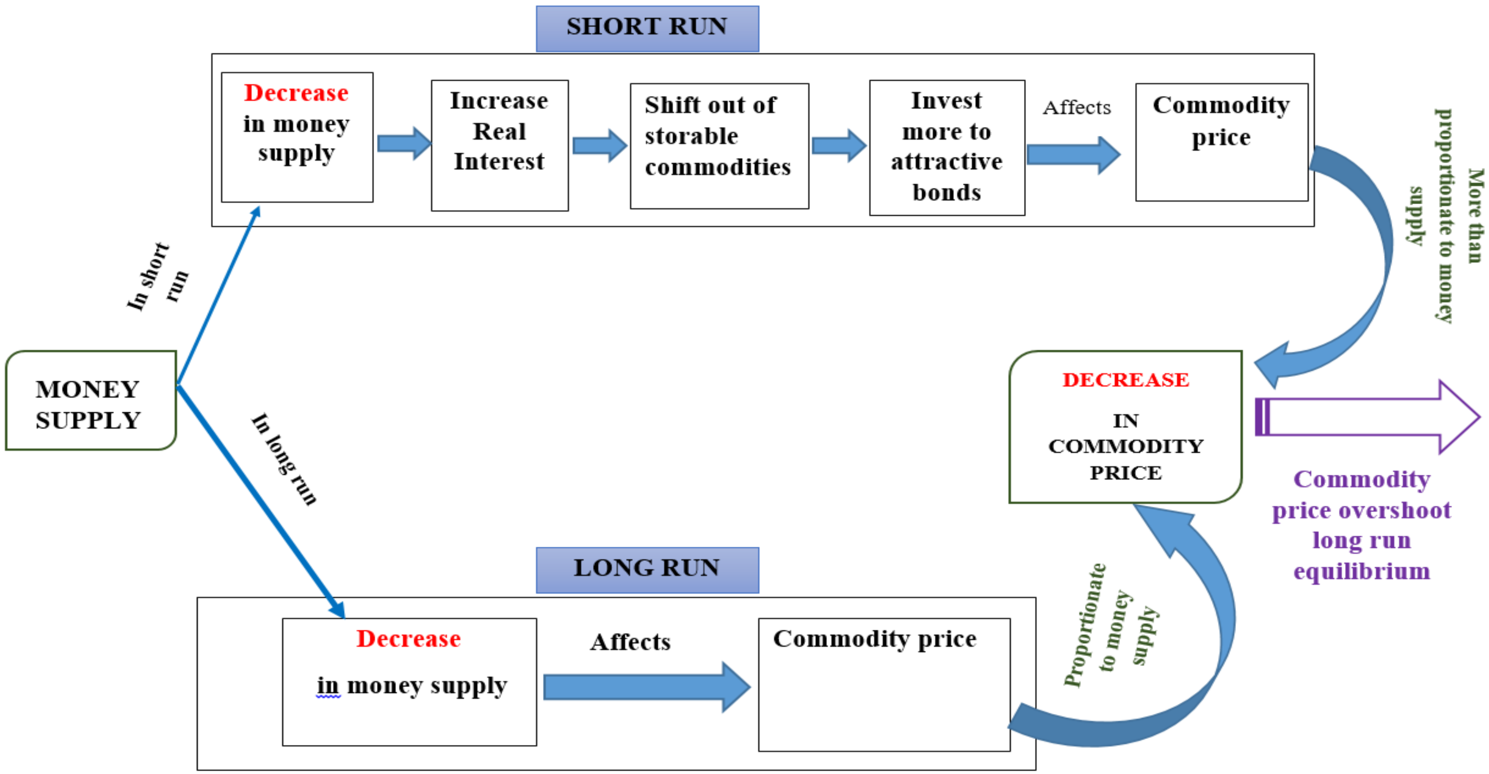

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Figure 3.4 Overshooting Feature of Commodity Prices

Frankel (1984) stated that commodities are similar to equities or other financial assets. Therefore, for a given known value at some future date, a rise in the interest rate today means that the present discounted value decreases. Besides this, investors might think of the flow demand for commodities as being determined in part by inventory demand. The interest rate is one of the costs of carrying inventories; therefore, increases in interest rates means an increase in costs, and thus a decline in the demand for the commodity. The final result will be decreased prices.

Frankel (1984) also demonstrated that if the decline in commodity prices can be matched by a decline in the general price level so that there is no change in the relative price of commodities, then one would not need the overshooting model. In a model where all prices are elastic, a drop in the rates of money growth and inflation would be enough to describe a decline in nominal commodity prices, but not a decrease in real commodity prices. Therefore, if we are to clarify the contributions of the macroeconomic influences to explain the decline in real commodity prices, we must depend on the overshooting model.

3.2.1.6 Reaction to News

Frankel (1984) stated that a market is considered an efficient one if the spot and future prices respond after obtaining public information on applicable economic variables; however, only to the degree that the variables diverge from what had earlier been anticipated. Understanding the market's reaction after obtaining these types of government announcements provides the researchers with the opportunity to study various macroeconomic interpretations as to how the world works. If the researchers can detect market prices instantly before and after the announcement is made, then they can think to have isolated its impact and to minimise the extent of the other developments that go into the error term (Figure 3.5).

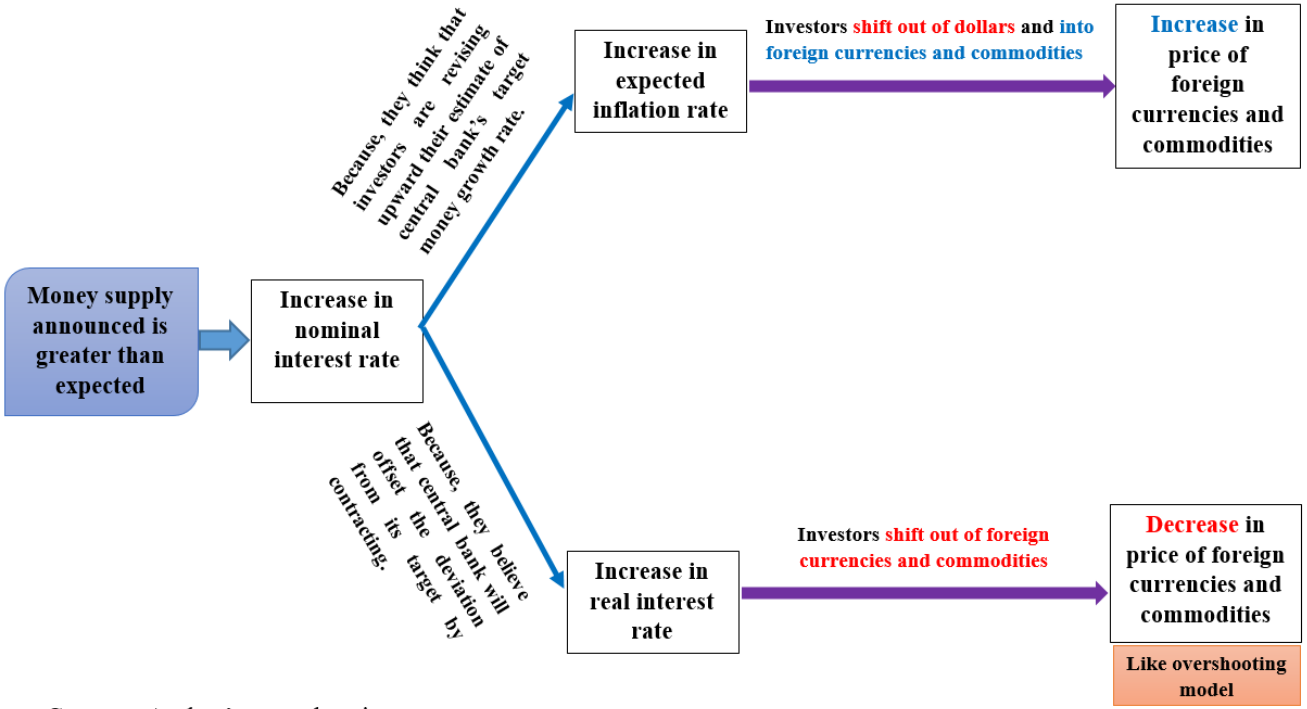

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Figure 3.5 Reaction to News on Commodity Prices

Frankel (1984) declared that the most broadly known statement is that when the money stock announced is greater than that had been expected, interest rates tend to jump in the same direction. The reason for this can be explained as the reaction to revised expectations about the future path of the money supply. However, nominal interest rates are widely considered to be a confusing gauge of expectations. One group of researchers believe that market investors revise upward their estimate of the central bank's target money growth rate in response to that unanticipatedly larger money announcement, and thus their expected inflation rate. Therefore, the initial increase in the nominal interest rate can be described by a rise in the inflation premium. The other point of view is that the surge in the nominal interest rate is an increase in the real interest rate. This can happen if market investors maintain confidence in the government's pledge to continue with the same money growth target. They trust that the central bank will rapidly act to balance the deviation from its aim by contracting, thereby increasing the real interest rate.

Interestingly, both views have the same consequences for interest rates. Therefore, one can choose between these two alternate views by looking at the responses in the foreign exchange and commodity markets. If the expected inflation rate increases, investors should shift out of dollars and into foreign currency and commodities, which would push up the prices of foreign currencies and commodities. On the other hand, if the real interest rate increases, investors should shift out of these alternative assets, thereby driving their prices down. This second option is similar to the overshooting model (Frankel, 1984).

3.2.1.7 The Risk Premium

The seventh concept in the literature for determining the commodity price is the risk premium. The traditional Theory of Storage by Kaldor (1939) was the starting point for risk premium discussion. This theory discusses the ‘cost of carry arbitrage’, which shows the link between the term structure of future prices and the level of inventories of commodities. This link expects that to encourage storage, future prices and expected spot prices of commodities have to increase sufficiently over time to reward inventory holders for the costs connected with that storage.

Gorton, Hayashi, and Rouwenhorst (2013) stated that in addition to market expectations of future spot prices, futures prices potentially embed a risk premium that is compensation for insurance against future spot price risk. This risk premium could be either positive or negative, depending on the number of people on each side of the market (Frankel, 1984).

Deaton and Laroque’s (1992) theory can be considered the modern version of the Theory of Storage. They principally explicate the behaviour of observed spot commodity prices. Future markets are ignored in their model. Routledge, Seppi, and Spatt (2000) extended the modern Theory of Storage with an introduction to the futures market into this model and demonstrated how the ‘convenience yield’ arises endogenously as a function of the inventory level and the shock of ‘harvests’ affect supply and demand of the commodity.

Gorton et al. (2013) proposed the extension of the models of Deaton and Laroque (1992) and Routledge et al. (2000). These authors stated that both the other two models’ agents are risk-neutral and, therefore, the commodity futures risk premium, which is central to the Theory of Normal Backwardation of Keynes (1930) and Hicks (1946), is zero by assumption. This model determines the risk premium paid by the inventory holders to risk adverse investors as a function of the extent of the size of the expected bankruptcy costs, the degree of risk aversion of the investors and the level of inventories. Deaton and Laroque (1992) showed that future spot price variance is negatively related to the level of inventories. Low inventories mean a higher variance of the future spot price due to an increased likelihood of a stock-out, resulting in the risk-averse long investors demanding a higher risk premium. Thus, the level of inventories matters for the risk premium.

3.2.2 Macroeconomic Drivers of Commodity Prices

From the beginning of this century, there have been severe ups and downs in commodity markets worldwide. The Australian experience has been no different from the rest of the world. There was an extensive feeling that favourable winds were blowing in the direction of Australia at the beginning of the current century. Much of the latest growth performance is usually credited to an infrequent situation of commodity prices and the terms of trade. In the latter case, we have observed an almost opposite scenario. Thus, commodity price shocks are definitely an important source of growth, volatility and uncertainty in a small open economy such as Australia.

Similar to many other countries globally, the Australian economy is heavily dependent on the commodity market. High commodity reliance impacts almost every policy standpoint in an open economy. Unstable prices enforce not only macroeconomic constraints over fiscal, monetary and exchange rate policies, but also influence consumers purchasing power, private and public savings, commercial policies and openness approaches, agricultural strategies, natural resources utilisation and investment provision among economic segments.

Therefore, the determinants of commodity prices are an important task. Frankel and Rose (2010) stated that enquiries related to the determination of prices for oil and other mineral and agricultural commodities have always fallen principally in the domain of microeconomics. However, there are times when many commodity prices are moving so far in the same direction that it becomes difficult to overlook the power of the macroeconomic phenomenon. For that reason, the present study attempts to shed light on the existing theories of identifying macroeconomic determinants of commodity prices at this stage.

3.2.2.1 The Theory of Ridler and Yandle (1972)

The variations in the value of the dollar have consequences on the real value of primary commodities and the revolutionary model of Ridler and Yandle (1972) presents a simple method of taking into account the number of exchange rate changes as they might influence the value of world exports of a primary commodity and the export earnings of a single country from the commodity. They applied comparative statics analysis in a single goods model to demonstrate that a real appreciation should result in a fall in dollar commodity prices.

Ridler and Yandle (1972) also showed that the magnitude of this negative elasticity should be less than one in absolute value since a 100 per cent general appreciation will cause a $100 * (1 - v_i)\%$ change in commodity i, where, v_i measures the relative significance of US as a producer and consumer of this good. This effect is known as the 'denomination effect' and has been utilised in the literature since then.

Bastourre, Carrera, and Ibarlucia (2007) argued that the Ridler and Yandle (1972) model is not consistent for utilising as a partial equilibrium model for each good without considering all possible interactions of commodity prices. Gilbert (1989) also stated that it is obviously inconsistent to compute the effects of an exchange rate change on the price of copper holding the price of aluminium constant, and then to compute the effect of the same change on the price of aluminium holding the price of copper constant. This feature inspired Chambers and Just (1979) to scrutinise the multi-commodity generalisation of the model of Ridler and Yandle (1972) from a different perspective. From this angle, the hypothesis of gross substitutability in production and consumption is enough to guarantee that the dollar exchange rate to commodity prices elasticity stays within the unit interval.

3.2.2.2 The Theory of Dornbusch (1985)

Dornbusch (1985) assumed global integration among the world commodity markets. His paper sets out a two-country market clearing model to describe external influences on relative commodity prices. The model assumed two consuming regions, domestic (US) and the rest of the world as 'the foreign country' and denoted by an asterisk. World demand for commodities depends on the real price of commodities in terms of the GDP deflators in each of the two regions and on real activity. The supply of commodities (S) is assumed to be exogenous:

$$S = D\left(\frac{P_c}{P}, \quad Y\right) + D^*\left(\frac{P_c^*}{P^*}, \quad Y^*\right) \text{ -------------- } (3.1)$$

where,

Y, Y^* are domestic and foreign activity;

P_c, P_c^* are commodity prices in home and foreign currency;

P, P^* are the domestic and foreign deflators in the respective currencies.

It is assumed that:

$$P_c = e\, P_c^* \text{------------------- } (3.2)$$

Owing to full arbitrage in commodity markets, the general solution for the variable of interest is:

$$\frac{P_c}{P} = H\left(Y, \quad Y^*, \quad \frac{P}{eP^*}; \quad S\right); \quad H_1, H_2 > 0; \;\; H_3 < 0 \text{ ------------- } (3.3)$$

This means that real commodity prices in dollars are positively related to domestic as well as foreign activity and are negatively influenced by the domestic effective real exchange rate ($\frac{P}{eP^*}$).

This model is shown in Figure 3.6. The schedule $D + D_0^*$ symbolizes world demand, which is prepared for a given RER and a given level of world activity. The preliminary equilibrium real price is $\left(\frac{P_c}{P}\right)_0$. The model suggests that an increase in activity raises real commodity prices. Dornbusch (1985) stated that this is the cyclical effect that until recently was the major macroeconomic effect noted in work on commodity prices. However, equation (3.1) illustrates that a real appreciation of the domestic currency will lower real commodity prices in terms of the domestic deflator while raising them in terms of foreign deflators.

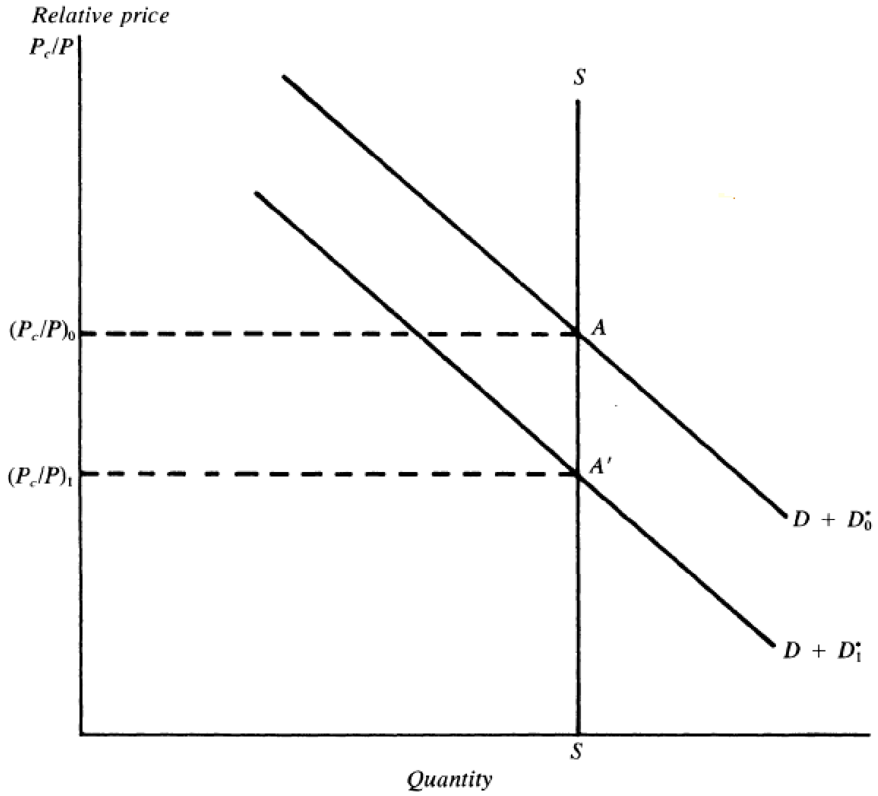


Figure 3.6 World Commodity Market

Source: Dornbusch (1985).

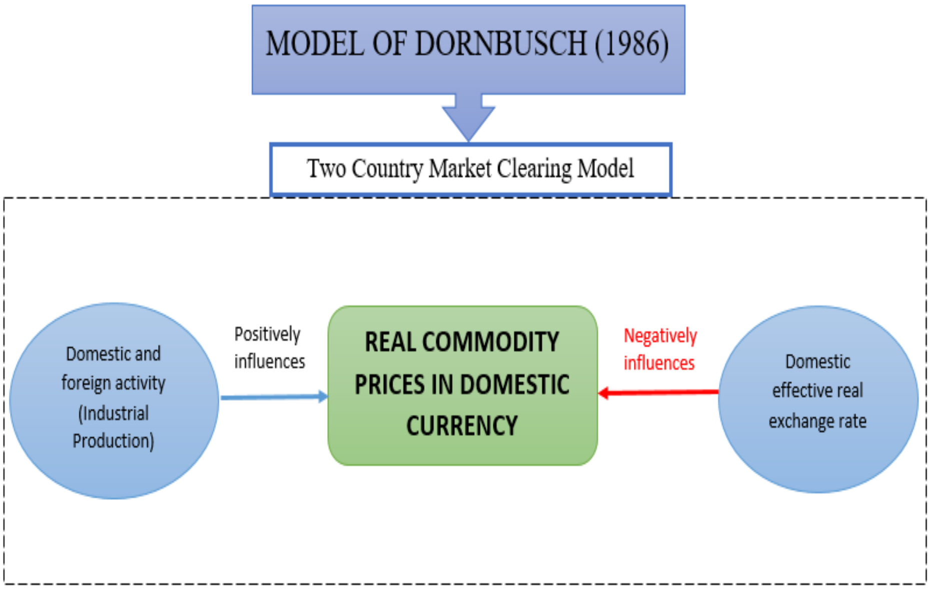
Dornbusch (1985) described the result of the above model in the following terms. Suppose that the GDP deflator in each country is given and the exchange rate moves. At a given domestic price of commodities, the real price at home would be unchanged. However, with the dollar appreciation, the foreign price of commodities is now higher and so is the real price abroad. Consequently, quantity demand abroad declines and there is a world excess supply, as shown by the downward shift of the world demand schedule in Figure 3.6. To restore equilibrium the real price in terms of the domestic deflator must fall to $\left(\frac{P_c}{P}\right)_1$.

Bastourre et al. (2007) discussed the model of Dornbusch (1985) and stated that the model shows similar features to Ridler and Yandle (1972) in that the elasticity of commodity prices to the RER would be less than one in absolute value. From equation (3.1) it is clear that the percentage change in the equilibrium price due to a real dollar appreciation is equal to:

$$\frac{\partial\, ln\left(\frac{P_c}{P}\right)}{\partial ln\left(\frac{P}{eP^*}\right)} = \frac{\frac{-\beta^*}{\eta^*}}{(\beta\eta+\beta^*\eta^*)} \text{ -----------------------------} \quad (3.4)$$

where, η and η^* are the domestic and foreign price elasticities of commodity demand, respectively, and β and β^* are the shares of the home country and the rest of the world in total demand, respectively. The elasticity of equilibrium price in terms of the domestic deflator therefore must be a fraction. With equal demand elasticities, the elasticity reduces to the foreign share in world demand.

To encapsulate, Dornbusch (1985) stated that growth in industrialised countries applies a solid effect on less developed countries' terms of trade. Since the prices of commodities in terms of the domestic deflator exaggerate the domestic RER, the real commodity price in terms of industrial countries' exports tends to decrease with a strengthening of the domestic currency (Figure 3.7). The consequence is that less developed countries have an interest not only in growth in industrial industries, but also in the sharing of growth between areas and in the policy mix, both of which affect the value of the domestic currency and hence the terms of trade. Other things being equal, a strengthening of the domestic currency will deteriorate the terms of trade of net commodity exporters and hence diminish their welfare. For net commodity importers, the opposite arrangement holds.



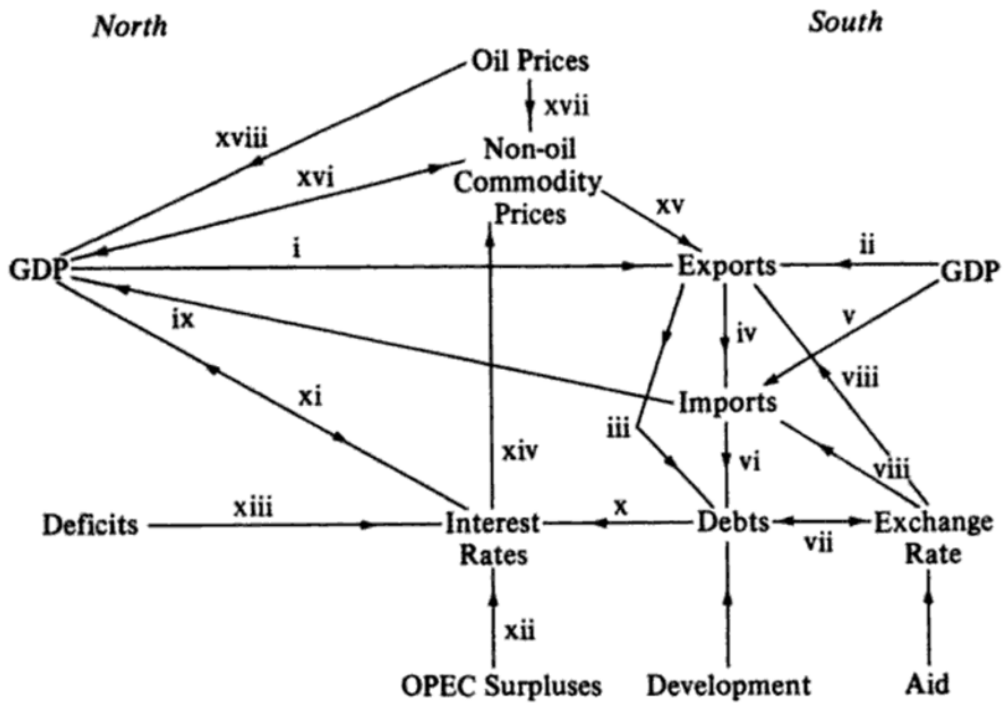
Source: Author's own drawing

Figure 3.7 Model of Dornbusch (1985)

3.2.2.3 The Theory of Beenstock (1988)

Beenstock (1988) showed a few factors that influence the world commodity prices as part of a general model of North-South interdependence (Figure 3.8). The model demonstrates that global economic activities operate within the geopolitical background that motivates global economic indicators settled by the International Monetary Fud (IMF). Thus, the world is separated into the following unions:

- Industrial countries (North),
- Oil importing developing countries (South),
- Oil exporting countries (Organization of the Petroleum Exporting Countries [OPEC]) and
- Centrally planned economies.



Source: Beenstock (1988).

Figure 3.8 Flow Chart of North-South Model

Inside the model, Beenstock (1988) pointed out two components of non-oil commodities demand. One is the flow element that reflects consumption of raw materials in the production process. The other is a stock element connected to speculative inventory demand for commodities. Therefore, the former varies directly with economic activity and inversely with the relative price of non-oil commodities. Whereas, the latter varies directly with the expected real capital gain on commodity holdings and inversely with the real rate of interest. The supply of commodities reflects their relative price as well as the relative price of oil.

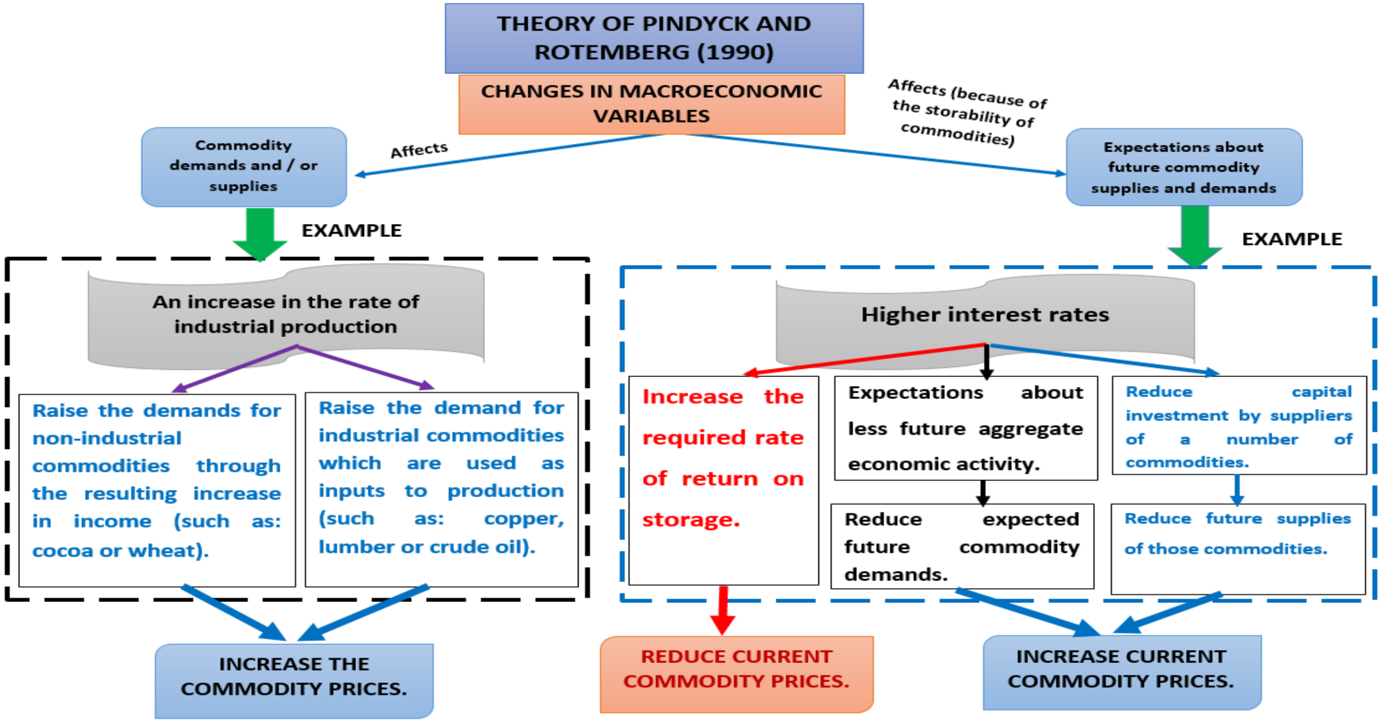
Although the model of Beenstock (1988) did not address structural issues, the following main lessons can easily be understood from testing of this model:

- The North affects the South to a much greater extent than vice-versa.
- Southern imports do not appear to influence Northern economic activity to any significant extent.
- Transfers of capital and aid from North to South induce 'Dutch Disease' in the South.
- The benefits to the South of expansion in the North are magnified by commodity price increases and associated terms of trade gains in the South.
- When oil prices increase, the harm to the South is partly counterbalanced by increases in the relative price of non-oil commodities.

3.2.2.4 The Theory of Pindyck and Rotemberg (1990)

Pindyck and Rotemberg (1990) investigated and endorsed the presence of a mystifying phenomenon that revealed that the prices of raw commodities have a persistent trend of changing together. Their investigation for excess co-movement was also a test of the typical competitive model of commodity price construction with storage. However, this excess co-movement casts doubt on the competitive commodity price model and a possible justification for it is that commodity movements are to some magnitude the consequence of 'herd' behaviour in financial markets.

Pindyck and Rotemberg (1990) demonstrated that the prices of a broad set of commodities may move together because of changes in macroeconomic variables. The reason for this is that it can influence demands and/or supplies of those commodities and these changes can affect prices in two ways. These two processes are shown in Figure 3.9.



Source: Author's own drawing

Figure 3.9 The Explanatory Power of Current and Past Macroeconomic Variables

The model of Pindyck and Rotemberg (1990) is similar in structure to the finished goods inventory model of Eichenbaum (1983) and is also similar to the commodity price models of Turnovsky (1983) and Stein (1986). Pindyck and Rotemberg (1990) formalised the model by writing the net supply of commodity i at time $t, Q_{i,t}$, as:

$$Q_{i,t} = a_{i,t} + b_i p_{i,t} \text{ ------------------------ } (3.5)$$

where, $p_{i,t} = log P_{i,t}$ and $P_{i,t}$ is the price of commodity i at t. The index $a_{i,t}$ captures changes in both supply and demand and depends on both commodity specific variables (e.g. a strike by copper miners or bad weather), as well as current and lagged values of a vector of macroeconomic variables (e.g. the index of industrial production, interest, inflation, and so on) that can affect many commodities. The evolution of inventory, $I_{i,t}$, is given by the accounting identity:

$$I_{i,t} = I_{i,t-1} + Q_{i,t} \text{ -------------------------- } (3.6)$$

Finally, under the assumption that risk-neutral inventory holders maximise expected profits, the evolution of the price of commodity i is given by:

$$r_t = \frac{[E_t P_{i,t+1} - C_{i,t} - P_{i,t}]}{P_{i,t}} \text{ -------------------- } (3.7)$$

where, r_t is the required rate of return, E_t is the expectation conditional on all information available at time t, and $C_{i,t}$ is the one-period holding cost of the commodity, less the capitalised flow of its marginal convenience yield over the period.

One can obtain benefits from holding stocks and that flow of benefits is the convenience yield. At the margin, the convenience yield depends on the total quantity of inventory held. It also depends on macroeconomic variables. Suppose an increase in industrial production raises the consumption of industrial commodities and, therefore, increases desired stocks. In Pindyck and Rotemberg's (1990) model $c_{i,t}$, the logarithm of $C_{i,t}$, as a linear function of $I_{i,t}$:

$$c_{i,t} = n_{i,t} + \gamma_i I_{i,t} \text{ --------------------------------- } (3.8)$$

where, $n_{i,t}$ is a function of current and past values of the vector of macroeconomic variables.

Equation (3.7) states that prices at t depend on expected future prices. Thus, current prices depend on anticipated future situations in the industry. Pindyck and Rotemberg (1990) assumed that predictions of the vector of macroeconomic variables, x_t, were based on current and past values of x_t, and also on current and past values of a vector z_t of exogenous economic variables that do not directly affect commodity prices (e.g. the money supply and the stock market):

$$E_t x_{t+j} = \theta_j(L)x_t + \varphi_j(L)z_t \text{ ---------------------- } (3.9)$$

where, $\theta_j(L)$ and $\varphi_j(L)$ are matrix polynomials in the lag operator L. Thus, the form of the estimable equation is:

$$\Delta p_{i,t} = \sum_{k=0}^{K} \infty_{ik} \, \Delta x_{t-k} + \sum_{k=0}^{K} \beta_{ik} \, \Delta z_{t-k} + \epsilon_{i,t} \text{ ------------------- } (3.10)$$

where, $\epsilon_{i,t}$ is serially uncorrelated and, under a null hypothesis, $E(\epsilon_{i,t}\epsilon_{j,t}) = 0$ for all $i \neq j$. To allow for the possibility that $\epsilon_{i,t}$ is serially correlated, Pindychk and Rotemberg (1990) also estimated the following equation:

$$\Delta p_{i,t} = \sum_{k=0}^{K} \infty_{ik} \, \Delta x_{t-k} + \sum_{k=0}^{K} \beta_{ik} \, \Delta z_{t-k} + \rho_i \Delta p_{i,t-1} + \epsilon_{i,t} \text{ ---------- } (3.11)$$

Equations (3.10) and (3.11) represent a simple concept, i.e. the prices of dissimilar commodities should change together completely in response to market participants' changing observations of the macroeconomic situation.

3.2.2.5 The Theory of Reinhart and Borensztein (1994)

Reinhart and Borensztein (1994) showed that the 'traditional structural approach' to defining real commodity prices has depended entirely on demand factors as the fundamentals, which describe the characteristics of commodity prices. However, this 'traditional structural approach' was inadequate for enlightening the clear and continuous weakness in the prices of commodities during the 1980s and 1990s. Rather, Reinhart and Borensztein (1994) extended the framework in two significant directions.

First, the extended model integrated commodity supply in the analysis and demonstrated the influence on prices of the sharp rise in commodity exports of developing countries during the debt crisis of the 1980s.

Second, this new extended model took a broader view of 'world' demand to extend beyond the industrial countries and includes output developments in Eastern Europe and the Soviet Union.

Thus, Reinhart and Borensztein (1994) linked real commodity prices to several key macroeconomic determinants. In their model, they assumed that the commodity was non-storable and internationally traded and also assumed that there were three countries, where the third country was considered to be a developing commodity supplier.

DEMAND FOR COMMODITIES

The demand for commodities is usually formulated as the demand for an input that is utilised for the production of final goods. Inputs are the demand for the commodities of two countries, i.e. the home country and an aggregate of the rest of the industrial countries. Production is considered to take place under a Cobb-Douglas technique. The cost function consistent with this method is as follows:

$$C(y, q, \omega) = yAq^{\alpha}\Omega \text{ --------------------- (3.12)}$$

where, y is the level of output in the domestic country, q is the price of non-oil commodity inputs relative to the price of domestic output, A is a constant, and Ω represents the contribution of other inputs to cost and is given by the product of functions of their real prices:

$$\Omega = \Pi\omega_i^{\beta^i} \text{ --------------------------- (3.13)}$$

where, the ω_i, $i = 1, \ldots, N$ represent real product prices of all the other inputs and factors utilised in production. Likewise, for the other industrial countries, the dual cost function is given by:

$$C^*(y^*, q, R, \omega^*) = y^*A^*(qR)^{\alpha}\Omega^* \text{ --------------------- (3.14)}$$

where, R is the ratio of the price of domestic output to the output of other industrial countries (the RER of the home country), and variables with a superscript asterisk have the same definition as in the domestic case but correspond to the "other industrial country" grouping. The demand for commodities by the two countries is given by:

$$M(y, q, \omega) = yA\alpha q^{\alpha-1}\Omega \text{ ------------------------- (3.15)}$$

And

$$M^* \,(y^* \,, q \,, R, \omega^*) = \; y^* A^* \alpha q^{\alpha-1} R^{\alpha-1} \Omega^*$$ ------------------------- (3.16)

SUPPLY AND MARKET CLEARING

According to Reinhart and Borensztein (1994), the supply of the commodity of an aggregate of developing countries is assumed to be fixed during a particular point in time. Commodity prices will then be determined to match present supply with the total demand by the two countries:

$$Q = M + \; M^*$$ ------------------------- (3.17)

To avoid inconvenient nonlinearities, the model assumes that the relative shares in commodity demand by the two countries stay constant, that is:

$$\frac{M}{M+ M^*} = \; \lambda \,; \quad \frac{M^*}{M+ M^*} = 1 - \; \lambda$$ -------------------- (3.18)

A composite demand for commodities is possible to form at this stage by applying equations (3.15) and (3.16) above. The market-clearing commodity price can then be obtained by equating supply and demand as follows:

$$log\, q = K + \; \frac{1}{1- \alpha} log\, IPW - (1 - \; \lambda)\, log\, R - \; \frac{1}{1- \alpha} log\, Q$$ ------------- (3.19)

where, $\log IPW = \; \lambda \log y + (1 - \; \lambda) \log y^*$ represents the aggregate level of production in the two countries (world industrial production), and K includes constant terms and terms in the other factors of production.

Equation (3.19) is a partial equilibrium specification of the market for commodities. A general equilibrium representation should specify the endogenous determination of the supply of commodities Q, the RER R, and the level of composite output IPW. This model shows that these variables can be determined jointly by aggregate demand conditions, factor market equilibrium, and government policies in the two countries and in the countries in which production of commodities occurs. Thus, the model shows the link of real commodity prices to several key macroeconomic determinants.

3.2.2.6 The Theory of Frankel and Rose (2010)

The theoretical model of Frankel and Rose (2010) presents the determination of prices for storable commodities that provides full expression to such macroeconomic aspects as economic activity and real interest rates. This model also considers other fundamentals related to commodity price determination and a number of microeconomic factors including inventories.

The theory of Frankel and Rose (2010) is similar to the prominent theory of exchange rate overshooting of Dornbusch (1976), although the price of commodities is substituted for the price of foreign exchange and the convenience yield is substituted for the foreign interest rate. The elements of the Frankel and Rose (2010) model have long been known to researchers (e.g. Frankel (1986; 2006)). The theory can be concentrated to its modest algebraic principle as a relationship between the real interest rate and the spot price of a commodity relative to its expected long-run equilibrium price. This connection can be derived from two simple hypotheses. The first directs expectations. Let:

s ≡ the natural logarithm of the spot price,

$\bar{s}$ ≡ its long-run equilibrium,

p ≡ the (log of the) economy wide price index,

$q \equiv s - p$, the (log) real price of the commodity, and

$\bar{q} \equiv$ the long run (log) equilibrium real price of the commodity.

Market contributors who notice that the real price of the commodity today is either above or below the observed long-run value presume that it will regress back to equilibrium in the future over time, at an annual rate that is proportionate to the gap:

$$E\,[\Delta(s-p)] \equiv E[\Delta q] = -\theta\,(q - \bar{q}) \text{ -------------------- } (3.20)$$

Or $E(\Delta s) = -\theta(q - \bar{q}) + E(\Delta p)$ ---------------------------------- (3.21)

Following the classic Dornbusch (1976) overshooting model, which established the model for the case of exchange rates, this model begins by simply stating the rationality of the form of expectations in these equations.

The model of Frankel and Rose (2010) considers another alternative that expectations also have an extrapolative element:

$$E\,(\Delta s) = -\theta(q - \bar{q}) + E(\Delta p) + \delta\,(\Delta s_{-1}) \text{ --------------------------- } (3.22)$$

The next equation shows the choice whether to hold the commodity for another period (e.g. leaving it in the ground, on the trees, or in inventory) or to sell it at today’s price and use the earnings to gain interest. The expected rate of return for these two alternatives must be the same:

$$E\,(\Delta s) + c = i \text{ ---------------------------------- } (3.23)$$

where,

$c \equiv cy - sc - rp$;

$cy \equiv$ convenience yield from holding the stock;

$sc \equiv$ storage costs;

$rp \equiv E(\Delta s) - (f - s) \equiv$ risk premium, where f is the log of the forward/futures rate at the same maturity as the interest rate; and

$i \equiv$ the nominal interest rate.

There is no reason why the convenience yield, storage costs or risk premium should be constant over time. If one is interested in the derivatives markets, the forward discount or slope of the futures curve, $f - s$ in log terms, is given by:

$$f - s = i - cy + sc, \text{ or equivalently } f - s = E(\Delta s) - rp \text{ ---------- } (3.24)$$

On average $f - s$ tends to be negative. According to Kolb (1992), this characteristic, ‘normal backwardation’, suggests that convenience yield on average outweighs the interest rate and storage costs. To obtain the main result of this theoretical model, Equations (3.22) and (3.23) are combined:

$$-\theta\,(q - \bar{q}) + E(\Delta p) + c = i \;\; => q - \bar{q} = -\left(\frac{1}{\theta}\right)(i - E(\Delta p) - c \text{--- } (3.25)$$

Equation (3.25) states that the real price of the commodity, measured relative to its long-run equilibrium, is inversely proportional to the real interest rate. When the real interest rate is high, as during the 1980s in the United States, money will flow out of commodities, just as it flows out of foreign currencies, emerging markets and other securities. This will remain until the prices of commodities are perceived to lie adequately below their future equilibria, creating expectations of future price increases, at which point the quasi-arbitrage state will be met. On the other hand, when the real interest rate is low, as in 2001–05 and 2008–09, money will flow into commodities. This will continue until the prices of commodities are perceived to lie adequately above their future equilibria, creating expectations of future price decreases, to satisfy the speculative condition.

Under the alternate arrangement that leaves a probable role for bandwagon effects, Frankel and Rose (2010) combined Equations (3.22) and (3.23) to obtain:

$$q - \bar{q} = -\left(\frac{1}{\theta}\right)(i - E(\Delta p) - c) + \left(\frac{\delta}{\theta}\right)(\Delta s_{-1}) \text{ --------------- } (3.26)$$

As previously noted, there is no reason for the net convenience yield, c, in Equation (3.25) to be constant. Substituting from (3.23) into (3.25):

$$c \equiv cy - sc - rp \Rightarrow$$

$$q - \bar{q} = -\left(\frac{1}{\theta}\right)[i - E(\Delta p) - cy + sc + rp] \Rightarrow$$

$$q = \bar{q} - \left(\frac{1}{\theta}\right)[i - E(\Delta p)] + \left(\frac{1}{\theta}\right)cy - \left(\frac{1}{\theta}\right)sc - \left(\frac{1}{\theta}\right)rp \text{ -------------- } (3.27)$$

Thus, even if the long-run equilibrium $\bar{q}$ is taken as a given, there are other variables in addition to the real interest rate that determine the real price, e.g. the convenience yield, storage costs and the risk premium. However, the long-run equilibrium real commodity price $\bar{q}$ does not necessarily need to be constant.

An extra proposition of interest is that storable commodities might assist as a hedge against inflation. From this perspective, an increase in the expected long-run inflation rate would then raise the demand for commodities, thereby increasing current real commodity prices. Adding the lagged inflation rate as a distinct explanatory variable in the equation is thus another likely method for determining the influence of monetary policy on commodity prices.

One way to detach monetary effects on commodity prices is to look at jumps in financial markets that occur in immediate response to government announcements that change insights of the macroeconomic condition. Frankel and Hardouvelis (1985) tested the monetary consequences of this general theory of commodity price determination and their model utilised Federal Reserve money supply announcements. Announcements related to tighter monetary policy induced statistically significant decreases in commodity prices, i.e. money announcements that caused interest rates to increase would on average cause commodity prices to fall, and vice versa.

By translating Equation (3.27) into empirically usable form, there are several measurable determinants of the real commodity prices, which are discussed separately below.

INVENTORIES

Storage costs increase to the extent that inventory holdings strain existing storage capacity: $sc = \Phi\ (INVENTORIES)$.

If the level of inventories is observed to be at the high end historically, then storage costs must be high, which has a negative effect on commodity prices. Substituting into Equation (3.27),

$$q = \bar{q} - \left(\frac{1}{\theta}\right)[i - E(\Delta p)] + \left(\frac{1}{\theta}\right)cy - \left(\frac{1}{\theta}\right)\Phi\ (INVENTORRIES) - \left(\frac{1}{\theta}\right)rp \text{ ------(3.28)}$$

Under the logic that inventories are bounded below by zero and above by some absolutely peak storage capacity, a logistic function might be appropriate. If one wished to estimate an equation for the determination of inventory holdings, one could use:

$INVENTORIES = \Phi^{-1}(sc) = \Phi^{-1}(cy - i - (s - f))$ ---------- *(3.29)*

Therefore, low interest rates should predict not only high commodity prices but also high inventory holdings.

ECONOMIC ACTIVITY

Economic activity is denoted by Y and is a determinant of the convenience yield cy, since it drives the transactions demand for inventories. GDP is usually utilised as the proxy of economic activity in the literature. Higher economic activity should have a positive effect on the demand for inventory holdings, and thus on prices. The relationship is shown in this model as $\gamma(Y)$ and the assumption of linearity is arbitrary.

MEDIUM TERM VOLATILITY

Medium term volatility is denoted by σ, which is another determinant of convenience yield, cy, and should have a positive effect on the demand for inventories and therefore on prices. It may also be a determinant of the risk premium.

RISK

The model considers risk such as political, financial and economic risk. The theoretical effect of risk on price is ambiguous. Risk is another determinant of cy, whereby it should have a positive effect on inventory demand and therefore on commodity prices. However, it is also a determinant of the risk premium rp, whereby it should have a negative effect on commodity prices.

THE SPOT-FUTURES SPREAD

Naturally the spot-futures spread shows the speculative return to holding inventories. It is one component of the risk premium, along with expected depreciation. A higher spot-futures spread, or lower future-spot spread, signifies a low speculative return and therefore should have a negative effect on inventory demand and prices.

Substituting these extra effects into Equation (3.28), we obtain:

$$q = C - \left(\frac{1}{\theta}\right)[i - E(\Delta p)] + \left(\frac{1}{\theta}\right)\gamma(Y) - \left(\frac{1}{\theta}\right)\Phi\,(INVENTORIES) + \left(\frac{1}{\theta}\right)\Psi(\sigma) - \delta(s - f) \text{ -- } (3.30)$$

Finally, to allow for the possibility of bandwagon and bubble effects, and a separate effect of inflation on commodity prices, the alternative expectations Equation (3.26) can be applied in place of (3.25). Equation (3.30) then becomes:

$$q = C - \left(\frac{1}{\theta}\right)[i - E(\Delta p)] + \left(\frac{1}{\theta}\right)\gamma(Y) - \left(\frac{\Phi}{\theta}\right)(INVENTORIES) + \left(\frac{\Psi}{\theta}\right)(\sigma) - \delta(s - f) + \lambda\, E(\Delta p) + \left(\frac{\delta}{\theta}\right)(\Delta s_{-1}) \text{ ------------------------------- } (3.31)$$

Thus, the theoretical model of Frankel and Rose (2010) shows the role of macroeconomic determinants of real commodity prices, along the lines of the 'overshooting' model and the resulting model includes economic activity and the real interest rate as macroeconomic factors. This model also includes microeconomic determinants, e.g. inventory levels, measures of uncertainty and the spot-futures spread.

3.2.3 Summary of Explanations for Volatile Commodity Prices

After discussing all the theoretical literature regarding the macroeconomic determinants of commodity prices, the major elements of the economy that drive commodity prices in different directions have been identified. These explanations also match most of the practical volatile experiences regarding commodity prices we examined in the different parts of the world.

Frankel (2008) discussed a 1999 cover story of the Economist magazine in which the magazine forecast that oil might be headed for a price of $5 a barrel. Interestingly, since then the world has seen tremendous increases in the prices of most mineral and agricultural commodities, many of them hitting records in nominal and even real terms. These trends continued in almost every part of the world up to the GFC. The world has experienced an opposite trend in the prices of commodity markets from that time onward. We have attempted to summarise the theoretical reasons of that volatile commodity market conditions in the following section.

3.2.3.1 Explanation for Soaring Commodity Prices

Most agricultural and mineral products differ from other goods and services in that they are both storable and relatively homogeneous. Moreover, literature (for example Frankel (1984) and Calvo (2008)) demonstrated that prices of these commodities are determined by supply of and demand for stocks and goods, for which the flows of supply and demand matter. Frankel and Rose (2010) pointed out three theories to clarify the prevalent rise of commodity prices:

A. Global Demand Growth Explanation

Conceivably the most typical explanation for soaring commodity prices was the global demand growth. This argument stems from the extraordinarily extensive growth in global economic activities. The strongest growth has, of course, been from China, India and other entrants to the list of important economies – together with the predictions of sustained high growth in those countries in the coming days. This growth has increased the demand for, and hence the price of, commodities.

B. Destabilising Speculation

According to Frankel and Rose (2010), a lot of commodities are easily storable and many are dynamically traded on futures markets. One can describe speculation as the acquisition of commodities (whether in physical form or via contracts traded on an exchange) in expectation of financial advantage at the time of resale. Certainly, speculation, as defined, is a major force in the market. However, the second justification is more precise, i.e. speculation was a major strength that pushed commodity prices up in the US during 2003–2008. From the lack of an important reason to expect higher prices, this would be an occasion of destabilising speculation or of a speculative bubble. However, the role of speculators need not be pernicious and perhaps speculation was stabilising during this period. If speculators were diminished, on average, they would have retained prices lower than they otherwise would be.

C. Easy Monetary Policy

According to Frankel and Rose (2010) the third justification, which is slightly less important than the other two, is that easy monetary policy was at least one of the elements contributing to either the high demand for, or low supply of, commodities. Easy monetary policy is often mediated via low real interest rates. Several researchers, such as Barsky and Kilian (2004), have debated that high prices for oil and other commodities in the 1970s were not exogenous, but were a consequence of easy monetary policy. A similar explanation can be observed in Frankel (2006). A reduction in real interest rates lowered the cost of carrying inventories and raised commodity prices during 2002–2004, which was discussed as being part of the 'carry trade'.

3.2.3.2 Explanation for Falling Commodity Prices

After the GFC almost all countries worldwide experienced a downward sloping commodity price trend, with this tendency continuing. Frankel (2014) discussed the global economic slowdown as the most common explanation of the above result and showed that the GFC diminished demand for energy, minerals and agricultural products. He argued that growth has slowed and GDP forecasts have been revised downward in most countries.

Frankel (2014) then discussed monetary policy, which is another important determinant of commodity prices and described the four possible channels that could affect commodity prices with evidence from economic theories:

- First, the extraction channel that is shown in Hotelling (1931). High interest rates reduce the price of non-renewable resources by increasing the incentive for extraction today rather than tomorrow, thereby boosting the pace at which oil is pumped, gold mined or forests logged.

- Second, the inventory channel based on studies by Frankel (1986, 2014). High rates reduce firms' wishes to carry inventories. Frankel (2014) provides an example of oil held in cisterns.

- Third, the financialisation channel that is shown by Hamilton and Wu (2014). Portfolio managers react to an increase in interest rates by moving into treasury bills and out of commodity contracts, which are now an 'asset class.'

- Finally, the exchange rate channel (Frankel, 2006). High real interest rates strengthen the domestic currency, thereby decreasing the price of internationally traded commodities in local currency, even if the price has not fallen in foreign currency terms.

3.3 Empirical Literature on the Determinants of Commodity Prices

Commodity markets perform a central role in transferring instabilities globally by connecting commodity importing countries to commodity suppliers (Reinhart & Borensztein, 1994) and understanding that the variabilities in commodity prices are significant for the prosperity of both developing as well as developed countries (Byrne et al., 2013; Daude, Melguizo, & Neut, 2011; J. A. Frankel, 2006; Neftci & Lu, 2008). For that reason, we will examine the available empirical evidence on the macroeconomic determinants of commodity prices in this section.

3.3.1 Empirical Literature from the Viewpoint of the Prebisch-Singer Thesis

Researchers have attempted to identify the reasons behind movements of commodity prices from different points of views. An influential empirical work in this area can be dated back to Prebisch (1950) and Singer (1950) and their debatable thesis (the Prebisch-Singer Thesis (PST)). The PST claims that the price of primary commodities drops compared to the price of manufactured goods over the long term, which causes the terms of trade of primary product-based economies to decline. Various recent statistical studies regarding this hypothesis have given moderate support to this idea (e.g. Arezki, Hadri, Loungani, & Rao, 2014; Harvey, Kellard, Madsen, & Wohar, 2010).

Since productivity rose quicker in industrial areas than in agricultural or mining areas during 1876–1947, Prebisch (1950) claimed that there existed a vital asymmetry in the global division of labour. For a developing country with a non-diversified and traditional export arrangement, there exists a positive link between the terms of trade and commodity prices. That is why much of the empirical research on the PST is not a direct test over terms of trade per se, but rather a test over decreasing commodity prices over time in nominal and/or real terms. Generally, this has been the common way to empirically investigate methodology regarding commodity prices (Bastourre et al., 2007) .

According to Byrne et al. (2013), the PST delivered explanation for import substitution policies as suitable instruments for development. An extensive literature has concentrated on the historical relationship between the price indices of primary commodities and manufactured goods. Among this research, there are many studies that have investigated long-run characteristics of commodity prices.

Grilli and Yang (1988) re-examined the empirical groundwork of the assumed secular decline in the prices of primary commodities relative to those of manufactured goods. They considered a newly created index of commodity prices and two revised indexes of manufactured goods prices, and determined that from 1900 to 1986 the relative prices of all primary commodities fell on trend by 0.5 per cent per year and those of non-fuel primary commodities fell by 0.6 per cent per year. Thus, they endorsed the sign, but not the magnitude, of the trend implicit in the work of Prebisch-Singer. Among others, the studies of Cuddington and Urzua (1989), Powell (1991), Bleaney and Greenaway (1993), Lutz (1999) and Ocampo and Parra (2003) have attempted to endorse or discard the outcomes of Grilli and Yang (1988). A number of studies also examined the long-term chronological link between the price indices of primary commodities and manufactured goods (e.g. Balagtas and Holt, 2009; Bunzel and Vogelsang, 2005; Cuddington, 1992; Harvey et al., 2010; Kellard and Wohar, 2005; Leon and Soto, 1997; Zanias, 2005).The common representation that appears from this research is that negative growth rates tend to prevail in the long run. However, according to Bastourre et al. (2007) this scenario is not true for all cases. While some studies claimed in favour of a trend that moves at a constant pace, others have found that more significant elements include structural negative shifts that are not fully recovered during the upward phase of commodity prices cycles over the long run.

Examining only long-term trends was not considered appropriate for another group of researchers. They considered that short- and medium-term volatility affected the behaviour of commodity prices to a greater extent. A supporter of this opinion, Cashin and McDermott (2002), showed that instability of commodity prices has amplified remarkably since the Bretton Woods collapse at the beginning of the 1970s.

3.3.2 Empirical Literature on Commodity Prices and Terms of Trade

Since the influential research of Prebisch (1950) and Singer (1950), a large component of the development economics literature has been alarmed by the secular decline in the net barter terms of trade of commodities (Mollick, Faria, Albuquerque, & Leon-Ledesma, 2008). The PST is important in the sense that the meaning of its certainty is that the achievements from trade as well as technological development for commodity-exporting countries are reduced.

Regarding the terms of trade between commodities and manufactured goods, Ardeni and Wright (1992) discovered a strong secular decline in the terms of trade. Zanias (2005) utilised the long terms of trade series of Grilli and Yang (1988) and reported a deteriorating tendency in terms of trade for approximately hundred years from 1900–1998. Mollick et al. (2008) discussed the proposal of Bunzel and Vogelsang (2005) that involved testing for trends in the data that does not require a priori information regarding the serial correlation characteristics of the data and found significant negative trends in the net barter terms of trade of primary commodities. The results of other studies by Bloch and Sapsford (1997), Powell (1991), Spraos (1980) and Thirlwall and Bergevin (1985) also showed deterioration in the terms of trade.

If one accepts that poor countries export mostly primary goods and industrialised countries concentrate on the export of manufactured products, the deterioration of commodities' terms of trade might lead to a decline in the living standards of poor countries and support a form of specialisation in commodities that would keep them poor. Under these situations, trade would mainly help industrialised countries (Mollick et al., 2008).

In their study, Mollick et al. (2008) explored the influence of globalisation on the terms of trade for relative prices and studied whether US relative prices were influenced by international prices. While they found a declining trend in relative prices, they claimed that this trend was not connected to globalisation or international integration. In this regard, they stated that policies intended to increase or decrease the amount of integration with the world economy would thus not be appropriate at altering this long-term trend.

The study by Makin and Rohde (2015) examined the influence of world commodity prices on national output and trade balances in four countries: Australia, Canada, New Zealand and Norway. This research showed that an improvement in the terms of trade would alter the composition, but not the level of national production, as labour transferred from the non-commodity sector to the commodity sector. Simultaneously, industry reform was complemented by an increase in national expenditure and macroeconomic welfare owing to the income effect restriction from the terms of trade enhancement. Hence, the negative effects of industry restructuring were counter-balanced by the positive effect of higher expenditure. Moreover, a fast increase in prices received for commodity exports did not definitely enhance net exports since income and substitution effects concurrently increased imports.

Chen, Rogoff, and Rossi (2010) created a structural link between exchange rates and future commodity prices via the terms of trade and income channel. Their research discovered that the exchange rates of small open economies with a large export share of primary commodities might have a predictive element for future commodity price indices. The rationale was that exchange rates, similar to any asset price, should be determined as the net present value of fundamentals, such as commodity prices.

Ferraro, Rogoff, and Rossi (2015) discussed several interesting issues to explain the Canadian example utilised in their research. They showed that crude oil is a significant component of Canada's total exports. Canada also has a long history of having a market-based floating exchange rate. Finally, Canada is a small open economy whose size in the world oil market is comparatively small, which explains the statement that it is a price-taker in that market. Thus, crude oil price variations might serve as an apparent and basically exogenous terms of trade shock for the Canadian economy.

3.3.3 Empirical Literature on the Co-movement of Commodities

Furthermore, several researchers considered the co-movement of commodities, rather than price indices, along with the assessment of the time series properties of individual commodities, e.g. Deaton (1999). Deaton (1999) followed the above mentioned assessment process to evaluate the diverse effect of commodity prices on developing and industrialised countries and judged the need for stabilisation policies. Among other literature, Cashin, Liang, and

McDermott (2000) subsequently considered these properties and estimated median unbiased half-lives of 60 commodity prices after considering monthly observation between 1957 and 1998. They demonstrated that shocks are usually long lasting and believed that stabilisation arrangements might be more expensive than advantageous. Cashin et al. (2000) stated that 'typical' commodity prices half-lives were in the range of five years. Similar outcome can be observed in other recent studies including Bleaney and Greenaway (2001), Chen and Rogoff (2003), Chen et al. (2010) and MacDonald and Ricci (2004).

Seminal research on the co-movement of commodity prices by Pindyck and Rotemberg (1990) proposed considerable price co-movement outside macroeconomic fundamentals and claimed, after considering monthly data, that this was due to commodity speculation. Cashin, McDermott, and Scott (2002) discovered confirmation of synchronisation in the prices of associated commodities when studying co-movement. One of the most recent studies by Byrne et al. (2013) examined long spans with a lower frequency in an effort to limit the degree of noise or speculation in the data. Their analysis provides significant evidence of co-movement in commodity prices. Building on a simple asset pricing model of commodity prices, Byrne et al. (2013) empirically related an identified common factor in real terms to the real interest rate, as also suggested by Frankel (2006) and Svensson (2008) and to risk, as previously suggested by Beck (1993, 2001). This study offers empirical indication in support of a negative relationship between real interest rates and real commodity prices, where shocks to the real interest rates appear to be absorbed within a five-year period. Thus, this research is consistent with the view that monetary easing might lead to higher commodity prices. Risk, captured by a measure of stock market uncertainty, is also negatively related to commodity prices in this study. These results are robust to the inclusion of shocks to proxies for global demand and supply, which appear positively related to the common factor in commodity prices. Hence, the present study cannot discount the assessments of Svensson (2008), although the preliminary period effect of global demand and supply elements is smaller than that of the real interest rate and risk.

3.3.4 Empirical Literature on Commodity Prices and the Business Cycle

Recent fluctuations in commodity prices have renewed interest in linking commodity prices with the business cycle along with the co-movement of commodity prices. A group of researchers are dedicated to assessing the conventional behaviour of commodity prices depending on the different stages of global business cycles. There are various studies in the literature regarding the reliance of commodity prices on business cycle circumstances.

Chevallier and Ielpo (2013) stated that the long-term representation of commodity markets was categorized by a rather low response to business cycle news, whereas Hess, Huang, and Niessen (2008) stated empirical suggestion that this reaction depends entirely upon the stage of the cycle, i.e. boom or bust (Hamilton, 1989).

Most worldwide research about the role of commodity futures in a diversified portfolio provide a similar summary, i.e. when situations are set at the appropriate moment, a varied portfolio benefits from investing in commodity futures both in terms of absolute returns and risk-adjusted returns

(Gorton & Rouwenhorst, 2005). To determine the appropriate economic circumstances to include commodities in a portfolio, Gorton and Rouwenhorst (2005) claimed that commodities propose an exciting investment opportunity at the early stage of a recession and at the trough stage of an expansion period.

Chevallier and Ielpo (2013) showed the growing 'financialisation' of commodities similar to other studies (Dionne, Gauthier, Hammami, Maurice, & Simonato, 2011; Tang & Xiong, 2010) as an asset class and the extent to which they are related to the underlying business cycle. The key outcome of this study was the assessment of commodity prices along the business cycle in diverse geographic regions based on the class of Markov regime-switching models. The results of the study by Chevallier and Ielpo (2013) showed the robust association that appears between commodity markets and the underlying business cycle. More predominantly, this study was able to identify an increased sensitivity to economic activity in China. Moreover, it executed a more qualitative study of the progress of commodity markets via the US business cycle.

In the literature, there is the use of another interesting phrase regarding the business cycle, i.e. 'the study of super cycles necessarily begins with the measurement of super cycles'(adapted from Baxter & King (1999), cited in Cuddington & Jerrett (2008)). Cuddington and Jerrett (2008) and Jerrett and Cuddington (2008) examined the existence of a super-cycle, which is the time span of 20 to 70 year cycles, in a set of metal goods prices and utilised correlation and principal component study to explore their degree of concordance.

Previous literature recognises the USA as being the foremost business cycle for commodity markets (Barnhart, 1989; J. Frankel & Hardouvelis, 1985); however, recent studies identify China as being the leading business cycle (see Chevallier & Ielpo, 2013; Cuddington & Jerrett, 2008; Yin & Han, 2016). This view is justified by the circumstance that the GDPs are closely connected to the global business cycle, particularly given the openness of these economies.

3.3.5 Empirical Literature on Commodity Prices and De-industrialisation

Widespread literature on the macroeconomics of commodity price variations has analysed how RER appreciation could affect de-industrialisation. The analysis usually states that an increase in resource exports leads to a real appreciation in the country's exchange rate, which lowers other exports and import-competing sectors. This specific occurrence of the economy is known as the 'Dutch Disease' (Corden & Neary, 1982), the 'Gregory Effect' and 'De-industrialization' (Avendano, Reisen, & Santiso, 2008). This type of resource boom influences the economy via the resource-movement as well as spending effects.

Based on a study by Williamson (2012), the resource boom has favoured the rich industrial economies far more than the poor commodity exporters. A commodity price boom inspires specialisation in the supplying countries, moving both them and their industrial trading allies, in the language of contemporary economics, to the corners (P. Krugman & Venables, 1995) or, in the language of older economics, to a New World Economic Order (Lewis, 1978). De-industrialisation would hinder the expansion of commodity exporters as industrialisation is the carrier of growth. Hirschman (1958) and Myrdal & Sitohang (1957) expressed the same view a long time ago and it was made more formal a few decades later (K. Murphy, Shleifer, & Vishny, 1989). In the past few decades, this assessment has been significantly improved and labelled endogenous growth. The confidence is that positive technological and financial externalities favour urban and industrial clusters (Venables, 2007), and thus these properties indicate growing returns (P. Krugman, 1981; P. Krugman, 1991; P. R. Krugman, 1991). According to these endogenous growth theories, once an economy begins focusing on manufactured goods, its proportional improvement in industry will be strengthened and its overall growth improved. Commodity exporters will not obtain the same benefit. Various studies have shown formally how a world trade boom can contribute to economic divergence between trading partners (Fujita, Krugman, & Venables, 1999; Gylfason, Herbertsson, & Zoega, 1999; Sachs & Warner, 2001).

After exploring the problems regarding competitiveness among economies because of the commodity export boom as well as increases in the RER, Avendano et al. (2008) discussed some studies to inverse the effects of the Dutch disease. Torvik (2001) showed that the conventional Dutch disease properties may be overturned if there are productivity spillovers in both tradable and non-tradable sectors. Adam and Bevan (2006) studied the situation where public infrastructure investment caused an inter-temporal productivity spillover for both tradable and non-tradable production, but in a hypothetically instable way. Their study discussed the effect of public investment in rural roads is likely to have more of an effect on the production of non-tradables (food crops) than on urban-based (tradable) manufactures and vice versa. Furthermore, Collier and Goderis (2007) showed that significant Dutch disease can clarify only a negligible part of the long-run negative growth result of higher non-agricultural commodity prices.

Thus, this macroeconomic phenomenon worsens the international competitiveness of an economy's traditional tradable industries, particularly in the manufacturing sector and can also lead to a trade deficit along with various other macroeconomic imbalances.

3.3.6 Empirical Literature on Commodity Prices and Macroeconomic News

The present volatility in the commodity markets influences the growth patterns and policies of both developed and developing countries. To have a better understanding of the reasons behind these commodity price fluctuations, it is important to examine the market reaction to economic news. A brief review of this subject helps understand how sensitive commodity markets are to unexpected news.

Based on a study by Ghura (1990), primary storable commodities are regarded as financial assets since they are always traded on future exchanges. Therefore, the short-run prices of these commodities are likely to be affected not only by market demand and supply situations, but also by 'news' of macroeconomic variables, such as money stock; interest, inflation and exchange rates; and real activity indices, which influence the terms where agents are ready to hold title to commodity futures contracts.

In an influential study, Frankel and Hardouvelis (1985) investigated the empirical relationship between commodities and economic news during 1980–1982. They discovered that inflation news was negatively interpreted on commodity markets, which was consistent with the negative reaction of these markets to the announcement of a tighter monetary policy. Barnhart (1989) stretched the empirical method taken by Frankel and Hardouvelis (1985) to cover the prices of a larger number of commodities and a greater amount of US macroeconomic announcements. These studies have revealed that commodity prices have reacted considerably to news and these reactions have been predominantly sensitive to the monetary policy regimes implemented by the Fed. However, this research ignored the price movements of commodities on days when no announcements were made.

The empirical investigation of Gilbert (1987) explained quarterly movements of metal prices as explained by shocks in quarterly exchange rates. Although his analysis is an important contribution to understanding the impact of exchange rate shocks on commodity prices, it masks the important impact of daily exchange rate shocks and periodic US macroeconomic announcements on daily commodity price movements.

Ghura (1990) was the first to cover the dataset for a financial crisis, namely the 1985–1989 period. His study contributes to the existing literature in various ways. First, it revealed that the responses of commodity prices to economic news was permitted to vary over diverse phases of the business cycle. Second, it investigated the instantaneous influences of news from US macroeconomic announcements and shocks from daily exchange and interest rate surprises on daily commodity price schedules. This study identified that gold responded positively to unemployment surprises; however, it lost its sensitivity to inflation or economic activity during that specific period of time.

Utilising a more recent dataset than previous studies (1992–1995), Christie-David, Chaudhry, and Koch (2000) showed that gold and silver prices had a limited number of market movers. They applied the ordinary least squares (OLS) estimation method. Formal variance tests showed gold and silver price volatility was higher during days where there were announcements. They also found that GDP, inflation and capacity utilisation rates led to higher precious metal prices.

By focusing on the gold price during 1994–1997, Cai, Cheung, and Wong (2001) established that unemployment, GDP and inflation news had a statistically significant impact on gold prices. They concluded that fewer market movers impact commodities compared to T-bonds or currencies. They utilised two-step estimations by the generalised autoregressive conditional heteroscedasticity (GARCH) model and a flexible Fourier form to capture smooth intraday patterns in their study.

Andersen, Bollerslev, Diebold, and Vega (2003) examined the association between macroeconomic news and the US dollar exchange rate against six major currencies. They endorsed that macroeconomic news usually has a statistically substantial correlation to intra-day movements of the US dollar, with 'bad' news having a greater influence than 'good' news. Galati and Ho (2003) discovered similar outcomes using daily data. Ehrmann and Fratzscher (2005) focused on the Euro-dollar exchange rate and discovered that

US news tended to have more of an effect on the exchange rate than German news did. Activity indicators such as GDP and labour market data had a huge and important consequence, with the news effect growing during times of high market uncertainty.

Hess et al. (2008) suggested a new input regarding the influence of news on commodity markets. Based on a dataset from 1989 to 2005 for two commodity indices (Commodity Research Bureau [CRB] and Goldman Sachs Commodity Index [GSCI]), the researchers were able to identify that the effect of news essentially depended on the stage of the business cycle. To perform this analysis, they utilised the OLS regression methodology. Periods of recession were characterised by a robust connection between economic news and the returns of the two commodity indices considered. On the contrary, during periods of expansion, commodity markets displayed a weak link – if any – with economic news.

With a similar, but expanded, dataset (1983–2008) and focusing on West Texas Intermediate (WTI) crude oil and US gasoline prices, Kilian and Vega (2011) did not find any statistically significant market mover. However, this study found some evidence that a broad set of selected forward-looking indicators were statistically significant over a period of one month.

The study by Roache and Rossi (2009) utilised an event study methodology to investigate which and how macroeconomic announcements affected commodity prices. They applied daily price data for 12 commodity futures contracts that had available price data from January 1997 to June 2009. This study showed evidence that the gold price reacted positively to inflation news, and negatively to unemployment news and the publication of leading surveys. Their study also revealed that commodity prices were increasingly reacting to macroeconomic news, as they became more and more integrated in the sphere of financial markets.

3.3.7 Literature on the Impact of Monetary and Macro Shocks on Commodities

Commodity price variations have proven wearisome in their disrupting influence on export revenues foreign exchange earnings and overall growth performance for both developed and developing countries. For that reason, there has been great interest over the past four decades in the theoretical and empirical linkages between macroeconomic variables (including monetary shocks) and commodity markets. Therefore, for a very long time, there has been various areas of global economic uncertainty, which contain variations in interest rates, instabilities in exchange rates among the major currencies, and changes in economic activities and in flows of financial resources. Volatility in these components has interacted with and caused variations in commodity markets. As a result, a growing economic literature has emerged that attempts to investigate these various relations.

3.3.7.1 Monetary Shocks and Commodity Prices

Stages of fluctuation in global liquidity and changes in interest rates have usually matched with volatilities in commodity prices. The effect of these monetary shocks on the prices of commodities, goods and assets has been an emphasis of contemporary studies. The development in comprehensive liquidity and decreases in interest rates have occurred since the beginning of the current century and are a consequence of improved activity in the carry trade that moved liquidity among different countries and extended investments in numerous asset classes including stocks, real estate and commodities (Batten, Ciner, & Lucey, 2010; A. Belke, Orth, & Setzer, 2010; A. H. Belke, Bordon, & Hendricks, 2014; Brana, Djigbenou, & Prat, 2012 ; J. Frankel, 2014; S. Hammoudeh & Yuan, 2008; Ratti & Vespignani, 2013, 2015).

The impact of monetary shocks on commodity prices has, however, been heterogeneous (Hammoudeh, Nguyen, & Sousa, 2014). Frankel and Hardouvelis (1985) claimed that fluctuation in commodities prices measured the market's assessment of the stance of monetary policy. Bernanke and Gertler (2000) also suggested that asset prices are relevant for monetary policy stances only when they signal potential inflationary pressure or deflationary forces. Similarly, Barsky and Kilian (2004) stated that monetary policy influenced commodity prices via expectations of larger growth and inflation.

Regarding the mixed influences of monetary shocks on commodity prices, the study by Brana et al. (2012) can be mentioned. They examined the effects of global excess liquidity on goods and asset prices for a sample of emerging market economies and discovered that additional liquidity at the global level had spillover effects on output and price levels; however, the impact on real estate, commodity and share prices was not significant at all. Likewise, monetary aggregates in the Organization for Economic Co-operation and Development (OECD) countries showed leading information on property prices and gold prices in the research by Belke et al. (2010). However, shocks to liquidity in that study did not appear to have influenced equity prices.

Since commodity prices assist in determining an extensive series of consumer and producer prices, the reaction of commodity prices to monetary policy is a significant feature of the monetary transmission mechanism (Scrimgeour, 2015). The existing literature shows different views of justifying the relationship between commodity prices and monetary policy. Several studies have blamed the inflation of the 1970s as the main cause of soaring commodity prices (for example, Blinder, 1982; Bruno & Sachs, 1985). On the other hand, Barsky and Kilian (2002) argued that loose monetary policy produced the fears of anticipated inflation that caused the tendency of the commodity prices to increase during 1970s.

Recent fluctuations in commodity prices have brought renewed attention to commodity markets. Scrimgeour (2015) stated that since commodities and bonds are both assets that can store value, when the Fed sells bonds to increase interest rates, demand for commodities drops. Therefore, commodity prices in the spot market should decrease when interest rates increase owing to monetary intervention. Other shocks, such as news about bond risk, might move bond prices and commodity prices in reverse ways.

Taylor (2009) stated a monetary clarification for the upsurge in commodity prices during the early periods of the latest financial crisis and claimed that oil prices increased in 2007 and 2008 because the Federal Open Market Committee reduced interest rates. Thus, this study claimed that loose monetary policy might have been behind the surge in commodity prices. In addition, many commodity producing countries connected the value of their currency to the US dollar. Monetary policy variations in the US could thus move economic consequences in these countries via the effect on commodity prices, as well as the straight interest rate passages (Scrimgeour, 2015).

In his seminal study, Frankel (1986) claimed that monetary policy and, more precisely, interest rates were key determinants for developments in commodity prices. In his research, Frankel (1986) extended the exchange rate overshooting model of Dornbusch (1976) to the case of commodity prices and utilising no arbitrage conditions clarified the connection between these two variables. In a later study, Frankel (2006) argued that reductions in interest rates could increase commodity prices and showed a negative relationship between interest rate and real commodity prices. If the interest rate rises by 100 basis points, commodity prices fall by 6 per cent, which held for the three commodity price measures that he considered, i.e. CRB, Dow Jones and Moddy's. In this research, Frankel (2006) postulated that an increase in the real interest rate offered motivation to exaggerate mining resources in an effort to invest the proceeds. As the supply of natural resources increased in consequence, their prices should come down. At the same time, higher rates of return on bonds would decrease projected demand for commodities and, hence, further cut their price. Moreover, Frankel (2006) showed that high interest rates decreased inventory demand, and thus reduced the demand for storable commodities or increased the supply, which reduced the market price of commodities. If this was the case, then a causal link from interest rate to commodity prices could be expected.

Similar to the previous study, Calvo (2008) claimed that the increase in commodity prices generally stems from the grouping of low interest rates, the growth of autonomous wealth funds and the resulting lower demand for liquid assets. However, he explained that the association was brief and would be adjusted in the long run. Empirically, these studies tended to show an indication of a negative influence of interest rates on commodity prices (see Bernanke, Boivin, & Eliasz, 2005; Bernanke & Mihov, 1998; Christiano, Eichenbaum, & Evans, 1999; C. Sims, 1992).

Furthermore, Caballero, Farhi, and Gourinchas (2008a, 2008b) showed the connection between interest rates and commodity prices. They explained that commodity prices were high at the same time that real interest rates were low in the 2000s. These researchers highlighted a global savings glut to describe levels of interest rates and commodity prices. During the early phases of the most recent financial crisis, when debt began appearing riskier, there was a sell-off in bonds and investors started to reshuffle their portfolios by replacing some commodities for bonds (Scrimgeour, 2015).

Akram (2009) explained in his important empirical analysis that controlling some macroeconomic variables such as the real exchange rate and economic activity is important for obtaining the appropriate results for the connection between commodities and interest rates. Florez (2010) claimed similar results in that the answer to this difficulty is to carry out an investigation that includes the monetary policy endogenously. Low interest rates mean high commodity prices that can lead to future increases in aggregate price indices as well as a contractionary monetary policy; therefore, there exists an endogeneity in this relationship between commodity prices and interest rates. Hence, it is considered more suitable to introduce a multivariate study to obtain this and other endogenous relationships. Therefore, Florez (2010) presented a Taylor rule in Frankel's (2006) method and, after applying structural vector autoregression methodology, the study found that for a 1 per cent increase in interest rate, commodity prices fell between 2.8 and 5.9 per cent. In the reverse direction, a rise in commodity prices of 1 per cent resulted in higher interest rates from 0.2 per cent to 0.5 per cent. Additionally, Florez (2010) showed that in recent years the influence on commodity prices has a lag.

In addition to the transmission mechanism of Frankel (2006), another indirect channel to influence commodity prices is described in the research of Akram (2009) and this channel works via the exchange rate. Based on uncovered interest parity, the exchange rate deviation depends on the interest rate differential between an economy and its international standard. Thus, the interest rate influences the exchange rate and the exchange rate in turn has an effect on the price of commodities (Cabrales, Castro, & Joya, 2014).

Based on the study by Arango, Arias, and Florez (2012) the real interest rate is not the only determinant of commodity price behaviour or that the effect is not only concurrent but more vibrant or that there is room for different opinions as that of the study of Obstfeld and Rogoff (1996). With respect to the relationship between real interest rates and commodity prices, particularly for oil prices, Obstfeld and Rogoff (1996) stated a dissimilar opinion. According to these authors, countries benefiting from the oil shock, which were mainly those from the OPEC, could not increase their spending at the same speed as the increase in their wealth given their lower marginal propensity to spend their transitory income. Consequently, savings increased in these economies and they observed current account surpluses; as a result, the real interest rate declined. Together, investment outside OPEC reduced, thereby pushing the interest rate further down. This was the truth during the first OPEC shock. Nonetheless, for the second shock that occurred at the end of the 1970s, the condition was relatively changed, since the increase in oil prices was followed by a rise in the real interest rate. One description was that in this instance, OPEC could spend all their transitory income quicker.

Monetary shocks are not the only determinants of commodity prices; therefore, the author of this study needed to investigate other empirical literature to observe the findings of other researchers in this field.

3.3.7.2 Exchange Rates and Commodity Prices

Exchange rates have long been believed to have a significant influence on the export and import of goods and services. Therefore, exchange rates should have an influence on the traded products of the world. This section provides the empirical evidence of the link between exchange rates and commodity prices.

Based on a study by Akram (2009), a negative association between exchange rates and commodity prices follows from the law of one price for tradable goods. Therefore, a drop in the value of the dollar must be balanced by an increase in the dollar price of commodities and/or a fall in their foreign currency prices to confirm the same price when measured in dollars. Besides, many commodities are priced in dollars in global markets, therefore a weaker dollar may increase the purchasing power and commodity demand of foreign consumers, while reducing the returns of foreign commodity suppliers and possibly their supplies. The price effect of shifts in demand and supply of commodities may be large if the demand or supply of commodities is comparatively price inelastic, which is usually believed to be the case for the majority of commodities (Hamilton, 2008).

To show the relationship between exchange rates and commodity prices, Fraser, Taylor, and Webster (1991) applied disaggregated commodity data of the UK and the USA from 1975 to 1980. They tested for the PPP. While few markets, including wood and lubricating oil, showed evidence of cointegration, the results of their study were unfavourable to the long-run proportionality of prices in a common currency. Therefore, the assumption that the exchange rate and relative prices in the UK and the USA inclined toward the PPP could be rejected.

Sephton (1992) considered the data from 1983 to 1988. This empirical study tested for cointegration between exchange rates and three agricultural commodity prices. In the long-run, currency depreciation was shown to have no lasting influence on the rates of inflation in these three commodity prices.

Dooley, Isard, and Taylor (1995) considered data from 1976 to 1990 and tested for the short- and long-run effects of gold prices on exchange rates conditional on other monetary and real macroeconomic variables. They utilised M1, short-term interest rate, consumer prices and industrial production during that period. Based on the concept of gold as an ‘asset without a county’ and the argument that changes in country preferences will be systematically reflected in the price of gold, the researchers demonstrated that gold price movements had explanatory power with respect to exchange rate movements, over and above the influences of fluctuations in monetary fundamentals and other variables.

Hua (1998) utilised the data from 1970 to 1993 and employed the cointegration technique. The researcher tested the hypothesis of a long-run quantifiable relationship between non-oil primary commodity prices and macroeconomic variables. The study found that the variations in industrial production and the effective exchange rate of the US currency appeared to have considerably affected the real non-oil primary commodity prices in both the long-run and short-run components, while the real interest rate had rather complex pricing dynamic effects.

Cashin, Cespedes, and Sahay (2004) utilised the world price data of 44 commodities from the IMF during 1980–2002. They investigated whether the RER of commodity-exporting countries and the real prices of their commodity exports move together over time. This study claimed evidence of a long-run relationship between national RERs and real commodity prices for approximately one-third of the commodity exporting countries investigated in this research.

The seminal research of Chen et al. (2010) emphasised the structural link between exchange rates and commodity prices via the terms of trade and income effect, and empirically examined the subsequent dynamic link between commodity price movements and exchange rate variations. After monitoring for time varying parameters, this study not only displayed a robust association, it also exposed an amazing result that exchange rates are very suitable in predicting future commodity prices.

Harri, Nalley, and Hudson (2009) considered the data from 2000 to 2008 to conduct their empirical study. This research examined the cointegration relationship between the primary agricultural commodities, exchange rates and oil prices. The researchers pinpointed that commodity prices were connected to oil for corn, cotton and soybean, but not for wheat, and that exchange rates did play a role in the connection of prices over time.

He, Wang, and Lai (2010) studied the data from 1988 to 2007 to investigate the cointegrating relationship among crude oil prices, global economic activity and trade-weighted US dollar index. It is well known that global economic activity is vital for modelling the demand side of the crude oil market and is, therefore, the key determinant of oil prices. They found that real futures prices of crude oil were cointegrated with the economic index of Kilian (2009) and the US currency index.

Sari, Hammoudeh, and Soytas (2010) tested the cointegration among the four precious metals (gold, silver, platinum and palladium), the oil price and the US Dollar/Euro exchange rate. They considered the data from 1999 to 2007. The study did not show a cointegration relationship among precious metals, oil prices and the exchange rate. These variables were not collectively driving forces of each other in the long run; therefore, they did not show cointegrated relationships during that time frame. However, precious metals exhibited strong correlations among themselves during the short run. In addition, the results of this study reflect the increasing disparity in economic, monetary and hedging uses between these commodities and exchange rates. Oil is controlled by OPEC and other oil-producing countries, and has its own seasonality, inventories and hedging strategies. Gold and silver have almost limited supplies, are considered safe haven assets and respond strongly to inflationary expectations. Since there is only rather weak evidence of a long-run relationship, Sari et al. (2010) concluded that investors might benefit from diversification into precious metals in the long run.

The empirical study of Lombardi, Osbat, and Schnatz (2012) utilised factor-augmented vector autoregressive methodology, where the factors were two common trends in prices of commodities particularly food and metals. With this structure, they studied the impulse response between the price of commodities, common trends, exchange rate, economic activity, oil prices and interest rates. Based on results from study, the exchange rate, economic activity, and common trends had a major influence on commodity prices. However, Lombardi et al. (2012) could not find any substantial link between oil prices and interest rates.

Overall, the above discussion indicates that, globally, exchange rates show strong economic associations between macroeconomic variables and commodity prices.

3.3.7.3 Industrial Production and Commodity Prices

When exploring the connection between commodity markets and a central macroeconomic variable such as industrial production, Chevallier and Ielpo (2013) showed that several economic forces automatically become the centre of investigative interest. First, in a situation of continuous economic growth, the demand for commodity markets is robust. Therefore, consumers' demand activates additional production effort from companies, which resort to several commodities as an input to their production.

Equally, in the circumstance of declining economic activity, some parts of the economy will be categorised by falling demand, and the related demand in terms of commodities will be less. Thus, one can assume cyclical movements in commodity prices, if they are coordinated with economic activity. Clearly, we can also notice counter-cyclical influences. For example, when industrial production falls, the price of gold rises as a refuge for value.

With respect to other macroeconomic theories, one can also suggest the assumption whereby high commodity prices dampen surges in industrial production because the prices of goods increase comparative to consumers' income. Low commodity prices can also reduce the costs of production and increase the demand for goods, as well as industrial production (Chevallier & Ielpo, 2013).

After considering all those macroeconomic mechanisms, the author conducted a survey on relevant literature to understand the connection between commodity prices and industrial production.

The research by Ghura (1990) stated that an unexpected increase in industrial output could have ambiguous effects on commodity price growth rates since this 'good' news could be viewed by investors in two ways, depending in part on the stage of the economic cycle. First, news of a strengthening of economic activity may increase investors' confidence about future growth in the economy. In such a case, investors will increase their demand for short-run investments causing short-term nominal rates and hence real interest rates to rise. As a result, the prices of commodity could fall. Second, investors might interpret the strengthening of economic activity as a sign of an 'overheating' economy. There are two possible price reactions in this case. If traders expect that the Central Bank will reduce the money supply, real rates should go up and hence commodity prices will fall. However, if traders believe that the government will remain passive and hence increase their inflationary expectations, real interest rates are supposed to fall causing commodity prices to rise as investors demand more commodity contracts. Therefore, the overall impact of real activity is ambiguous and can only be determined empirically.

Cody and Mills (1991) examined the macroeconomic interactions between industrial production in the US and the CRB basket of commodities. They considered monthly data over the period from 1959 to 1987 and tested for cointegration between the two series in their research. The study could not reject the null hypothesis of no cointegration. In a later VAR examination, while commodity prices did not react to variations in the macroeconomic variable of interest here, they were important in clarifying the future path of industrial production. Finally, the authors stated that commodity prices were a primary sign of the current state of the economy.

Labys and Maizels (1993) conducted Granger causality tests to analyse commodity price fluctuations and macroeconomic adjustments in developed countries. They considered data from France, Germany, Italy, Japan, the UK and the USA for the period from 1953 to 1987. To conduct the econometric tests, the study utilised various IMF commodity indices and the industrial production index. The main results suggested a causality in the direction of commodity prices to industrial production except for one country, France.

Hua (1998) studied 22 developed countries and analysed the data from 1970 to 1993. This study showed the cointegration between commodity prices and economic activity. The outcomes were supportive of the hypothesis that non-oil primary commodity prices were cointegrated with macroeconomic variables, and that long-run relationships existed between them. The author was also able to endorse the presence of an equilibrium adjustment in commodity prices to macroeconomic shocks via a feedback mechanism. The strong significance of the error correction coefficients supports the view that non-oil primary commodity prices in particular vary together with the variations in economic activity. The outcomes were more difficult to interpret for agricultural commodities.

Labys, Achouch, and Terraza (1999) attempted to determine the impact of macroeconomic influences on metal price fluctuations. They utilised factor models and considered the data from 1971 to 1995. They studied five industrial metals: aluminium, copper, lead, tin and zinc. They found strong influences of industrial activity on metal prices for France, Italy, Japan and the OECD. Therefore, the straight effect of industrial production on metal price cycles was dominant during this time frame.

Awokuse and Yang (2003) considered the data from 1975 to 2001 and performed Granger causality tests between IMF commodity indices and the US industrial production. They discovered that commodity prices might offer indications about the future trend of the economy, with inflation and other macroeconomic activities such as industrial production.

Cunado and De-Gracia (2003) analysed the oil prices-macroeconomic relationship by studying the impact of oil price changes on both inflation and industrial production growth rates for 15 European countries from 1960 to 1999. The major contribution of this study was the utilisation of different proxies of oil price shocks to measure their impact on inflation and industrial production. They obtained dissimilar results depending on whether they utilised a world oil price index or a national real price index for each of the countries measured in the currency of each country. The authors could not recognise a cointegrating long-run association between oil prices and economic activity, which suggests that the influence of oil shocks on this variable is limited to the short run. Furthermore, they did not find any indication of a long-run relationship between these two variables even when applying a structural break.

Bloch, Dockery, and Sapsford (2006a, 2006b) showed associations between all commodities reported in the World Bank’s development indicators except for fuels and industrial production data from the OECD countries covering the 102 years data from 1900 to 2001. Their regression outcomes stated that a decrease in the rate of economic growth could lead dropping the rate of increase in commodity prices. Hence, there was a weak connection between world economic growth and the rate of change of commodity prices over the past century. This study showed that world commodity prices move pro-cyclically with world industrial production and authenticates the link between the use of commodities such as raw materials and increases in industrial production in the case of Australia and Canada during 1960–2001.

Pieroni and Ricciarelli (2005) studied the data from 1955 to 2000 and utilised copper data of the US to investigate the properties of a VECM extended to macroeconomic variables such as industrial production. Their study demonstrated that price corrections depend on the short-run dynamic element of the model, whereas the long-run dynamic was statistically rejected. Hence, there was no cointegration between copper and industrial production during this time frame.

Ai, Chatrath, and Song (2006) showed the connections between five agricultural commodity prices (wheat, barley, corn, oats and soybean) and industrial production of the US. They considered data from 1957 to2002. Their study failed to categorise significant cointegration relationships between macro indicators such as industrial production and agricultural commodity prices.

Cheung and Morin (2007) examined the cointegration between the Bank of Canada Commodity Price Index and industrial production of the OECD countries from 1980 to 2006, and also considered any possible structural breaks. While the authors could not identify statistically the existence of cointegration, they highlighted the role played by emerging Asian industrial activity in driving the price of oil and industrial metals in particular.

Hamori (2007) conducted Granger causality tests between the Bank of Japan Commodity Price Index and industrial production in Japan between 1990 and 2005. The author found no causal relationship between the Bank of Japan

Commodity Price Index and the industrial production index, even when assuming a structural break in February 1999.

The empirical work of Bhar and Hamori (2008) examined whether commodity prices have causal relationships with industrial production, and vice versa. They utilised the Commodity Research Bureau index and considered monthly US data during 1957–2005. Based on Granger causality tests, the authors validated the hypothesis that commodity price indices provide information on future changes in production.

Baffes and Savescu (2014) utilised a reduced-form of price-determination model from 1991 (Q1) to 2010 (Q4) for six base metals (aluminium, copper, lead, nickel, tin and zinc). This research mainly evaluated the influence of short- and long-term interest rates on metal prices. It revealed that the imminent monetary contraction by the world's major central banks was likely to have only a minimal effect on metal prices as long as it contained only an increase in short-term interest rates. Finally, it concluded that among the remaining fundamentals, industrial production activity positively affects metal prices the most.

Although the relationship between commodity prices and industrial production can be explained by strong economic theory, the final conclusions of these various empirical studies appear to vary depending on the commodity types, the economic regions and the period considered.

3.3.7.4 Stock Prices and Commodity Prices

The linkages between asset markets and commodity prices are also very important to understand the volatility of commodity prices. Commodity prices and equities are influenced by deviations in global demand and, more commonly, by the growth rate of industrial production (Chevallier & Ielpo, 2013).

In this section, we briefly summarise the findings from various studies dedicated to the connections between asset markets and commodities.

The empirical study by Zeng and Swanson (1998) examined the cointegrating relationship between the S&P 500 index, treasury bonds, gold and crude oil from 1990 to 1995. Their outcomes showed that error correction models offered a reasonable fit to the data compared to other models for forecasting purposes.

Buyuksahin, Haigh, and Robe (2010) considered the period from 1991to 2008 and could not find any cointegrating vector between the S&P 500 and GSCI sub-indices during that time frame. However, they discovered some unstable cointegration between the benchmark commodity and equity indices for the sub-period from 1997 to 1999. Therefore, they finally stated that there was slight indication of a common long-term trend between investable commodity and equity indices, and no sign of secular strengthening of any such trend. A consequence of this is that passive investors are likely to obtain benefits over the long run by diversifying portfolios across the two asset classes.

Rossi (2012) explored the relationship between equity and commodity markets, concentrating precisely on its progression over time. This study showed that a country’s equity market value has noteworthy out-of-sample projecting capability for the future global commodity price index for several primary commodity-exporting countries. The out-of-sample predictive capacity of the equity market appeared around the 2000s. The outcomes were significant for utilising numerous control variables as well as firm-level equity data. Lastly, the outcomes specified that exchange rates are a better predictor of commodity prices than equity markets, particularly in the short run.

Creti, Joets, and Mignon (2013) inspected the relationship between price returns for 25 commodities and stocks from January 2001 to November 2011 by providing a precise consideration to energy raw materials. Depending on the dynamic conditional correlation GARCH methodology, they demonstrated that the correlation between commodity and stock markets developed through time and were extremely instable, especially since the 2007–2008 financial crisis. While the stock market collapse loosened the relationship between both markets in the very short run, maximum correlations were detected during the financial turmoil, which showed better connections between stock and commodity markets.

Sarkar, Ratti, and Westerholm (2015) explored the connotation between the price of iron ore and stock prices to determine the influence of the newly developed robust correlation between the iron ore price and Australian share prices. They endorsed that Australian share prices were positively correlated to the iron ore spot price and that the influence differed considerably in strength and magnitude across various industry sectors. They also found that there was a straight relationship between the price of iron ore and economic activity in such sectors as consumer goods, consumers, telecom and financials as well as basic materials and industrials.

Finally, we can conclude from the above literature review that to obtain or suggest effective as well as efficient policy suggestions, it is very important to thoroughly assess the relationships between commodity prices and all other macroeconomic as well as monetary variables.

3.4 Literature on Australian Commodity Prices

Australia is one of the major commodity exporters in the world and, at the same time, Australia has experienced regular as well as large commodity export price shocks similar to commodity exporters in Asia, Africa and Latin America (Bhattacharyya & Williamson, 2011). Researchers have conducted numerous studies to understand the connection between commodity prices and other Australian macroeconomic variables. It is possible to summarise these studies from two broad point of views.

3.4.1 Macroeconomic Variables affecting Australian Commodity Prices

In this regard, we can discuss the seminal empirical work of Bloch, Dockery, and Sapsford (2006a). The model of this study is an extension of the study by Bloch (1992) or Bloch and Olive (1999) for Australia where they allowed the price of competing foreign products to affect prices of domestic finished goods. The main objective of the study by Bloch et al. (2006a) was to discover the meaning of inflation in countries with substantial net commodity exports, especially for Australia and Canada. The study showed that the true meaning depended on movements in commodity prices, changes in foreign exchange rates and the determinants of domestic price inflation. They estimated equations to provide indications of the strength of each of these forces for both

Australia and Canada. The result also showed that world commodity prices moved pro-cyclically with world industrial production and that rates of change in commodity prices were directly related to domestic inflation in both countries. This study suggested that it was the real commodity price rather than the nominal price that was affected by the world business cycle. Furthermore, there was an offsetting impact of exchange rate changes, which was strong enough in the case of Australia to substantially eliminate the inflationary impact of a commodity price boom. This was another interesting feature of this study, which was actually the extended version of the model by Bloch and Sapsford (2004).

In this concern, we can also mention the research by Cagliarini and McKibbin (2009) that investigated the influence on Australia of an increase in energy and mining commodity prices relative to manufacturing prices driven by rising productivity growth of manufacturing sectors relative to non-manufacturing sectors in developing economies, a reduction in global risk premia and monetary easing in the US. It was demonstrated that the income and GDP in Australia were reduced by drawing capital away from the OECD countries and increasing global real interest rates. This has occurred mainly because of an increase in commodity prices driven by an increase in manufacturing productivity in China.

Jaaskela and Smith (2011) investigated the influences on the Australian economy of variations in the terms of trade arising from mainly three things: a rise in global demand; developments in individual commodity markets; and globalisation and the rise of Asia, where increasing commodity demand and prices were accompanied by lower manufacturing prices. The last shock was related to a drop in manufactured prices, an increase in commodity prices and a rise in global economic activity. The assessed influences were evidently different for output, inflation and the exchange rate. The main outcome of this research was that higher terms of trade tend to be expansionary but are not always inflationary. A crucial outcome was that the floating exchange rate provided a significant buffer to the external shocks that moved the terms of trade.

A lot of studies have been undertaken to better understand the volatility of the Australian dollar against other currencies, especially the US dollar and its impacts on exports and pricing of different commodities (for example, see Ali & Rahman, 2013; Aruman & Dungey, 2003; Edison, Cashin, & Liang, 2003; Flood & Rose, 1999; Frankel & Meese, 1987; Frenkel & Mussa, 1980; Graham & Waring, 1998; Mimuroto, 2000; Sheen & Kim, 2002). In these studies, many authors examined the relationship between the Australian exchange rate and one particular commodity, such as Graham and Waring (1998) suggested that the Australian coal supply was dependent mostly on the effects of the Australian dollar exchange rate and coal prices. They discovered that if the Australian dollar rate started to appreciate, then Australian coal would not be affected considerably in the short run and would not be expected to be affected in the long run, unless the US dollar increased to a level that was adequately high enough to affect the Australian dollar. Mimuroto (2000) analysed the steam coal price and the factors behind price fluctuations. He found that the exchange rate of the Australian dollar and coal productivity appeared to have the most direct impact on future coal prices. Ali and Rahman (2013) showed that Australian coal exporters made a loss, which occurred because of a strong Australian dollar, and was less than the profit from increasingly higher prices of Australian steam coal. Therefore, they chose to export more when the price was high. The empirical results of this analysis confirmed that for each one cent increase in the Australian dollar value against the US dollar, the Australian steam coal price increased by 0.8182 US dollars and for each additional one million tons export of Australian steam coal, the Australian steam coal price increased by 1.752 US dollars.

The study by Groenewold and Paterson (2013) also throws light on the Australian commodity-currency issue and this research showed that the link from the exchange rate to commodity prices was stronger and more consistent than that in the opposite direction in Australia.

The issue of commodity price prediction for the Australian economy has also been investigated by Chen et al. (2010), Rossi (2012), and Wei and Chang (2016). Chen et al. (2010) looked at the linkage between the exchange rate of commodity exporters and future commodity prices via the channel of terms of trade. They suggested that commodity currencies, which included the Australian, Canadian, and New Zealand Dollars; the South African Rand and the Chilean Peso, contained important information on market expectations. They also showed that commodity currencies helped predict price movements in the aggregate commodity market for both in-sample and out-of-sample tests. In contrast, Rossi (2012) utilised quarterly stock price data from Australia, New Zealand, Canada, Chile and South Africa to forecast country specific and global commodity prices. However, both these studies concluded that exchange rates were a better predictor of commodity prices than equity markets. In addition, the study of Wei et al. (2016) explored the linkage between equity markets and commodity markets, and found that the stock price indices of Australia, Canada, Chile, New Zealand and South Africa contained information about future movements in the commodity markets.

3.4.2 Commodity Prices Influencing the Australian Economy

Commodity price shocks have influential but uneven influences on labour, capital, and land of a country. Various renowned Australian academics have conducted research on such an effect of commodity prices, called 'Dutch disease' (see Connolly & Orsmond, 2011; Cook & Seiper, 1984; Corden, 1984; Corden & Neary, 1982; J. Edwards, 2014; Gregory, 1976; Minifie, Cherastidtham, Mullerworth, & Savage, 2013; Plumb et al., 2013; Sheehan & Gregory, 2013), which have emphasised that a boom in commodity exports often influenced the wider economy by inducing an appreciation of the RER. This tends to elevate general living standards by dropping the relative cost of imports. However, the appreciation also deteriorates the competitiveness of other exporters and of import-competing industries such as manufacturing.

The recent study by Downes et al.(2014) was also largely based on the previously mentioned research and they discovered that the mining boom had considerably improved Australian living standards. Their research also showed that the boom led to a large appreciation of the Australian dollar that had weighed on other industries exposed to trade, such as manufacturing and agriculture. However, because manufacturing benefits from higher demand for inputs to mining, the 'Dutch disease' effect has not been strong. Based on results from their study, Australia has narrowly escaped the deindustrialisation that occasionally accompanies resource booms.

We can mention the research of Freebairn (1991), which analysed the historical relationship between the RER of Australia and its terms of trade, especially focusing on commodity prices. This study utilised data from 1902 to 1988 and found a correlation of 0.43 between these two series. The study concluded that the Australian dollar is a ‘commodity currency’.

Bleaney (1996) utilised ninety-two years of Australian data to analyse how RERs of primary commodity exporters responded to variations in the relative prices of their exports. The outcomes displayed a substantial negative correlation between these two variables. Oddly though, the real Australian dollar exchange rate did not show the significant downward trend observed in the commodity prices. To solve this paradox, this study then applied a pure time series analysis of the respective series and concluded that the apparent long-run decline in the relative price of primary commodities was due to an inadequate quality adjustment in the price series for manufacturers.

Webber (1997) employed a different approach to determine whether Australia was a price taker in its commodity export trade by examining commodity export pass-through. The results of this study showed that Australia was likely to be a price-taker in the trade of commodity items such as coal, copper, wool and zinc; however, it appeared to have some market power and hence price-making behavior in the trade of its main commodity exports of wheat, iron ore and sugar, as well as aggregate commodity prices. This paper has also found that the world price of the important commodities (coal and wheat) had a significant influence on the direction of the Australian dollar exchange rate.

The study by Simpson and Evans (2004b) also identified Australia as a price taker and showed that volatility in commodity prices was reflected in volatility in exchange rates. They suggested that Australian exporters of commodities should continue to closely examine the trends of foreign exchange and commodity markets. The study provided evidence that commodity price changes led AUD/USD exchange rate changes.

Using Australian quarterly data from the post-float period 1984:1–2003:1 and a partial system, Hatzinikolaou and Polasek (2005) classified and identified two cointegrating relations, one for the interest-rate differential and the other for the nominal exchange rate. The outcome of the long-run elasticity of the exchange rate with respect to commodity prices was 0.939, which intensely supported the usually held view that the floating Australian dollar is a 'commodity currency'.

To have a better understanding of the influences of commodity prices on the Australian economy, the study by Bhattacharyya and Williamson (2011) can also be mentioned, which explored the Australian terms of trade volatility since 1901. This paper categorised two main price shock episodes before the latest mining-led boom and burst. It evaluated their comparative degree, their influence on deindustrialisation and distribution during the booms, and the labor market and policy reactions to the shocks. It was shown that Australia had indeed reacted differently to unstable commodity prices than had other commodity exporters.

Contrary to the Dutch disease theory based on RER adjustments, the paper by Makin and Rohde (2015) highlighted the relative price effects of terms of trade changes on GDP and net exports with reference to the experience of Australia, Canada, New Zealand, and Norway. The econometric analysis of this study showed that, except for Canada, no Granger causality ran from the terms of trade to GDP. Moreover, terms of trade movements driven by commodity price swings had no significant short-run impact on GDP in these economies. As implied by the theory, causality may or may not run from the terms of trade to the trade balance or net exports. While there was evidence of causality between the terms of trade and net exports for Australia and Norway, this was not the case for Canada and New Zealand. Again, consistent with the alternative theoretical perspective, somewhat counter-intuitively there was no evidence of any strong positive relationship between terms of trade fluctuations and net exports in these economies.

The study by Bashar and Kabir (2013) sought to identify major factors behind recent fluctuations in the Australian dollar. Utilising quarterly data for over 30 years and cointegration and error correction models, the study showed that in the long run, the exchange rate was determined by commodity prices, interest rates and other factors such as the GFC. They showed two-way Granger causality between exchange rate and commodity prices, but only one-way Granger causality from the GFC to commodity prices.

The research by Makin (2013) proposed a straightforward model for analysing the impact of export commodity price fluctuations on open macroeconomies with particular reference to Australia and New Zealand, who are major commodity exporters in the Asian region. The main lessons for macroeconomic policy from this research was that a free-floating exchange rate acted as a useful shock absorber for national output in the face of commodity price shocks. Evidence provided in this paper revealed this was clearly the case in Australia. Yet a flexible exchange rate might not be optimal if over longer periods commodity prices exhibit a sustained trend rise. This is because national output then falls short of its potential level due to persistent currency appreciation, which reduced production elsewhere in the economy. Finally, this study suggested that under a floating exchange, the trade balance reacted oppositely to what might be expected. For instance, instead of positive commodity price shocks yielding trade surpluses via increased export values on the real side of the economy, they generate trade deficits due to exchange rate appreciation stemming from pressures exerted on the monetary side.

Bhar (2015) showed the impact of export commodity prices on the Australian dollar/US dollar exchange rate. Within a regression context, the influence of four commodity sub-indices was explored: rural, non-rural, base metal and bulk commodities. The purpose was to discover whether a specific type of commodities correlated especially well with variations in exchange rate given the commodities boom that Australia had just experienced. The non-rural commodity sub-index appeared to have the most explanatory influence. The addition of the balance of trade variable in the model displayed a marginal improvement in the explanatory power.

The impact of commodity price shocks in the Australian economy is assessed from a different angle in the research by Knop and Vespignani (2014).

This study reported that commodity price shocks predominantly affected the mining, construction and manufacturing industries in Australia. However, the financial and insurance sectors were found to be relatively unaffected. Mining industry profits and nominal output substantially increased in response to commodity price shocks. Construction output was also found to increase significantly, especially in response to a bulk commodity shock, as a result of increased demand for resource-related construction.

The distributional consequences of commodity price shocks were assessed in the research by Bhattacharyya and Williamson (2016). Utilising a GARCH model, the study found that Australia experienced more volatility than many commodity exporting developing countries. They conducted cointegration tests to assess the commodity price shock inequality nexus. A single equation error correction model suggested that commodity price shocks increased the income share of the top 1, 0.05, and 0.01 per cent in the short run. The very top end of the income distribution benefited from commodity booms disproportionately more than the rest of the society. The short-run effect was mainly driven by wool and mining and not agricultural commodities. A sustained increase in the price of renewables (wool) reduced inequality whereas the same for non-renewable resources (minerals) increased inequality.

3.5 Concluding Remarks

This chapter provides a detailed literature review of both theoretical and empirical literature that is available on commodity prices dynamics and their relationship with other macroeconomic variables. This chapter also summarises the available literature in the context of Australia. This information helps to identify the research gap in this context to undertake the present study efficiently.

Chapter 4 ANALYTICAL FRAMEWORK OF COMMODITY PRICE DYNAMICS

4.1 Introduction

This study conducted an empirical analysis to shed light on the Australian commodity price dynamics and considered various macroeconomic variables from the existing literature to identify the interactions of those variables to explain recent fluctuations in commodity prices.

4.2 Analytical Framework

The analytical framework of this thesis is discussed in the following five sub-sections. The study specifies the empirical model of Australian commodity prices in the first section, followed by the definition of the variables in the model and the sources of our data in second two. Section three explains the expected signs for the relationship among the considered variables of the model. The fourth section contains a review of the estimation techniques for the study of determinants of the commodity prices, and concluding remarks are provided in the fifth section.

4.2.1 Model Specification

After considering the theoretical background of commodity prices in the previous chapter, this study utilises the equations of a competitive market model to try and understand the dynamics of various macroeconomic variables that are affecting commodity prices. The base theoretical framework of the analytical model is the model by Frankel and Rose (2010), which has been described in detail previously.

There are several techniques available to estimate the parameters of the analytical model, ranging from classical regression methods to cointegration-based techniques. Classical regression methods assume that all stationary variables need to be included in a regression analysis. However, most of the economic series are not stationary in their levels and estimations based on this technique can give spurious results. One of the preferred approaches to cause the variables to become stationary is to differentiate them. However, this mechanism places shadows on the long-run information that might remain in the data. These problems instigate the development of a new generation of models based on cointegration and error correction modelling. Currently, several types of cointegration-based methods are available. However, utilising them for multivariate models causes various problems in most cases.

The present study utilises Johansen's (1988, 1991) cointegration technique, which has emerged as the most powerful and popular method in this area. The Johansen (1988, 1991) approach captures the underlying time series properties of the data. According to Chowdhury (1998), Johansen methodology begins with determining the number of cointegrating vectors in a system and then estimating them. This procedure commences with a general VAR model with variables of interest. These models have become gradually standard in modern times. They are assessed to deliver empirical suggestion on the reaction of macroeconomic variables to various exogenous impulses. Thus, these models help to differentiate between alternative theoretical models of the economy.

To analyse the dynamic interaction of various macroeconomic variables on commodity prices of the study, it assumes a vector of g variables (here, g = 5) and four of which are $I(1)$:

$$Y_t = [rci, rr, rer, ip, spr]$$

where, rci denotes real commodity price, rr represents real interest rate, rer shows the trade weighted RER of Australia, ip denotes industrial production index over time and spr shows S&P/ASX 200 resources index in real form. These five variables are thought maybe to be cointegrated and the purpose of employing the Johansen (1988, 1991) cointegration test is to determine whether the variables in the commodity price model are cointegrated or not. Johansen's method takes as a starting point the VAR of order k lags and the equation can be written in the following format:

$$\underset{g\times 1}{Y_t} = \underset{g\times g}{\beta_1}\underset{g\times 1}{Y_{t-1}} + \underset{g\times g}{\beta_2}\underset{g\times 1}{Y_{t-2}} + \cdots + \underset{g\times g}{\beta_k}\underset{g\times 1}{Y_{t-k}} + \underset{g\times 1}{u_t} \text{…… (4. 1)}$$

where, Y_t is a 5 × 1 vector of variables based on five endogenous variables, namely rci, rr, rer, ip, spr. The basic VAR model of equation (4.1) can be written as the following general equation forms:

$$rci_t = \sum_{j=1}^{k}\beta_{1j} \quad rci_{t-j} + \sum_{j=1}^{k}\gamma_{1j} \quad rr_{t-j} + \sum_{j=1}^{k}\delta_{1j} \quad rer_{t-j} + \sum_{j=1}^{k}\theta_{1j} \quad ip_{t-j} + \sum_{j=1}^{k}\varphi_{1j} \quad spr_{t-j} + u_{1t} \text{ --------------------- (4.2)}$$

$$rr_t = \sum_{j=1}^{k}\beta_{2j} \quad rci_{t-j} + \sum_{j=1}^{k}\gamma_{2j} \quad rr_{t-j} + \sum_{j=1}^{k}\delta_{2j} \quad rer_{t-j} + \sum_{j=1}^{k}\theta_{2j} \quad ip_{t-j} + \sum_{j=1}^{k}\varphi_{2j} \quad spr_{t-j} + u_{2t} \text{ -------------------- (4.3)}$$

$$rer_t = \sum_{j=1}^{k}\beta_{3j} \quad rci_{t-j} + \sum_{j=1}^{k}\gamma_{3j} \quad rr_{t-j} + \sum_{j=1}^{k}\delta_{3j} \quad rer_{t-j} + \sum_{j=1}^{k}\theta_{3j} \quad ip_{t-j} + \sum_{j=1}^{k}\varphi_{3j} \quad spr_{t-j} + u_{3t} \text{ --------------------- (4.4)}$$

$$ip_t = \sum_{j=1}^{k}\beta_{4j} \quad rci_{t-j} + \sum_{j=1}^{k}\gamma_{4j} \quad rr_{t-j} + \sum_{j=1}^{k}\delta_{4j} \quad rer_{t-j} + \sum_{j=1}^{k}\theta_{4j} \quad ip_{t-j} + \sum_{j=1}^{k}\varphi_{4j} \quad spr_{t-j} + u_{4t} \text{ ---------------------- (4.5)}$$

$$spr_t = \sum_{j=1}^{k} \beta_{5j} \quad rci_{t-j} + \sum_{j=1}^{k} \gamma_{5j} \quad rr_{t-j} + \sum_{j=1}^{k} \delta_{5j} \quad rer_{t-j} + \sum_{j=1}^{k} \theta_{5j} \quad ip_{t-j} + \sum_{j=1}^{k} \varphi_{5j} \quad spr_{t-j} + u_{5t} \text{ -------------------- } (4.6)$$

It is expected that the majority of the macro series are integrated of the same order, preferably $I(1)$.

However, researchers sometimes get confused about the practicability of mixing variables with different orders of integration in their multivariate forming of non-stationary economic time series model.

The confusion originates from the representation theorem of Engle and Granger (1987), which shows the characterisation of cointegration from a multivariate method with all variables having the same order of integration. Other researchers such as Gourieroux and Monfort (1990) and Banerjee, Dolado, Galbraith, and Hendry (1993) also discuss the same definition in their research. However, the later work states that a more general structure is possible for developing a model.

Lutkepohl (1991) essentially showed an extensive explanation, which permits for dissimilar integration orders in the fundamental model. and Flores and Szafarz (1996) stated that the basic motivation for a broader definition of cointegration comes from the fact that a long-run relationship might take place between economic variables of different integration orders. Their research considered an extended definition of cointegration where there is a mixture of I(1) and I(0) processes, which are much more readily dealt with by the Johansen approach (Juselius, 1995). This view is also strongly supported by Hunter, Burke, and Canepa (2017). Based on their study, when the Johansen (1991) procedure is utilised, I(0) and I(1) processes can be mixed if there are at least two I(1) variables in the system.

Brooks (2002) showed that variables with differing orders can also be combined and, in that case, the grouping will have an order of integration equal to the largest. However, a linear combination of $I(1)$ variables can only be $I(0)$ if they are cointegrated. Although the group of variables may trend upward in a stochastic fashion, they may be trending together. This characteristic of time series is similar to the approximating of two dancing partners after following unlike random pattern and their random walks appear to be in unison (Gujarati & Porter, 2009). In this way, the linear combination of two or more macro time series can be stationary.

To utilise the Johansen test, the VAR (equation 4.1) above needs to be turned into a VECM, which will take the following form:

$$\Delta Y_t = \Pi Y_{t-k} + \Gamma_1 \Delta Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \cdots + \Gamma_{k-1} \Delta Y_{t-(k-1)} + u_t \quad \text{--- (4.7)}$$

where, $\Pi = \left(\sum_{i=1}^{k} \beta_i\right) - I_g$ and $\Gamma_i = \left(\sum_{j=1}^{i} \beta_j\right) - I_g$

In the present study, the VAR contained five variables in first differenced form on the left hand side and k-1 lags of the dependent variables in first differences on the right hand side. Each of them had a Γ coefficient matrix attached to it. The lag length employed in the VECM can actually affect the Johansen test. For that reason, it is advantageous to attempt to select the lag length optimally. The Π matrix is one of the most important parts of the Johansen test as this test centres on an investigation of this matrix, which can be interpreted as a long-run coefficient matrix. In equilibrium, all the ΔY_{t-i} will be zero, and setting the error terms, u_t, to their expected value of zero will leave $\Pi Y_{t-k} = 0$.

The test for cointegration between Xs was calculated by liking at the rank of the Π matrix via its eigenvalues. Rank-restricted product moment matrices provide the eigenvalues of the test statistics and not of Π itself. The rank of a matrix is equal to the number of its characteristic roots that are different from zero. The characteristic roots are also known as eigenvalues. Brooks (2002) showed the algebraic explanations of the eigenvalues of a matrix.

Let Π denote a $g \times g$ square matrix, c denotes a $g \times 1$ non-zero vector, and λ denote a set of scalars. λ is called a characteristic root or set of roots of the matrix Π if it is possible to write:

$$\underset{g\times g}{\Pi}\ \underset{g\times 1}{c} = \lambda \underset{g\times 1}{c} \quad \text{--------------------} \ (4.8)$$

This equation can also be written as:

$$\Pi c = \lambda I_g c \quad \text{--------------------} \ (4.9)$$

where, I_g is an identity matrix, and hence:

$$(\Pi - \lambda I_g)c = 0 \quad \text{------------------} \ (4.10)$$

Since $c \neq 0$ by definition, then for this system to have a non-zero solution, the matrix $(\Pi - \lambda I_g)$ is required to be singular. Therefore,

$$|\Pi - \lambda I_g| = 0 \quad \text{-------------------} \ (4.11)$$

The eigenvectors would be the values of c corresponding to the eigenvalues. The eigenvalues $(\lambda_i)$are placed in ascending order $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_g$. If λs are roots, in this context they must be less than 1 in absolute value and positive. λ_1 will be the largest and the closest to one. On the other hand, λ_g will be the smallest and the closest to zero. If the variables of equation (4.1) are not cointegrated, the rank of Π will not be significantly different from zero. Therefore, $\lambda_i \approx 0 \forall i$. The test statistics actually incorporate $\ln(1 - \lambda_i)$, rather than the λ_i themselves. However, the fact is when $\lambda_i = 0$, $\ln(1 - \lambda_i) = 0$. Thus, for Π to have a rank of 1, the largest eigenvalue must be significantly non-zero, while others will not be significantly different from zero.

There are two test statistics for cointegration under the Johansen approach. These two approaches can be formulated as follows:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{g} ln(1 - \hat{\lambda}_i) \qquad \text{----------- } (4.12)$$

and:

$$\lambda_{max}(r, r+1) = -T\ ln(1 - \hat{\lambda}_{r+1}) \qquad \text{----------- } (4.13)$$

where, r is the number of cointegrating vectors under the null hypothesis and $\hat{\lambda}_i$ is the estimated value for the ith ordered eigenvalue from the Π matrix. Intuitively, the larger $\hat{\lambda}_i$ is, the more large and negative will be $\ln(1 - \lambda_i)$ and hence the larger will be the test statistic. Each eigenvalue will have associated with it a different cointegrating vector, which will be eigenvectors. A significantly non-zero eigenvalue indicates a significant cointegrating vector.

λ_{trace} is a joint test where the null hypothesis is that the number of cointegrating vectors is less than or equal to r against an unspecified or general alternative that there are more than r. It begins with p eigenvalues and then the largest is removed consecutively. $\lambda_{trace} = 0$ when all the $\lambda_i = 0$, for $i = 1, \ldots, g$.

On each eigenvalue, λ_{max} conducts discrete tests. The null hypothesis for this test is that the number of cointegrating vectors is r against an alternative of $r + 1$.

Johansen and Juselius (1990) provide critical values for the two statistics. The test statistics have a non-standard distribution and the critical values depend on the number of non-stationary components of the system, which is on the value of $g - r$ as well as whether constants are included in each of the equations. Intercepts can be included in the cointegrating vectors themselves. Moreover, it can be included as additional terms in the VAR and according to Brooks (2002) this process is equivalent to including a trend in the data generating processes for the levels of the series. Osterwald-Lenum (1992) provides a more comprehensive set of critical values for the Johansen test.

If the test statistics are greater than the critical value from Johansen's tables, reject the null hypothesis that there are r cointegrating vectors. In the case of λ_{trace}, the result remains in favour of the alternative that there are $r + 1$ cointegrating vectors and for λ_{max}it remains in favour of the alternative that there are more than r cointegrating vectors. The testing is conducted in a sequence and under the null hypothesis, $r = 0, 1, \ldots, g - 1$ so that the hypotheses for λ_{max} are:

$$H_0 : r = 0 \quad versus \quad H_1 : 0 < r \leq g$$

$$H_0 : r = 1 \quad versus \quad H_1 : 1 < r \leq g$$

$$H_0 : r = 2 \quad versus \quad H_1 : 2 < r \leq g$$

$$\vdots \qquad \vdots \qquad \vdots$$

$$H_0 : r = g - 1 \quad versus \quad H_1 : r = g$$

The first test involves a null hypothesis of no cointegrating vectors and this test corresponds to Π having zero rank. If this null hypothesis is not rejected, it would be concluded that there are no cointegrating vectors and the testing would be completed. However, if $H_0 : r = 0$ is rejected, the null hypothesis that there is one cointegrating vector (i.e. $H_0 : r = 1$) would be tested and so on. Thus, the value of r is constantly increased until the null hypothesis is no longer rejected.

During this whole process, r is the rank of Π. The original Y_t represents stationary components if Π has full rank (g). If Π has zero rank, then by analogy to the univariate case, ΔY_t depends only on ΔY_{t-j} and not on Y_{t-1}; therefore, there is no long-run relationship between the elements of Y_{t-1}. Hence, there is no cointegration. Thus, this process corresponds to a test of the rank of the Π matrix. For $1 < rank\ (\Pi) < g$, there are r cointegrating vectors. Π is then defined as the product of two matrices, α and β', of dimension $(g \times r)$ and $(r \times g)$, respectively, i.e.:

$$\Pi = \alpha\beta' \qquad \text{------------------------------} \quad (4.14)$$

In the above equation (4.14), matrix β represents the cointegrating vectors and α shows the amount of each cointegrating vector entering each equation of the VECM. This α is also known as the ‘adjustment parameters’ and it represents the speed of adjustment to disequilibrium. Johansen’s method is to estimate the Π matrix from an unrestricted VAR and to test whether we can reject the restrictions implied by the reduced rank of Π.

Brooks (2002) stated that the Johansen setup allowed testing of hypotheses about the equilibrium relationships between the variables. In this test, researchers can view the hypothesis as a restriction on the Π matrix to test a hypothesis about one or more coefficients in the cointegrating relationship. If there exist r cointegrating vectors, only these linear combinations or linear transformations of them, or combinations of the cointegrating vectors, will be $I(0)$. Actually, the product of the matrix of cointegrating vectors β and any non-singular conformable matrix will be a new set of cointegrating vectors.

A set of required long-run coefficient values or relationship between the coefficients does not necessarily imply that the cointegrating vectors have to be restricted. The reason is that any mixture of cointegrating vectors is also a cointegrating vector. Therefore, it may be possible to combine the cointegrating vectors thus far obtained to provide a new one or, overall, a new set having the required properties. The modest and fewer the mandatory properties are, the more likely that this recombination process will automatically yield cointegrating vectors with the required properties. This recombination process is also known as renormalisation. Nonetheless, as restrictions become more frequent or involve more of the coefficients of the vectors, it will ultimately become difficult to satisfy all of them by renormalisation. After this point, all other linear combinations of the variables will be non-stationary. If the restriction does not affect the model greatly, then the eigenvectors should not change a great deal following imposition of the restriction (Brooks, 2002). A test statistic to test this hypothesis can be written as:

$$test\ statistic = -T\ [ln(1-\lambda_i) - ln(1-\lambda_i^*)] \sim \chi^2(m) \quad \text{-----} \ (4.15)$$

where, λ_i^* are the characteristic roots of the restricted model, λ_i are the characteristic roots of the unrestricted model, r is the number of non-zero characteristic roots in the unrestricted model and m is the number of restrictioins.

Restrictions are actually imposed by substituting them into the relevant α and β matrices as appropriate, so that tests can be conducted on either the cointegrating vectors or their loadings in each equation in the system or both.

Suppose, for our present study that $g = 5$; therefore, the system contains five variables. The elements of the Π matrix would be written as:

$$\Pi = \begin{pmatrix} \pi_{11} & \pi_{12} & \pi_{13} & \pi_{14} & \pi_{15} \\ \pi_{21} & \pi_{22} & \pi_{23} & \pi_{24} & \pi_{25} \\ \pi_{31} & \pi_{32} & \pi_{33} & \pi_{34} & \pi_{35} \\ \pi_{41} & \pi_{42} & \pi_{43} & \pi_{44} & \pi_{45} \\ \pi_{51} & \pi_{52} & \pi_{53} & \pi_{54} & \pi_{55} \end{pmatrix} \text{----------------------} \ (4.16)$$

Now, if $r = 1$, so that there is one cointegrating vector, then α and β will be (5×1):

$$\Pi = \alpha\beta' = \begin{pmatrix} \alpha_{11} \\ \alpha_{21} \\ \alpha_{31} \\ \alpha_{41} \\ \alpha_{51} \end{pmatrix} (\beta_{11} \quad \beta_{12} \quad \beta_{13} \quad \beta_{14} \quad \beta_{15}) \qquad \text{-----} (\ 4.17)$$

Suppose, now that $g = 5$ and $r = 1$, as in equation (4.17) above, then there are five variables in the system, rci, rr, rer, ip and spr, that exhibit one cointegrating vector. Then, ΠY_{t-k} will be given by:

$$\Pi = \begin{pmatrix} \alpha_{11} \\ \alpha_{21} \\ \alpha_{31} \\ \alpha_{41} \\ \alpha_{51} \end{pmatrix} (\beta_{11} \quad \beta_{12} \quad \beta_{13} \quad \beta_{14} \quad \beta_{15}) \begin{pmatrix} rci \\ rr \\ rer \\ ip \\ spr \end{pmatrix}_{t-k} \qquad \text{-----------} \ (4.18)$$

Equation (4.18) can also be written as:

$$\Pi = \begin{pmatrix} \alpha_{11} \\ \alpha_{21} \\ \alpha_{31} \\ \alpha_{41} \\ \alpha_{51} \end{pmatrix} (\beta_{11}\, rci + \beta_{12} rr + \beta_{13} rer + \beta_{14} ip + \beta_{15} spr)_{t-k} \quad \text{---- (4.19)}$$

Given equation (4.19), it is possible to write out the separate equations for each variable ΔY_t. Thus, the VECM can be written by the following equations:

$$\Delta rci_t = \gamma_1 + \sum_{i=1}^{k-1} \delta_{1i} \Delta rci_{t-i} + \sum_{i=1}^{k-1} \zeta_{1i} \Delta rr_{t-i} + \sum_{i=1}^{k-1} \eta_{1i} \Delta rer_{t-i} + \sum_{i=1}^{k-1} \theta_{1i} \Delta ip_{t-i} + \sum_{i=1}^{k-1} \lambda_{1i} \Delta spr_{t-i} + \alpha_{11} ETC_{t-k} + \varepsilon_{rci} \quad \text{--------- (4.20)}$$

$$\Delta rr_t = \gamma_2 + \sum_{i=1}^{k-1} \delta_{2i} \Delta rci_{t-i} + \sum_{i=1}^{k-1} \zeta_{2i} \Delta rr_{t-i} + \sum_{i=1}^{k-1} \eta_{2i} \Delta rer_{t-i} + \sum_{i=1}^{k-1} \theta_{2i} \Delta ip_{t-i} + \sum_{i=1}^{k-1} \lambda_{2i} \Delta spr_{t-i} + \alpha_{21} ETC_{t-k} + \varepsilon_{rr} \quad \text{-------- (4.21)}$$

$$\Delta rer_t = \gamma_3 + \sum_{i=1}^{k-1} \delta_{3i} \Delta rci_{t-i} + \sum_{i=1}^{k-1} \zeta_{3i} \Delta rr_{t-i} + \sum_{i=1}^{k-1} \eta_{3i} \Delta rer_{t-i} + \sum_{i=1}^{k-1} \theta_{3i} \Delta ip_{t-i} + \sum_{i=1}^{k-1} \lambda_{3i} \Delta spr_{t-i} + \alpha_{31} ETC_{t-k} + \varepsilon_{rer} \quad \text{------------ (4.22)}$$

$$\Delta ip_t = \gamma_4 + \sum_{i=1}^{k-1} \delta_{4i} \Delta rci_{t-i} + \sum_{i=1}^{k-1} \zeta_{4i} \Delta rr_{t-i} + \sum_{i=1}^{k-1} \eta_{4i} \Delta rer_{t-i} + \sum_{i=1}^{k-1} \theta_{4i} \Delta ip_{t-i} + \sum_{i=1}^{k-1} \lambda_{4i} \Delta spr_{t-i} + \alpha_{41} ETC_{t-k} + \varepsilon_{ip} \quad \text{------------ (4.23)}$$

$$\Delta spr_t = \gamma_5 + \sum_{i=1}^{k-1} \delta_{5i} \Delta rci_{t-i} + \sum_{i=1}^{k-1} \zeta_{5i} \Delta rr_{t-i} + \sum_{i=1}^{k-1} \eta_{5i} \Delta rer_{t-i} + \sum_{i=1}^{k-1} \theta_{5i} \Delta ip_{t-i} + \sum_{i=1}^{k-1} \lambda_{5i} \Delta spr_{t-i} + \alpha_{51} ETC_{t-k} + \varepsilon_{spr} \quad \text{---------- (4.24)}$$

It is also common to ‘normalise’ on a particular variable, so that the coefficient on that variable in the cointegrating vector is one. Therefore, after all the previous discussion on analytical framework we can appropriately state that the VECM is merely a restricted VAR designed for use with non-stationary series that have been found to be cointegrated (Takaendesa, 2006). The specified cointegrating relation in the VECM restricts the long-run behavior of the endogenous variables to converge to their cointegrating relationships, while allowing for short-run adjustment dynamics. Therefore, after estimating the parameters, the residuals from the VECM need to be checked for autocorrelation and heteroscedasticity.

4.2.2 Data Definition and Source

To analyse the recent instabilities in commodity prices in Australia, the present study utilised mainly five variables to conduct the empirical analysis. These variables are real world commodity price index, short-term real interest rate, Australian RER, real industrial production index and Australian real resources stock price index. The author formulated the econometric models for seasonally adjusted monthly time series from January 2000 to December 2015. This research utilised the following variables to construct the model:

rci = log of Australian real commodity price index

rr = real interbank overnight cash rate

rer = log of Australian trade weighted RER

ip = log of industrial production index

spr = log of Australian real resources stock price index.

To construct the model for the present study, four variables were applied in logs (*rci*, *rer*, *ip* and *spr*) and real interest rate (*rr*) after following Akram (2004, 2009), Bloch, Fraser, and MacDonald (2012), Cashin et al. (2004), Frankel and Rose (2010), Rossi (2012) and the references therein. The definition and the data sources of the variables of this model are given below.

4.2.2.1 Real World Commodity Price Index (rci)

To conduct the present study, the world commodity price index of the RBA was utilised. The data for this ICP was retrieved from the statistics available from the RBA website (RBA, 2016).

Various kinds of world commodity price indices are available for research. Some of these are the Economist index, the IMF index and the CRB index of commodity futures prices. Researchers need to be careful to choose the appropriate index according to the objectives of the study. According to the RBA (1993), some of the indices are not relevant to Australia because of the inclusion of several commodities that are not produced in Australia. Moreover, the Economist and IMF indices are constructed by applying fixed weights to current commodity prices. On the other hand, the CRB index is a simple average of futures prices of 21 commodities; therefore, the same weight applies to each price.

Therefore, according to the RBA (2011), because of different weighting schemes as well as differences between price and investor return indices, we can observe the clear divergent trends in RBA ICP and CRB indices (Figure 4.1).

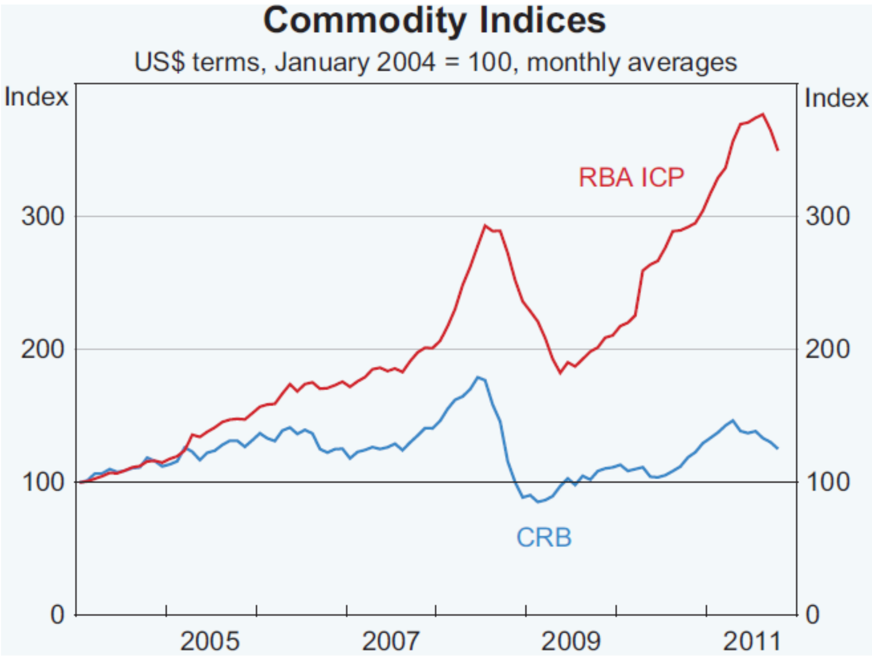


Figure 4.1 Australian Commodity Indices in US$.

Source: RBA (2011)

Among other commodity price indices, the Australian Bureau of Agricultural and Resource Economics publishes a separate Australian commodity price index and another index published by the Commonwealth Bank of Australia (CBA). The first one is a fixed weight index and the CBA index is a moving weight index. However, these indices have a commodity composition slightly different from that of the RBA index.

The present study was conducted on the Australian economy, with Robinson and Wang (2013) demonstrating that the RBA ICP provides a timely indicator of the prices received by Australian commodity exporters. It is a Laspeyres index, which means that it is a weighted average of recent changes in commodity prices, where the weight given to each commodity reflects its importance in total commodity export values during a base period.

Before considering the RBA ICP as the desirable index for the present study, the author performed the cross-correlation between IMF aggregate (global) commodity price index and RBA ICP and found that they have almost perfect positive correlation (0.9401).

This study also considered the Australian dollar index that shows the price received by the Australian commodity exporters in domestic currency. This reveals both world commodity prices and the Australian dollar exchange rate. Earnings of Australian exporters increase with the rise in world commodity prices. Australian dollar prices received by commodity exporters can vary with the exchange rate changes, even if there is no change in the foreign currency price of exports. The prices received in domestic currency will increase with a depreciation in the exchange rate and decrease with an appreciation in the exchange rate (RBA, 1993).

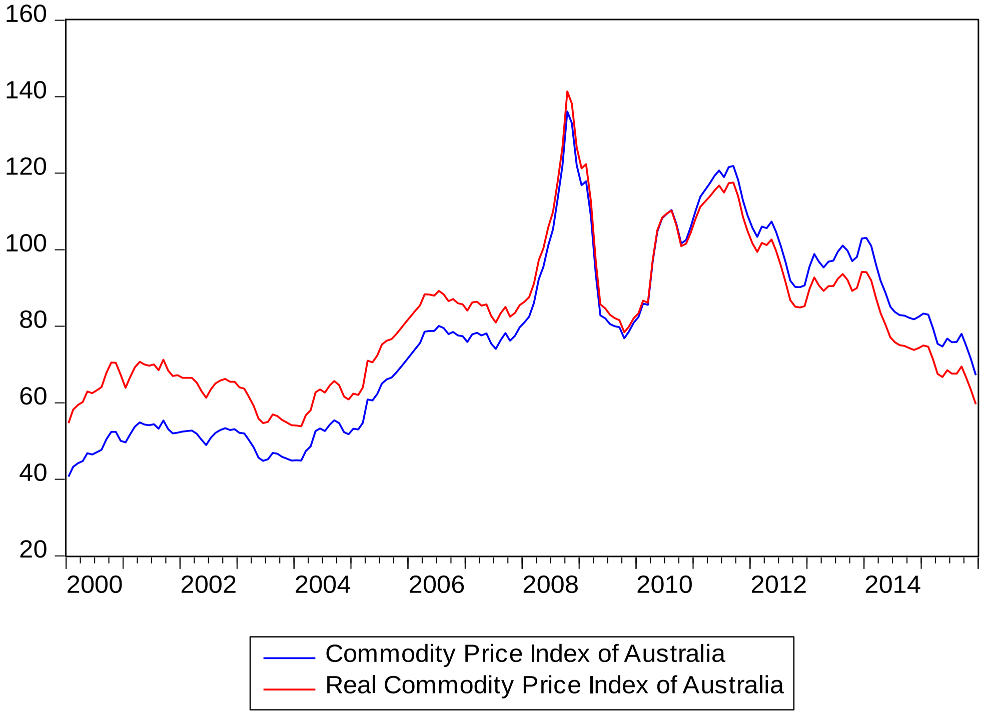


Figure 4.2 World Commodity Price Index; AU$ terms, 2010 = 100.

Source: Datastream (2016a, 2016b).

To convert this data for the ICP into real terms, we rebased the data appropriately after considering 2010 as the base year and deflated the data with the Australian inflation rate. However, the author have taken extra caution to construct the real commodity price index as Richards and Rosewall (2010) suggested. They stated that the introduction of the New Tax System saw large increases in the Australian consumer price index (CPI) between June 2000 and September 2001, the majority of which occurred in the September quarter of 2000. Therefore, movements such as this should be viewed cautiously as temporary volatility in CPI indicators may not necessarily reflect changes to the underlying inflationary trend (Figure 4.2). The author deflated the monthly commodity price index by average annual inflation for only 2000 and 2001. Thereafter, we followed the usual process of calculating the real commodity price index of Australia. After considering this modification, the author constructed the data for the Australian real commodity price index (rci) from January 2000 to December 2015 for the present study. The same cautious processes have been followed for construction of the real interest rate series (rr) as well as real resources price index for Australia (spr).

4.2.2.2 The Australian Real Exchange Rate (rer)

To conduct this research, the monthly data for the 'real Australian trade weighted index' was obtained from the Thomson Reuters Datastream (2016a, 2016b) for January 2000 to December 2015. The RER indices (Figure 4.3) were calculated based on the methodology by Ellis (2001). This real trade weighted index 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 prices indices, where available, from these countries. Where core consumer price indices were not available, headline measures were applied.

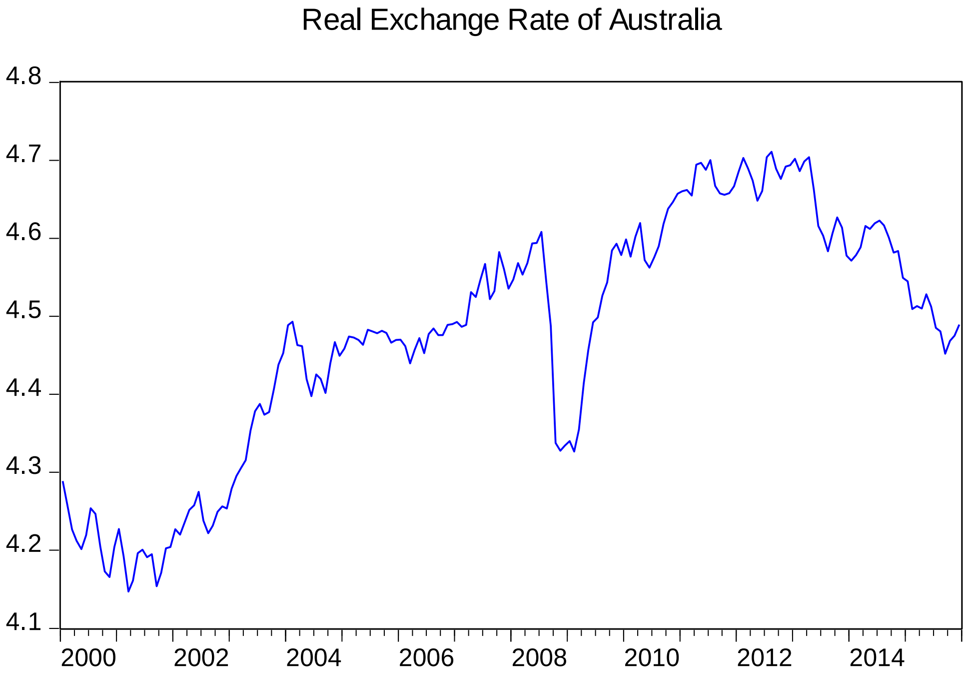


Figure 4.3 AU Real Exchange Rate (rer)

Source: Datastream (2016a, 2016b)

4.2.2.3 Australian Industrial Production Index (ip)

This study also considered the industrial production index as a real economic activity as Rossi (2012) did and the data of industrial production index was extracted from the Thomson Reuters Datastream (2016b) and the index was a volume index (Figure 4.4). The base year of this index was 2010.

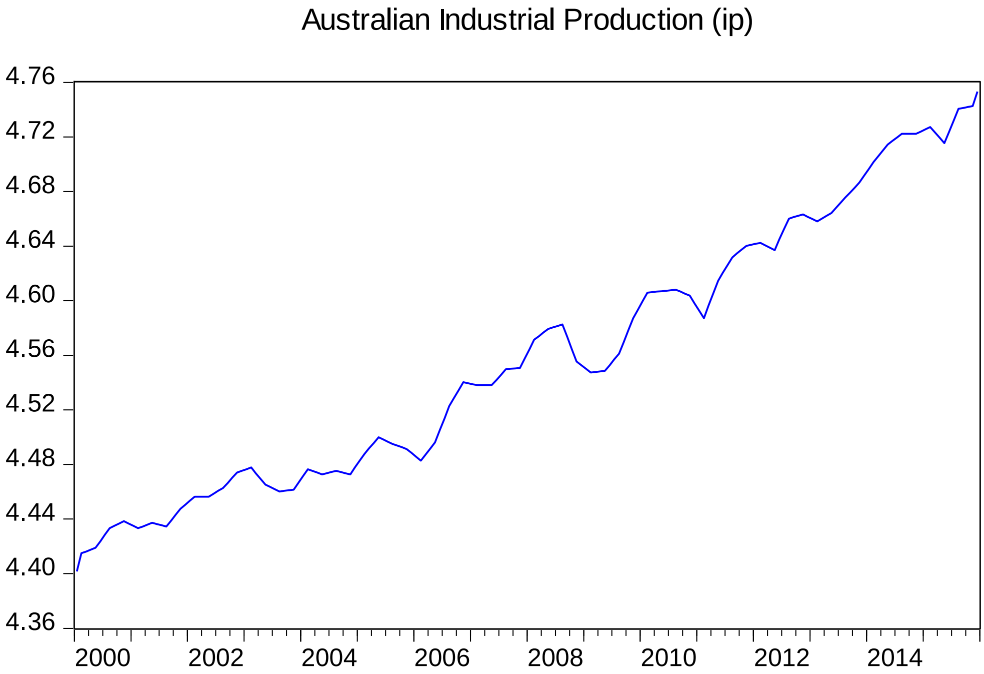


Figure 4.4 AU Industrial Production Index

Source: Datastream (2016b)

4.2.2.4 Real Interest Rate of Australia (rr)

To conduct the present study, the author considered the interbank overnight cash rate as interest rate and the data was taken from the RBA. The interbank rate is a weighted average for the interest rates at which banks have borrowed and lent exchange settlement funds overnight. Then, by following Rossi (2012), the author constructed the real interest rate by taking the difference between the interbank overnight cash rate and the changes in Australian CPI. However, this study has taken extra caution to construct the real interest rate as Richards and Rosewall (2010) suggested. Thus, the author has constructed the data for Australian real interest rate (rr) from January 2000 to December 2015.

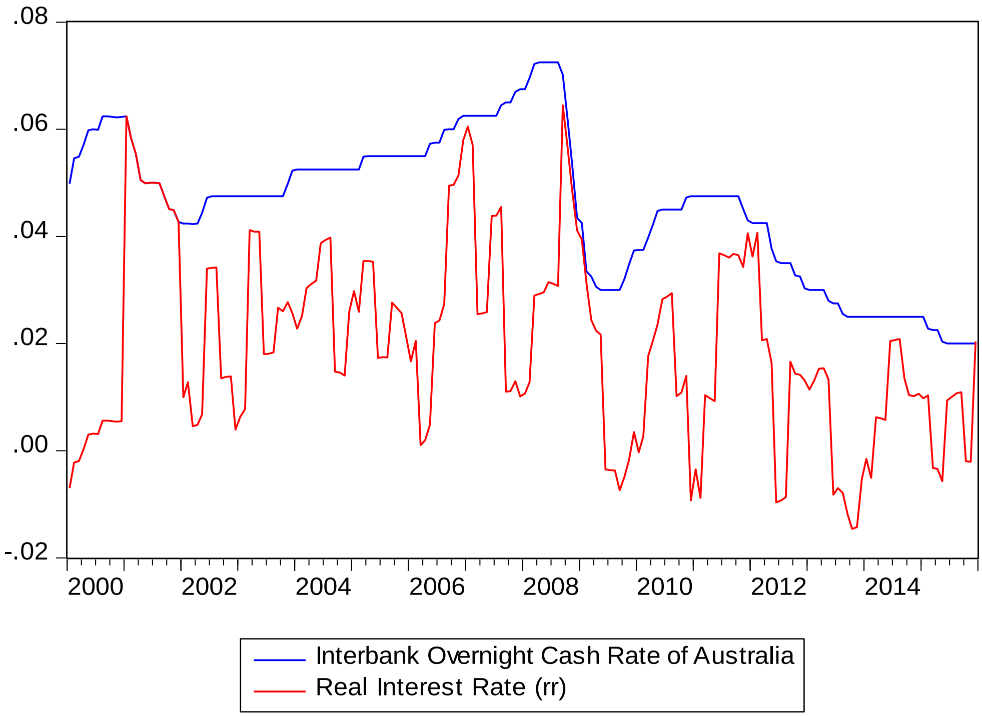


Figure 4.5 Interest Rate of Australia

Source: RBA

4.2.2.5 Australian Real Resources Stock Price Index (spr)

S&P/ASX 200 resources is a sector sub-index of the S&P/ASX 200 index (Figure 4.6). According to McGraw Hill Financial (2015), this index provides investors with a sector exposure to the resources sector of the Australian equity market as classified as members of the GICS resources sector. Resources are defined as companies classified in the energy sector [GICS Tier 1], as well as companies classified in the metals and mining industry sector [GICS Tier 3].

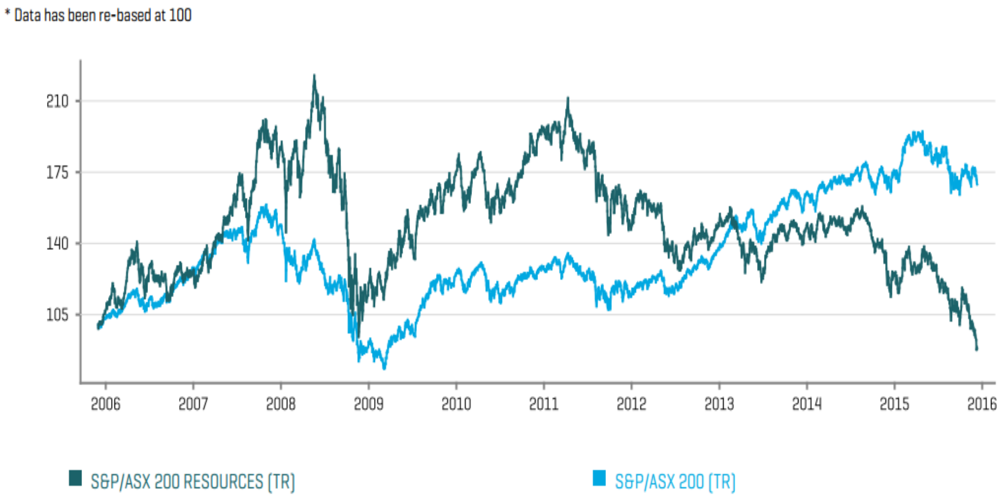


Figure 4.6 Historical Performance of S&P/ASX 200 Resources

Source: McGraw Hill Financial (2015)

For the present study, the author considered the data for S&P/ASX 200 resources index from January 2000 to December 2015 and the data was taken from the Thomson Reuters Datastream (2016b). This study also adjusted the index to Australian inflation rate to obtain the real resources stock index (Figure 4.7).

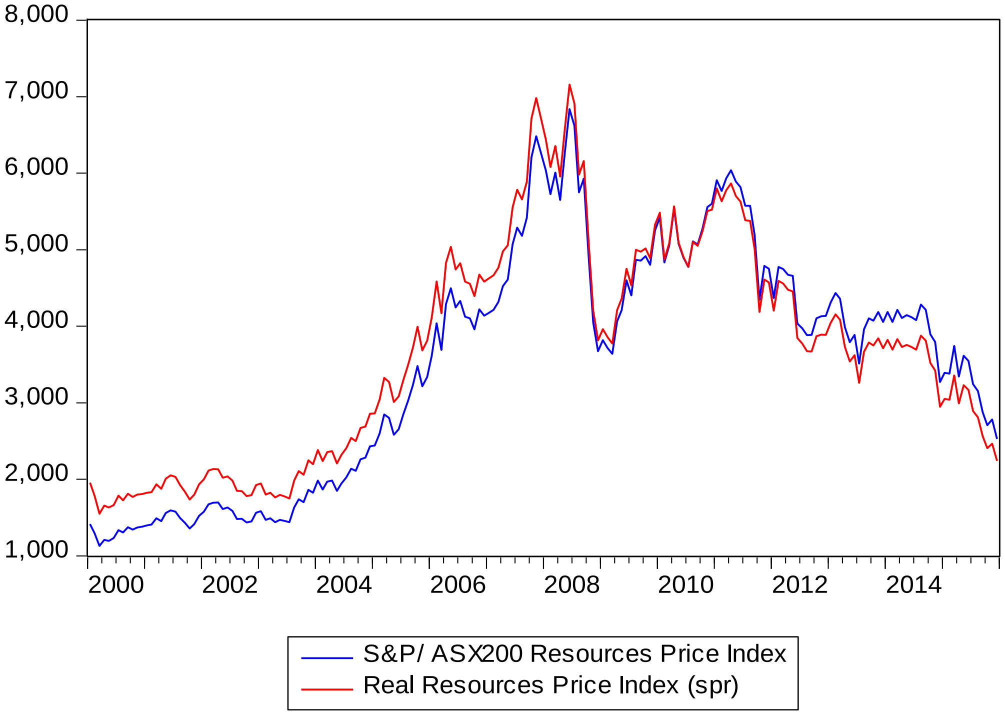


Figure 4.7 Real and Nominal S&P/ASX 200 Resources Price Index

Source: Datastream (2016b).

4.2.3 Expected Signs of Variables from Selected Literature

This section summarises the key findings of some of the relevant literature to show the direction of the relationship between commodity price and other macroeconomic variables to provide an idea of our expected signs for those variables in our model (Table 4.1).

Table 4.1 Sign of Variables from Selected Literature

	LITERATURE	**MAJOR FINDINGS**	**KEY RELATIONSHIP**
1	Frankel (2006)	In his seminal paper, he showed that if the interest rises by 100 basis points, commodity prices fall by 6 per cent and this confirmation holds for the three commodity price measures that he considered.	(-) relationship between interest rate and commodity price.
2	Taylor (2009)	This study showed that a monetary clarification resulted in the rise in commodity prices during the early periods of the last GFC and that oil prices increased in 2007 and 2008 because the Federal Open Market Committee reduced interest rates.	(-) relationship between interest rate and commodity price.

3	Arango et al. (2012)	The interest rate is negatively correlated to the real price of commodities. This paper suggested that the abrupt movement of commodity prices was actually the result of monetary decisions of the authorities made previously.	(-) relationship between interest rate and commodity price.
4	Scrimgeour (2015)	This study estimated that monetary policy surprises have a smaller impact on commodities than on stock prices; however, the effect is the same order of magnitude. This study also showed that the movements in commodity prices following a monetary policy surprise are similar to the change in exchange rate, which is consistent with global commodity market integration in which changes in interest rates have minor effects on commodity prices, but induce large changes in US dollar prices.	(-) relationship between interest rate and commodity price.
5	Akram (2009)	This important research showed a drop in the value of the dollar must be balanced by an increase in the dollar price of commodities and/or a fall in the foreign currency	(-) relationship between exchange rates and commodity prices.

		prices to confirm the same price when measured in dollars. This follows from the law of one price for tradable goods.	
6	Ghura (1990)	This research stated that industrial output had ambiguous effects on commodity prices and was dependent on the stage of the economic cycle of that region. Strengthening of economic activity can boost investors' confidence, which can increase short-run demand. Thus, interest rate could go up and could affect commodity price negatively. Inversely, if the investors consider the same situation as a sign of an 'overheating' economy, two things could happen. Expectation for contracting money supply could increase real rates and hence commodity prices fall. The opposite expectation would increase inflationary expectations and the commodity price would rise.	(+) or (-) relationship between industrial production and commodity prices. The overall impact can only be determined empirically.
7	Bloch et al. (2012)	This study showed that changes in industrial growth initially led to inflation in the permanent component of the real commodity price, but this was followed by roughly	(+) relationship at the beginning and then (-)

		equal negative impact. After roughly one year, the permanent component of the real commodity price returned to its original level.	between industrial production and commodity price.
8	Baffes and Savescu (2014)	Their study utilised a reduced-form of price-determination model and considered the quarterly data for twenty years for six base metals. It concluded that industrial production activity positively affects metal prices the most.	(+) relationship between industrial production and commodity prices.
9	Rossi (2012)	Global commodity price indices are positively correlated with equity values. The study also showed that a country's equity market value has significant out of sample predictive ability for the future global commodity price index.	(+) relationship between equity values and global commodity price.
10	Sarkar et al. (2015)	They assessed the connection between the price of iron ore and stock prices to determine the influence of the newly developed robust correlation between iron ore price and the Australian share prices.	Australian share prices have (+) correlation to the iron ore spot price.

4.2.4 Review of Estimation Techniques

For parameter estimation of the model we can use several techniques, ranging from classical regression methods to cointegration-based techniques. The former methods are based on the assumption that all stationary variables need to be included in a regression analysis; however, the fact is that most of the economic series are not stationary in their levels, and estimations based on this technique can give spurious results (Fazle, 2011). However, before examining the actual analytical framework of the current model, this study will discuss various estimation techniques of the model in the following section.

4.2.4.1 Review on Stationarity and Unit Root Testing of Data

Before starting the analytical part of this research, it is very important to understand the stationarity of our data. Traditionally, the concept of a stationary process has played a significant part in the analysis of time series. According to Wooldridge (2003), a stationary time series process is one whose probability distributions are stable over time in the sense that if we take any collection of random variables in the sequence and then shift that sequence ahead h time periods, the joint probability distribution remains unchanged.

Thus, the stochastic process $(x_t: t = 1, 2, \ldots)$ is stationary if for every collection of time indices $1 \leq t_1 < t_2 < \cdots < t_m$, the joint distribution of $(x_{t_1}, x_{t_2}, \ldots x_{t_m})$ is the same as the joint distribution of $(x_{t_{1+h}}, x_{t_{2+h}}, \ldots x_{t_{m+h}})$ for all integers $h \geq 1$. This explanation is slightly theoretical; however, its meaning is straightforward. Stationarity does require that the nature of any correlation between adjacent terms is the same across all time periods.

A stochastic process that is not stationary is said to be a non-stationary process. Since stationarity is an aspect of the underlying stochastic process and not of the available single realization, it can be very difficult to determine whether the data being analysed were generated by a stationary process or not. Instead, it could be generated via a covariance stationary process.

According to Wooldridge (2003), if a stationary process has a finite second moment, then it must be covariance stationary; however, the converse is certainly not true. Sometimes, to emphasise that stationarity is a stronger requirement than covariance stationarity, the former is referred to as 'strict stationarity' and for correct analysis of this study, the author needs to consider the assumptions related to strict stationarity.

4.2.4.2 Reasons for Utilising Stationarity in Time Series Econometrics

There are several reasons for conducting an examination of whether a series can be viewed as stationary or not. Wooldridge (2003) stated the following reasons for conducting such a test:

- On a technical level, stationarity simplifies statements of the law of large numbers and the central limit theorem.
- On a practical level, if we want to understand the relationship between two or more variables using regression analysis, we need to assume some sort of stability over time. If we allow the relationship between two variables (say, y_t *and* x_t) to change arbitrarily in each time period, then we cannot hope to learn much about how a change in one variable affects the other variable if we only have access to a single time series realization.

Brooks (2002) also discussed several reasons for conducting such tests to check the stationarity in the time series data before further analysis. Some of those reasons are as follows:

- The stationarity or the non-stationarity of a time series can intensely affect its behavior and properties. Suppose, the word 'shock' is frequently utilised to represent a variation or an unexpected change in a variable or possibly just the value of the error term during a specific time period. In case of a stationary series, these 'shocks' to the system will progressively die away. That is, a shock during time t will have a smaller consequence in time $t + 1$, a smaller influence still in time $t + 2$, and so on. This can be differentiated with the case of non-stationary data, where the perseverance of shocks will always be endless.
- Using non-stationary data can lead to spurious regressions. If two stationary variables are generated as independent random series, then when one of those variables is regressed on the other, the t-ratio on the slope coefficient would be expected not to be significantly different from zero, and the value of R^2 would be expected to be very low. This appears clear, for the variables are not linked to one another. However, if two variables are trending over time, a regression of one on the other could have a high R^2 even if the two are completely unconnected. Therefore, if standard regression techniques are applied to non-stationary data, the end result could be a regression that appears good under standard measures with significant coefficient estimates and a high R^2, but which is actually worthless.
- If the variables utilised in a regression model are not stationary, then it can be shown that the standard assumptions for asymptotic analysis will not be

effective. In other words, the usual ‘t-ratios’ will not follow a t-distribution, and the F-statistic will not follow an F-distribution, and so on.

Therefore, in summary, we can appropriately say that if we are dealing with time series data, we must make sure that the specific time series are either stationary or that they are cointegrated. If this is not the case, we may be open to the responsibility of engaging in spurious or nonsense regression analysis (Gujarati & Porter, 2010).

4.2.4.3 Unit Root Test

The theory behind autoregressive integrated moving average calculation is founded on stationary time series. A series is said to be (weakly or covariance) stationary if the mean and autocovariances of the series do not depend on time (EViews7, 2009).

According to Gujarati and Porter (2009), the value of the covariance between the two time periods depends on the distance or lag between them, and not on the time at which the covariance is calculated.

Most of the economic indicators typically follow a non-stationary path; however, in a classical regression model we normally manage the relationship between stationary variables. If the dependent variable is a function of a non-stationary process, the regression will produce spurious results (Gujarati & Porter, 2009). In other words, the dependent variable will follow the trend of its explanatory variables and the result will be meaningless. In such a case, it may be possible to obtain significant t-ratios and a very high R^2 even though the trending variables are completely unrelated. Therefore, we need to perform unit root or stationarity tests before proceeding with the tests for cointegration and estimation of parameters.

Hamilton (1994) and Hayashi (2000) explained the basic unit root theory in detail. However, it can be explained with a simple AR(1) process:

$$y_t = \rho y_{t-1} + x_t'\delta + \epsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4.25)}$$

where, x_t are optional exogenous regressors that might consist of constant, or a constant and trend; ρ and δ are parameters to be estimated; and t ϵ_t are assumed to be white noise. If $|\rho| \geq 1$, y is a non-stationary series and the variance of y increases with time and approaches infinity. If $|\rho| < 1$, y is a (trend) stationary series. Thus, the hypothesis of (trend) stationary can be evaluated by testing whether the absolute value of ρ is strictly less than one.

Thus, the unit root tests conduct the test of the null hypothesis $H_0 : \rho = 1$ against the one-sided alternative $H_1 : \rho < 1$. In some cases, the null hypothesis is tested against a point alternative. In contrast, the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) Lagrange Multiplier (LM) test evaluates the null hypothesis of $H_0 : \rho < 1$ against the alternative $H_1 : \rho = 1$.

From the above discussion, it is clear that there are several ways to test the stationarity of a series. For the present study, we conducted both unit root tests and stationarity test. We performed both these tests to achieve what Brooks (2002) referred to as *confirmatory data analysis*. In addition, we also conducted modified Augmented Dickey-Fuller (ADF) tests to identify any possible breakpoints in our data set.

4.2.4.3.1 The Augmented Dickey-Fuller (ADF) Test

The stationarity of a time series can be tested directly with a unit root test. In the literature, both the Dickey-Fuller (DF) and the ADF tests are most frequently adopted as the procedure of testing unit root. The standard DF test is performed by an estimation equation (4.25) after subtracting y_{t-1} from both sides of the equation:

$$\Delta y_t = \alpha y_{t-1} + x_t'\delta + \epsilon_t \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (4.26)$$

where, $\alpha = \rho - 1$. The null and alternative hypotheses may be written as:

$$\begin{aligned} H_0 &: \alpha = 0 \\ H_1 &: \alpha < 0 \end{aligned} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots. \quad (4.27)$$

and evaluated applying the conventional t-ratio for α:

$$t_\alpha = \hat{\alpha} / (se(\hat{\alpha})) \quad \dots\dots\dots\dots\dots\dots\dots.. \quad (4.28)$$

where, $\hat{\alpha}$ is the estimate of α and $se(\hat{\alpha})$ is the coefficient standard error.

This statistic does not follow the conventional Student's t-distribution under the null hypothesis of a unit root, and Dickey and Fuller (1979) derived asymptotic results and simulated critical values for several test and sample sizes. In recent times, MacKinnon (1991, 1996) implemented a much greater set of simulations than those presented by Dickey and Fuller (1979). Moreover, MacKinnon (1991,1996) estimated response surfaces for the simulation results, permitting the calculation of DF critical values and p-values for arbitrary sample sizes.

If the series of a data set is an AR(1) process, only then is the above simple DF unit root test valid. The hypothesis of white noise disturbances ϵ_t is violated, if the series is correlated at higher order lags. Actually, the ADF test constructs a parametric correction for higher order correlation by assuming that the y series follows an AR(p) process and adding p lagged difference terms of the dependent variable y to the right-hand side of the test regression:

$$\Delta y_t = \alpha y_{t-1} + x_t'\delta + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + \cdots + \beta_p \Delta y_{t-p} + v_t \quad \ldots (4.29)$$

This augmented specification is then utilised to test equation (4.26) using the t-ratio in equation (4.28). An important result obtained by Fuller is that the asymptotic distribution of the t-ratio for α is independent of the number of lagged first differences included in the ADF regression. Said and Dickey (1984) showed that the ADF test was asymptotically valid in the existence of a moving average element, given that necessary lagged difference terms are added in the test regression.

4.2.4.3.2 Dickey-Fuller Test with GLS Detrending (DFGLS)

Researchers may elect to include a constant, or a constant and a linear time trend, while performing the ADF regression. For these two cases, Elliott, Rothenberg, & Stock (1996) suggested a simple modification of the ADF tests in which the data were detrended so that explanatory variables are 'taken out' of the data prior to running the test regression.

Elliott et al. (1996) defined a quasi-difference of y_t that depended on the value a representing the specific point alternative against which we wish to test the null hypothesis:

$$d\,(y_t|a) = \begin{cases} y_t & if\ t = 1 \\ y_t - a y_{t-1} & if\ t > 1 \end{cases} \quad \ldots\ldots\ldots\ldots (4.30)$$

Next, consider an OLS regression of the quasi-differenced data $\mathrm{d}\,(\mathrm{y_t}|\mathrm{a})$ on the quasi-differenced $\mathrm{d}\,(\mathrm{x_t}|\mathrm{a})$:

$$d\ (y_t|a) = \ d\ (y_t|a)'\ \delta(a) + \ \eta_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\text{. (4.31)}$$

where, x_t contains either a constant, or a constant and trend, and let $\hat{\delta}(a)$ be the OLS estimates from this regression.

Now, it is required to estimate the value for a. Elliott et al. (1996) recommended the use of $a = \ \bar{a}$, where:

$$\bar{a} = \begin{cases} 1 - 7\ /\ T & if\ x_t = [1] \\ 1 - 13.5\ /\ T & if\ x_t = [1, t] \end{cases} \quad \ldots\ldots\ldots\ldots\text{.. (4.32)}$$

The generalised least squares (GLS) detrended data y_t^d can be defined as follows:

$$\Delta y_t^d = \ \alpha y_{t-1}^d + \ \beta_1 \Delta y_{t-1}^d + \cdots + \ \beta_p \Delta y_{t-p}^d + \ v_t \quad \ldots\ldots\ldots\ldots\ldots\text{. (4.33)}$$

Because y_t^d are detrended, x_t is not included in the DFGLS test equation. Similar to the ADF test, the *t*-ratio for $\hat{\alpha}$ from this test equation is considered. While the DFGLS *t*-ratio follows a DF distribution in the constant only case, the asymptotic distribution differs when one includes both a constant and trend.

The ADF and DFGLS unit root tests can provide precise answers about stationarity or non-stationarity; however, they also have weaknesses. They may fail to notice a false null-hypothesis. Both Brooks (2002) and Gujarati and Porter (2009) showed that unit root tests had low power if the process was stationary but with a root close to the non-stationary boundary. Thomas (1997) indicated that this lack of power meant that the tests failed to detect stationarity when the series followed a stationary process.

Takaendesa (2006) stated that an increase in sample size could solve this problem. Alternatively, we can use a stationarity test, e.g. the KPSS test, which is performed in the present study for overcoming this potential problem.

4.2.4.3.3 The Kwiatkowski, Phillips, Schmidt and Shin (KPSS) Test

Stationarity tests, unlike unit root tests, have stationarity under the null hypothesis, thus reversing the null and alternative hypothesis under unit root tests such as the ADF or the DFGLS of the previous section. Kwiatkowski, Phillips, Schmidt, and Shin(1992) assumed the series to be trend-stationary under the null hypothesis for their suggested test. Their test is derived by starting with the model presented in the following equation:

$$y_t = \beta' D_t + \mu_t + v_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \ (4.34)$$

where, $\mu_t = \mu_{t-1} + \varepsilon_t$, $\varepsilon_t \sim WN\,(0, \sigma_\varepsilon^2)$ and D_t contains deterministic components (constant or constant plus time trend).

The LM statistic can be defined as:

$$KPSS = (T^{-2} \sum_{t=1}^{T} \hat{S}_t^2) \,/\, \hat{\lambda}^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots.. \ (4.35)$$

where, $\hat{S}_t^2 = \sum_{j=1}^{t} \hat{v}_j$, $\hat{v}_j$ is the residual of a regression of y_t on D_t and $\hat{\lambda}^2$ is a consistent estimate of the long-run variance of v_t using $\hat{v}_t$.

The calculated LM statistic is compared to the KPSS (1992) critical values to determine a conclusion about the stationarity of a series. If the calculated LM statistic is smaller than the critical values, the null hypothesis is accepted and the conclusion will be that the series is stationary. The opposite will be true for a non-stationary time series.

4.2.4.3.4 Modified Augmented Dickey-Fuller with A Breakpoint

If the data are trend stationary with a structural break for any research, then conventional unit root tests are biased toward a false unit root null hypothesis. This is something that all researchers should keep in mind. Perron (1989) discussed this issue and reminded researchers that structural change and unit roots are closely related. This finding has encouraged advances in a vast literature outlining several unit root tests that stay valid in the existence of a break.

We also investigated this issue in the present study. The existence of a break in any macroeconomic indicator or growth curve over time may be identified by an analyst or a researcher before the corresponding time series data is completely obtained or collected (Agung, 2009). By looking at the graph of the variables of our model, it was possible to guess a break in 2008 to 2009 for most of the variables. In addition to this process, we utilised several types of modified ADF tests, which permit for levels and trends that diverge via a single break date. This process allowed us to compute unit root tests with a single break where:

- The break can occur slowly or immediately.
- The break consists of a level shift, a trend break, or both a shift and break.
- The break date is known, or the break date is unknown and estimated from the data.
- The data are non-trending or trending.

Before describing the process of modified ADF, it is useful to define a few variables that allowed us to characterise the breaks according to EViews9.5

(2016). The complete procedure follows the straightforward outline discussed in studies by Banerjee, Lumsdaine, and Stock (1992), Perron (1989, 2006), Vogelsang and Perron (1998) and Zivot and Andrews (1992). Let $1(\cdot)$ be an indicator function that takes the value 1 if the argument $(\cdot)$ is true, and 0 otherwise. Then, the following variables are defined in terms of a specified break date T_b,

- An intercept break variable

$$DU_t(T_b) = 1\ (t \geq\ T_b)$$

which takes the value 0 for all dates prior to the break, and 1 thereafter.

- A trend break variable

$$DT_t(T_b) = 1(t\ \geq\ T_b) \cdot (t -\ T_b + 1)$$

which takes the value 0 for all dates prior to the break, and is a break date re-based trend for all subsequent dates.

- A one-time break dummy variable

  $$D_t(T_b) = 1(t =\ T_b)$$

  which takes the value of 1 only on the break date and 0 otherwise.

According to EViews9.5 (2016), the break date is the first date for the new regime. This is in contrast to a lot of the literature that defines the break date as the last date of the previous regime. It considers four basic models for data with a one-time break. The first model with a one-time change in level for non-trending data; for trending data, the models with a change in level; a change in both level and trend; and a change in trend. In addition, it considers two versions of the four models that differ in their treatment of the break dynamics:

the innovational outlier model assumes that the break occurs gradually, with the breaks following the same dynamic path as the innovations, while the additive outlier model assumes the breaks occur immediately. The tests considered here evaluate the null hypothesis that the data follow a unit root process, possibly with a break, against a trend stationary with break alternative. Within this basic framework there are a variety of specifications for the null and alternative hypotheses, depending on the assumptions one wishes to make about the break dynamics, trend behaviour, and whether the break date is known or determined endogenously.

4.2.5 Concluding Remarks

The purpose of this chapter was to establish an analytical framework on the basis of the theoretical models of commodity prices. After considering all the important accessible data in Australia, an empirical model that relates commodity prices to various Australian macroeconomic variables was determined. If the estimated model passed numerous residual diagnostic checks detailed in the subsequent chapter, then it would be employed to examine the influence and degree of shocks to each of the macroeconomic variables on the Australian commodity prices.

Chapter 5 OUTCOMES OF AUSTRALIAN COMMODITY PRICE DYNAMICS

5.1 Introduction

The previous chapter provides the analytical framework and reviews various techniques for evaluating the Australian commodity price dynamics utilised in the present study. In this chapter, the long-run as well as short-run determinants of Australian commodity prices have been examined. This chapter will also assess the impact on commodity prices after the shocks on these macroeconomic variables and will reveal the timeframe that these shocks will be transmitted onto the Australian commodity prices. We employ the Johansen (1988, 1991) cointegration and VECM approach first, followed by the Granger causality along with the impulse response and variance decomposition technique to evaluate the Australian commodity price dynamics.

5.2 Empirical Findings

The empirical findings of the study are provided in five sub-sections. We present the results of unit root tests in section one, followed by the cointegration test and the long-run relationships of the Australian commodity prices as well as the macroeconomic variables in the second sub-section. The third sub-section presents the VECM results, including several diagnostic checks to show the short-run dynamics of this relationships. The fourth sub-section of this chapter shows VEC Granger causality test results and the last sub-section analyses the dynamic behaviour of the VECM utilising the IRF as well as variance decomposition.

5.2.1 Unit Root Results

The first step in Johansen's (1988, 1991) methodology is to determine the order of integration of the series. This research began with the unit root test for all the variables included in the present study, using the ADF and DFGLS tests, with the null hypothesis of a unit root against the alternative of stationarity of data series. The test results are shown in Table 5.1, which includes both 'intercept' and 'trend and intercept' options.

The results of the ADF tests in Table 5.1 reveal that with the 'intercept' and 'trend and intercept' options, four series in our model (rci, rer, ip and spr) were first difference stationary $I(1)$ in all the cases and the rr series is level stationary, as was expected. With the same option, the DFGLS tests in Table 5.1 show that three variables ($rci, rer,$ and spr) were first difference stationary I(1), while only two variables ($rr\ and\ ip$) were level stationary $I(0)$. In case of only two variables (ip and spr) with the option of 'intercept' only, the DFGLS tests showed higher order (more than 1) stationarity of the variables.

To confirm the stationarity of most of the variables of our model, we applied a third test, the KPSS test. It should be remembered here that the ADF and DFGLS methods test the null hypothesis of a unit root, while the KPSS has as its null hypothesis that the series is stationary; therefore, a rejection of the null hypothesis under both the ADF and the DFGLS means that the series does not have a unit root, while the rejection of the null hypothesis under the KPSS is interpreted as evidence of non-stationary or presence of a unit root in the series.

The results of the KPSS tests in Table 5.1 show that with the 'intercept' and 'trend and intercept' options, (rr) was only level stationary $I(0)$. Moreover, with both the options, all our variables of the model (rci, rr, rer, rip and spr) were first difference stationary $I(1)$ at the 1 per cent as well as at the 5 per cent level of significance.

Test		rci		rr		rer		ip		spr	
		Intercept	Trend & Intercept	Intercept	Trend & Intercept	Intercept	Trend & Intercept	Intercept	Trend & Intercept	Intercept	Trend & Intercept
ADF	Level	-1.82	-1.35	-4.36*	-3.83*	-1.80	-2.00	-1.78	-2.83	-1.45	-0.14
	1st Difference	-7.75*	-7.86*			-10.47*	-10.50*	-4.21*	-4.67*	-13.91*	-14.18*
	Order of Integration	I(1)	I(1)	I(0)	I(0)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
DFGLS	Level	-1.16	-1.41	-2.67*	-3.33**	-0.95	-2.19	3.19	-2.83***	-0.64	-0.30
	1st Difference	-2.59*	-6.49*			-3.76*	-8.60*	-0.73		-0.83	-5.12*
	Order of Integration	I(1)	I(1)	I(0)	I(0)	I(1)	I(1)	-	I(0)	-	I(1)
KPSS	Level	0.82**	0.28***	0.54	0.11	1.29**	0.24*	1.68*	0.32*	0.91**	0.38*
	1st Difference			0.24**	0.05*						
	Order of Integration	I(1)	I(1)	I(0)	I(0)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)

Test with a breakpoint (Modified ADF)	Level	-2.67	-2.97	-5.27* **(01/10/2008)**	-5.25* **(1/10/2008)**	-3.22	-3.65	-0.89	-4.60	-2.37	-2.20
	1st Difference	-8.58* (1/04/2009)	-8.59* **(1/10/2008)**			-12.39* **(1/10/2008)**	-12.54* **(1/10/2008)**	-6.47* (1/09/2015)	-6.51* (1/09/2015)	-14.91* **(1/10/2008)**	-14.90* **(1/10/2008)**
	Order of Integration	I(1)	I(1)	I(0)	I(0)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)

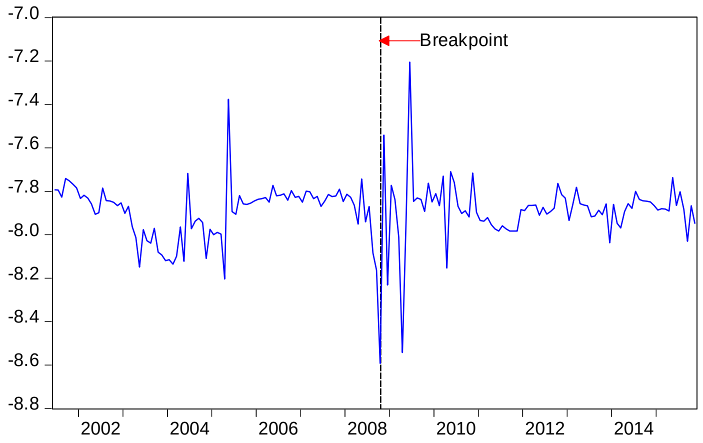
Table 5.1 Unit Root Test Results

Note: *, ** and *** represent No Unit Root at 1 per cent, 5 per cent and 10 per cent level of significance, respectively. The dates inside the () show the breakpoints identified by the modified ADF test.

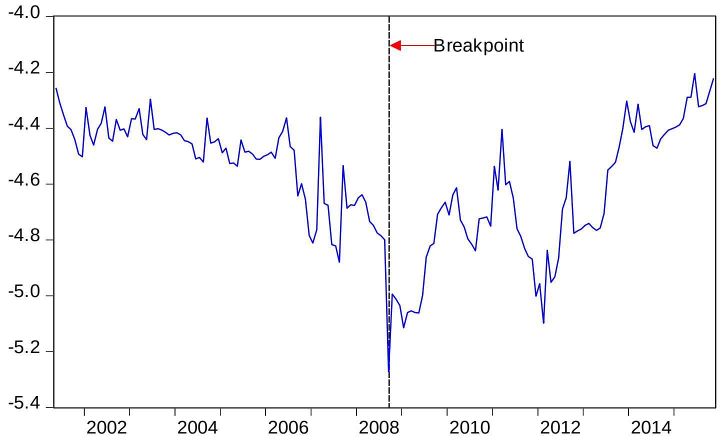
To identify the existence of possible breakpoints in our model, we also conducted modified ADF tests (Table 5.1). The modified ADF tests identified several breakpoints in the data series of the variables of our model. However, four out of five variables of our model showed the same break date in the series, i.e. the rci, rr, rer and Australian spr had the break date as 1 October, 2008. Moreover, the Australian ip, which is a volume index, showed the break date as 1 September, 2015. However, in the case of the rci with the option of 'intercept' only, the break date was 1 April, 2009. Because in the majority of the cases the break date was revealed as being the 1 October, 2008, this can be justified by the influence of the GFC on the Australian economy. Therefore, we considered this date to be the break date of our model. The modified ADF tests revealed all the variables of our model as first difference stationary $I(1)$, except for the rr, which was a level stationary $I(0)$ series.

Figure (5.1) represents the graphs of DF *t*-statistics for all the variables, which has the same breakpoint at 1 October, 2008 and the variables were rci, rr, rer and spr.

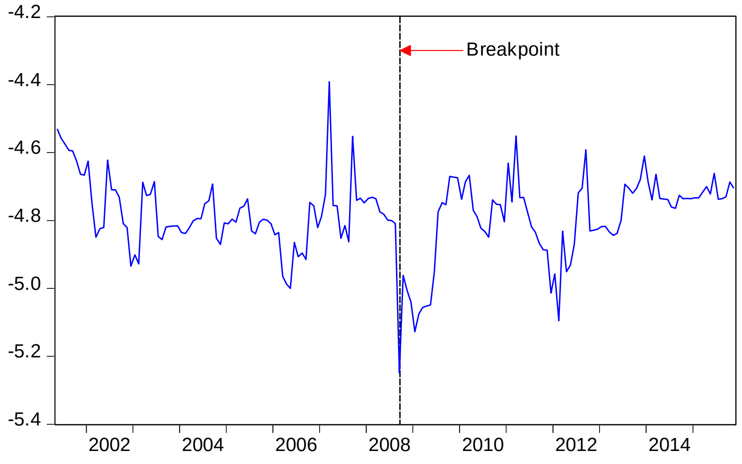
Dickey-Fuller t-statistics : With Intercept & Trend for d(rci)



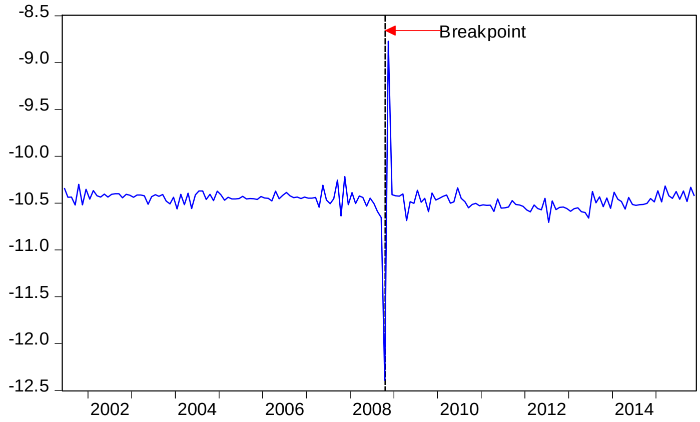
Dickey-Fuller t-statistics : With Intercept only for (rr)



Dickey-Fuller t-statistics : With Intercept & Trend for (rr)

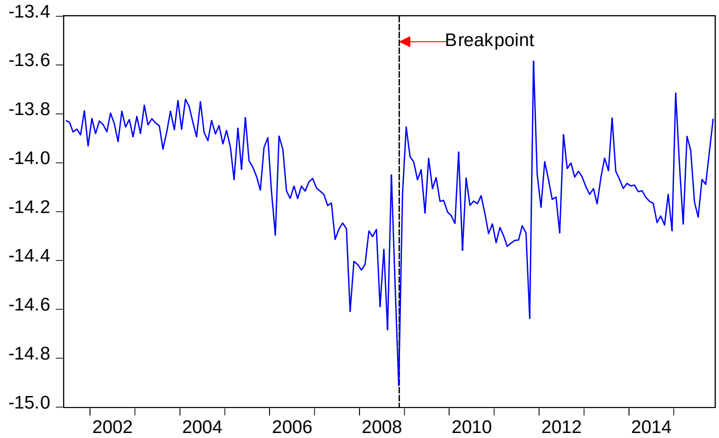


Dickey-Fuller t-statistics : With Intercept only for d(rer)



Dickey-Fuller t-statistics : With Intercept & Trend for d(rer)

Dickey-Fuller t-statistics: With Intercept only for d(spr)



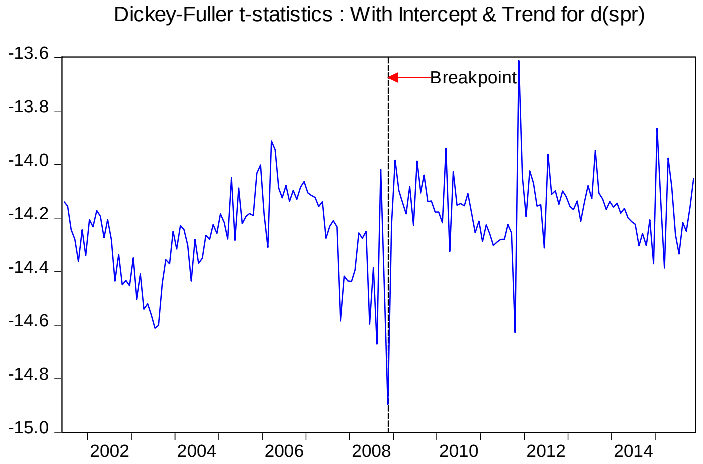


Figure 5.1 Test Statistics Graphs with the Same Breakpoint

The above graphs in Figure 5.1 show that the first different Australian real commodity price index (rci) with the 'intercept and trend' option had a breakpoint at 1 October, 2008 and the *t*-statistics (-8.59) confirmed the first difference stationarity at a 1 per cent significant level. The graphs of the DF t-statistics of real interest rate show the breakpoints at 1 October, 2008 in both cases and confirm that the series is level stationary. The first difference of the Australian rer with both of the options of 'intercept only' as well as 'intercept and trend' confirms the breakpoint at the same point of time and also endorses the first difference stationarity of the series at a 1 per cent level of significance.

The last two graphs of Figure 5.1 represent the DF *t*-statistics for the first difference of Australian resources spr for 'intercept only' and 'intercept and trend' and confirm the same breakpoint at 1 October, 2008. The *t*-statistics of -14.91 and -14.90 are significant at a 1 per cent level and both of them confirm the first difference stationarity of the spr series.

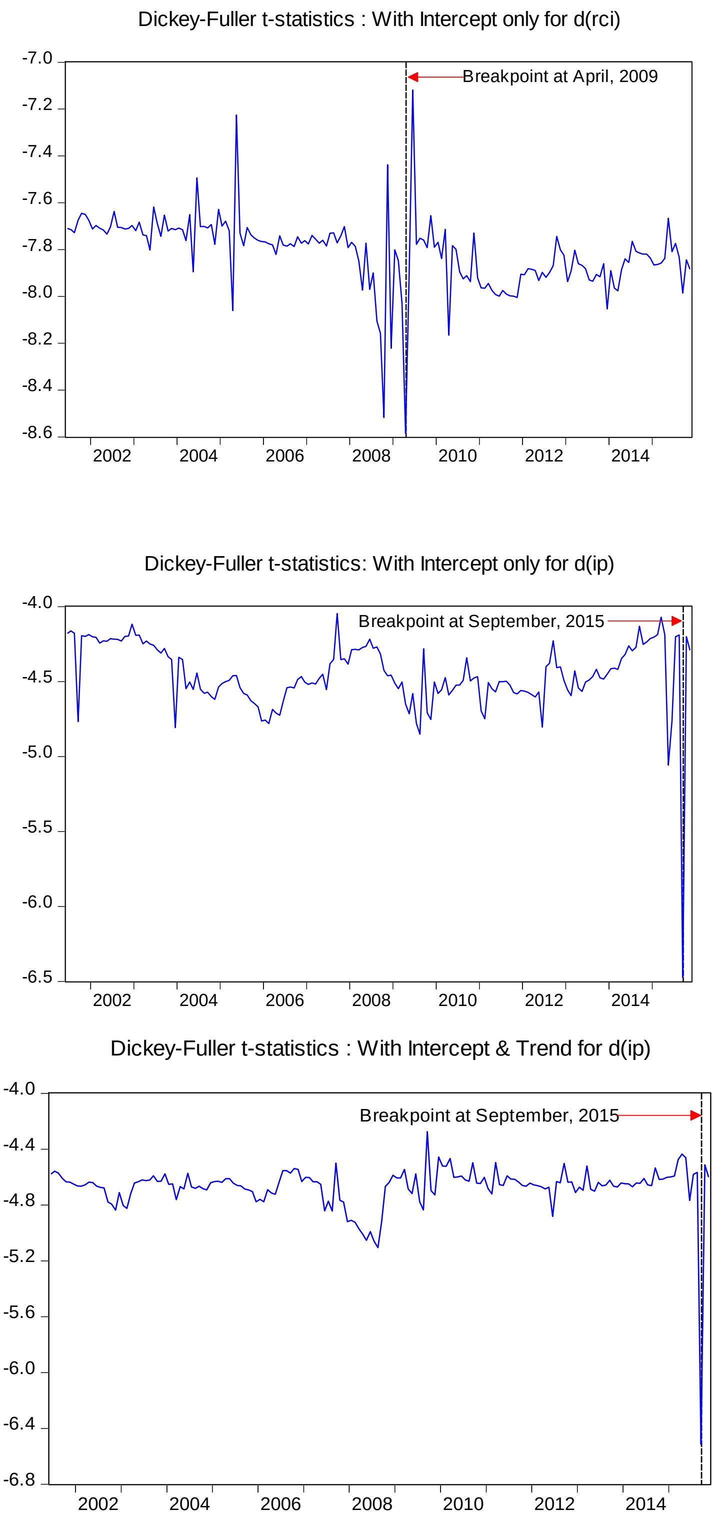
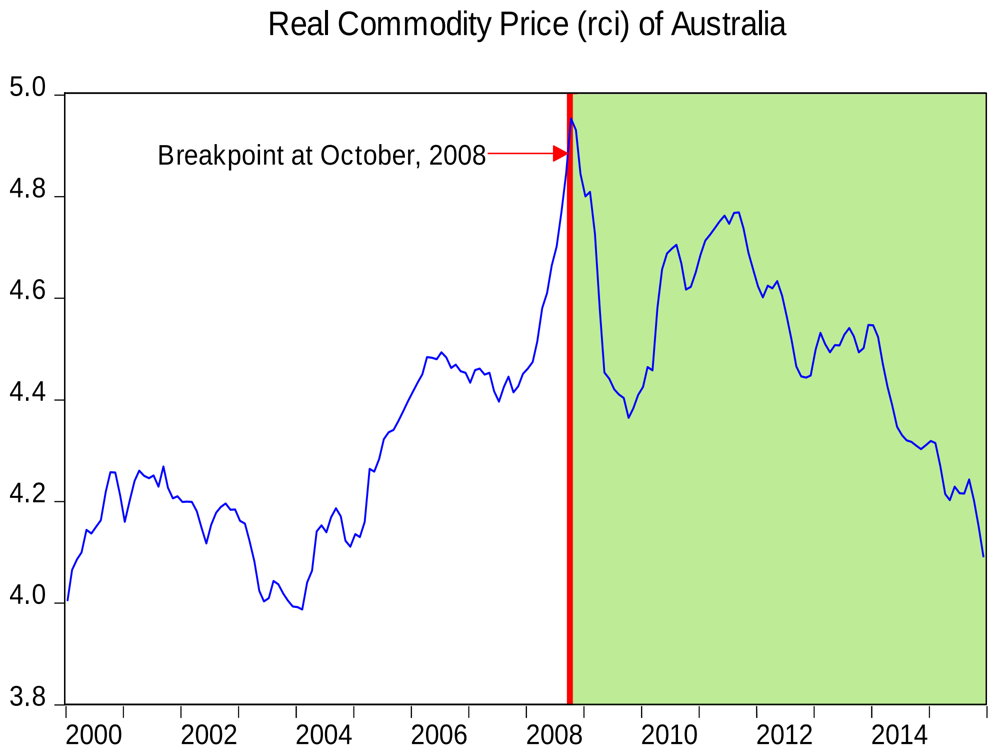
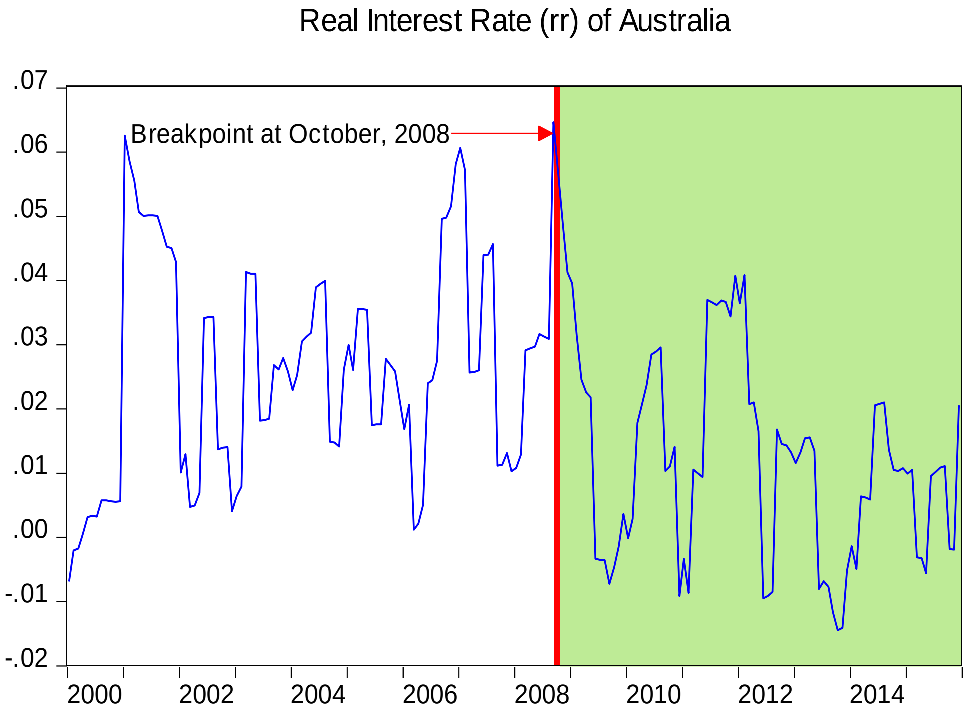


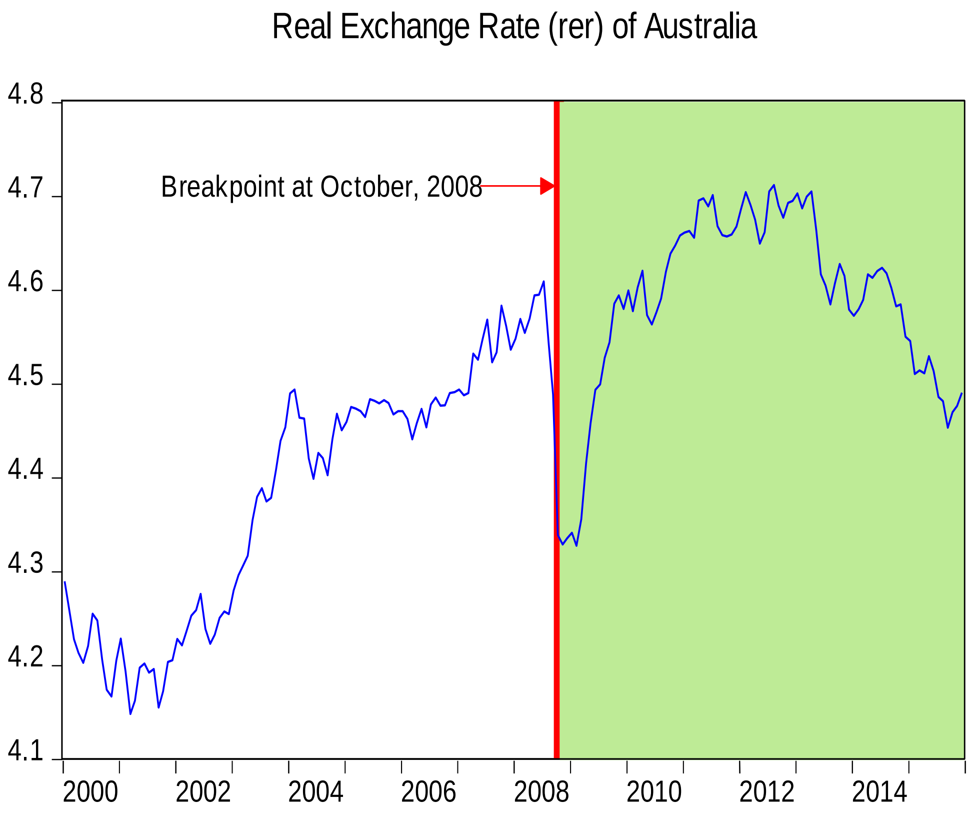
Figure 5.2 Test Statistics Graphs with Different Breakpoint

Figure 5.2 shows the graphs of the DF *t*-statistics of various variables with different breakpoints. The first graph represents the DF *t*-statistics for the first difference of the Australian real commodity price (rci) and shows the breakpoint at April, 2009. The *t*-statistic for this is -8.58 and is significant at the 1 per cent level. The Australian economic activity that is represented by the *ip* has the possible breakpoint at September 2015 and this is the case for both 'intercept only' as well as 'intercept and trend' options. This variable is first difference stationary $I(0)$ in both cases and significant at the 1 per cent level.

The normal visual representation of the graphs in Figure 5.3 also show the possible breakpoint at October, 2008 for four of our variables in the model. They are rci, rr, rer and spr. We also conducted further statistical tests to confirm the possible break at this point.




Real Interest Rate (rr) of Australia
.07
.06
.05
.04
.03
.02
.01
.00
-.01
-.02
Breakpoint at October, 2008
2000
2002
2004
2006
2008
2010
2012
2014


Real Exchange Rate (rer) of Australia
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
Breakpoint at October, 2008
2000
2002
2004
2006
2008
2010
2012
2014

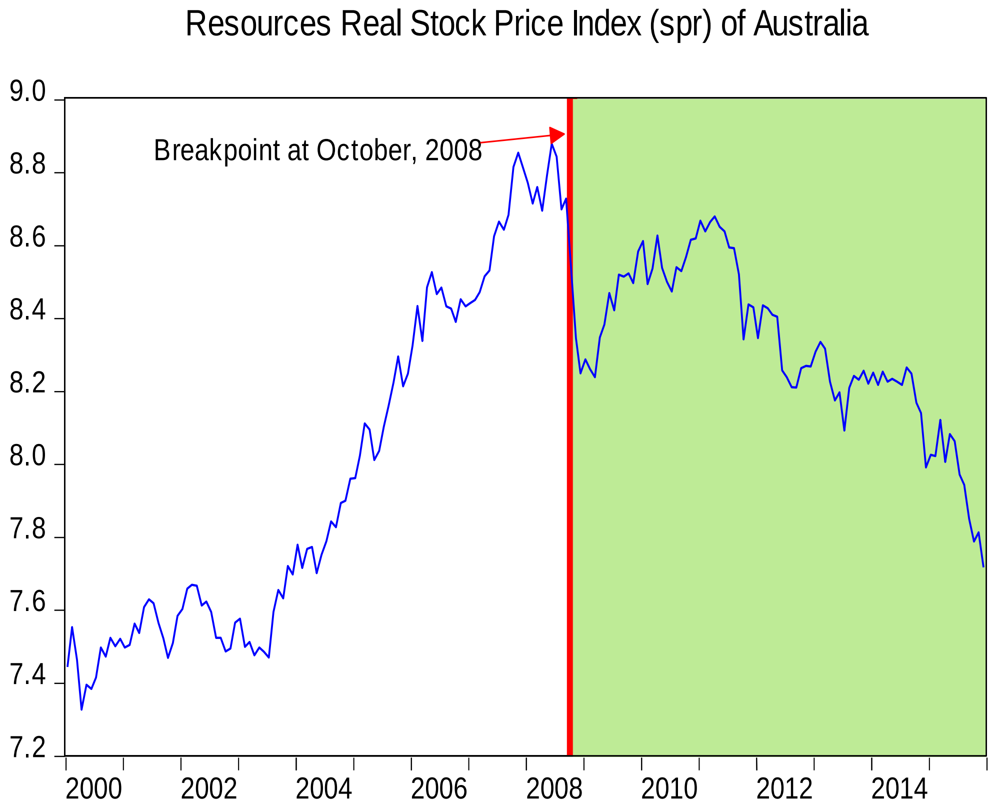


Figure 5.3 Graphical Representation of the Variables with Possible Breakpoint at October, 2008

The study conducted the Chow's breakpoint test for the model after assuming 1 October, 2008 as the possible break date. The results are shown in Table 5.2.

Table 5.2 Chow's Breakpoint Test

Chow Breakpoint Test: 1/10/2008
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2000M01 2015M12

F-statistic	30.31857	Prob. F(5,182)	0.0000
Log likelihood ratio	116.3356	Prob. Chi-Square(5)	0.0000
Wald Statistic	151.5929	Prob. Chi-Square(5)	0.0000

The results in Table 5.2 confirm the possible breakpoints in our time series in 1 October, 2008 on the basis of p-value = 0.0000. It means that the null hypothesis of 'no breaks at specified breakpoints' (here, 1 October, 2008) is rejected. We considered this specific date as a possible breakpoint of our model preliminary on the basis of the unit root test results with a breakpoint. Thus, we constructed a *dummy* variable, which assumes value 0 from January 2000 to the month of the breakpoint and 1 thereafter. This is because we defined the break date as the first date for the new regime of our commodity price model (EViews9.5, 2016).

5.2.2 Lag Selection Criteria and Stability of the Model

The commodity price model specified in our research should have the accurate number of lags included. Too many included lags will mean that we lose many degrees of freedom. According to Thomsen, Sandager, Logerman, Johanson, and Andersen (2013), the determination of lag length is a trade-off between the curse of dimensionality and reduced models, which are not appropriate to indicate the dynamic adjustment. Even with enclosure of a small lag length interval we would have to estimate many parameters. Increasing the number of parameters means that the degrees of freedom decrease.

The following table (Table 5.3) shows the summary test statistics to select the appropriate lag length for our commodity price model. After considering the final prediction error and Akaike information criterion, we decided to choose three as our appropriate lag length.

Table 5.3 Lag Order Selection Criteria

Lag Order Selection Criteria		
Endogenous variables: rci, rr, rer, ip, spr, dummy		
Exogenous variables: C		
	FPE	AIC
Lag	3	3
LogL	2835.453	2835.453
Test Statistics	2.98e-21*	-30.23836*

* indicates lag order selected by the criterion. Here, FPE = Final prediction error and AIC = Akaike information criterion.

The author wanted to minimise the information criteria by selecting the appropriate lag length. The information criteria functions are functions of the log-likelihood function. Thus, the information criteria seek to handle the trade-off between a parsimonious model and a comprehensive model.

However, to check the residuals for serial independence is another important issue when selecting the appropriate lag length for the model. Table 5.4 shows the results for the VAR residual serial correlation LM tests.

Table 5.4 Residual Serial Correlation LM Test

VAR Residual Serial Correlation LM Tests

Null Hypothesis: no serial correlation at lag order h

Included observation: 188

Lags	LM-Stat	Prob
1	43.03791	0.1954
2	36.70363	0.4361
3	51.63546	0.0442
4	44.18991	0.1641

Probabilities from chi-square with 36 degrees of freedom

The author found the problem was that at lag length 3, the model rejected the null hypothesis of 'no serial correlation at lag order h'. This serial correlation was removed if we increased the maximum lag length to 4. At lag length 4, the LM-stat is 44.19, which cannot reject the null hypothesis and endorses no serial correlation among the variables at lag order 4. Thus, the author decided to choose 4 as our appropriate lag length for each variable of our model in the present study. The graphs of the VAR residuals are presented in the Figure 5.4.

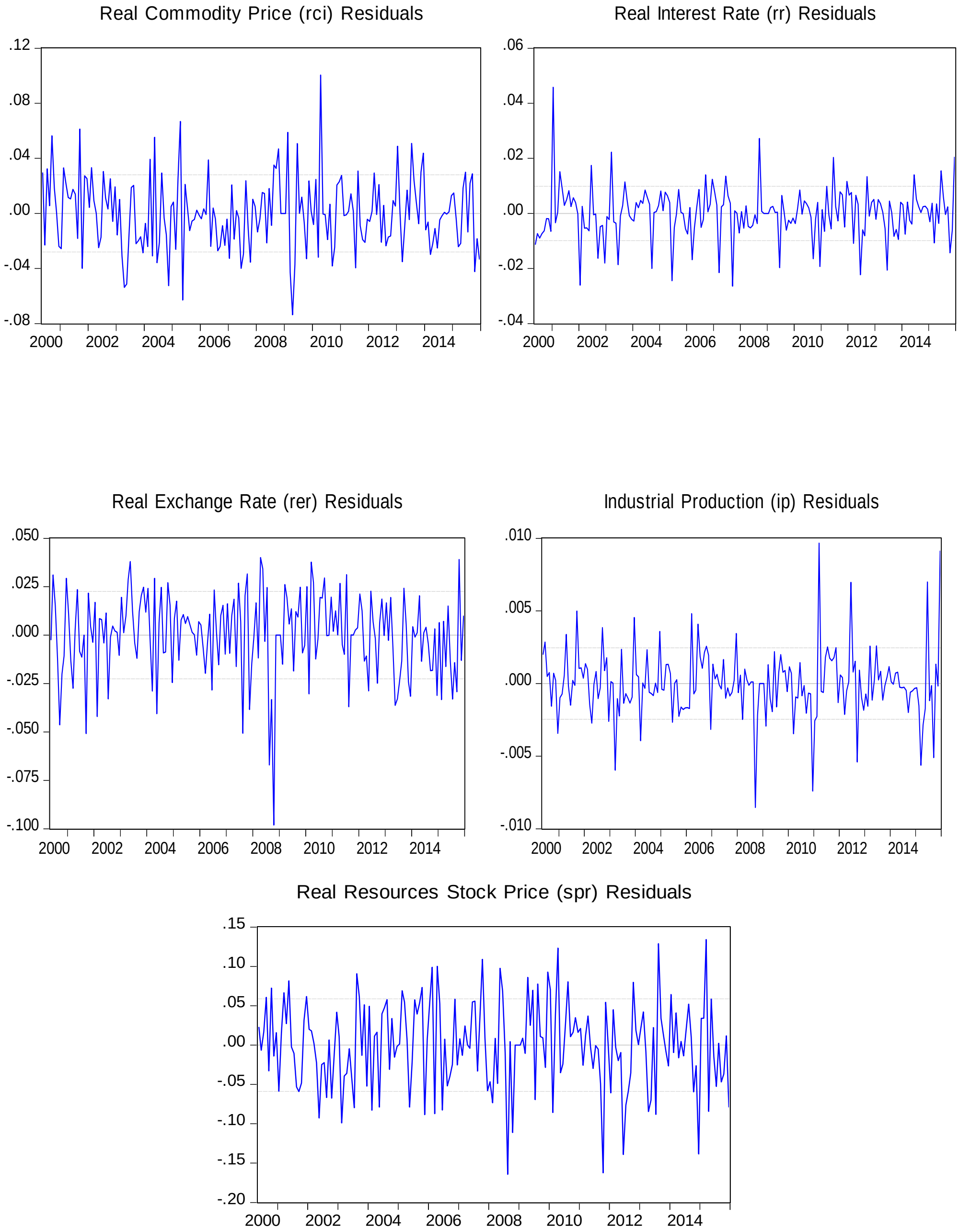


Figure 5.4 VAR Residual Graphs

After considering the lag length as 4 based on the relevant statistical tests, the author conducted further econometric procedures to determine the dynamic interactions among the variables of our commodity price model.

5.2.3 Cointegration Results

The author conducted the Johansen (1988, 1991) procedure to perform cointegration analysis in the present study to determine whether there is a long-run equilibrium relationship between the commodity price and other macroeconomic variables. The existence of cointegration specifies that there is a theoretical connection among the variables and they are in equilibrium in the long run in spite of short-run deviance from each other (Kabir, Bashar, & Masih, 2014). According to MaMasih, Alsahlawi, and DeMello (2010), cointegration shows that the variables in the system are interdependent and highly integrated and each variable contains information for the prediction of other variables in the cointegrated system.

Table 5.5 Unrestricted Cointegration Rank Test Results

Trend Assumption: Linear deterministic trend

Variables: $rci, rr, rer, rip, spr, dummy$

Cointegration Rank Test Type	Cointegrating Equation(s)	Eigenvalue	Statistic	0.05 Critical Value	Prob**
Trace	01	0.227301	115.8825*	95.75366	0.0010
		0.134956	67.66159	69.81889	0.0.0734
Maximum Eigenvalue	01	0.227301	48.22095*	40.07757	0.0049
		0.134956	27.11041	33.87687	0.2575

Note: * denotes rejection of the hypothesis at the 0.05 level;

** MacKinnon, Haug, and Michelis (1999) p-values

In the cointegration analysis, the author considered four macroeconomic variables (rr, rer, ip and spr) to determine their influence on rci. The results are shown in Table 5.5, which shows the cointegration test results for the commodity price model that we specified, based on trace and maximum eigenvalue statistics.

Beginning with the trace test, the null hypothesis of no cointegrating vector was rejected, since the test statistic of approximately 115.88 is greater than the 5 per cent critical value of approximately 95.75 with the probability of 0.0010. However, the null hypothesis, that there is at most one cointegrating vector, cannot be rejected since the test statistic of approximately 67.66 is now less than the 5 per cent critical value of approximately 69.82. The trace test, therefore, indicates one cointegrating relationship at the 5 per cent level of significance.

The maximum eigenvalue form of the Johansen test also rejects the null hypothesis of no cointegration. Table 5.5 shows that the maximum eigenvalue statistic of 48.22 is greater than the 5 per cent critical value of approximately 40.08 with the probability of 0.0049. However, the null hypothesis, that there is at most one cointegrating vector, cannot be rejected since the test statistic of approximately 27.11 is now less than the 5 per cent critical value of approximately 33.88. Thus, the maximum eigenvalue test indicates one cointegrating relationship at the 5 per cent level of significance as well.

The trace and eigenvalue statistics yielded the same results for the number of cointegrating vectors. Moreover, the eigenvalue statistics dropped sharply for both tests from 0.23 to 0.13. Therefore, we can say that the statistical model of our study represents the commodity price model fairly.

After normalising the value of rci, we obtained the following cointegrating Equation (5.1) with the standard error in parentheses:

$$rci = -\underset{(2.096)}{\mathbf{9.291\,rr}} - \underset{(0.351)}{0.019\,rer} - \underset{(0.640)}{\mathbf{3.303\,ip}} + \underset{(0.102)}{\mathbf{0.773 spr}} + \underset{(0.097)}{\mathbf{0.191\,dummy}} \text{---------} \; (5.1)$$

Equation (5.1) shows the expected sign of all the variables based on the literature. However, *rr*, *ip*, *spr* and the dummy are significant in our model. The result shows that the Australian *rr*, *rer* and *ip* have an adverse effect on the *rci*. However, the effect of the *rer* on real commodity prices in the long run is not significant. On the other hand, the spr showed a significant favourable effect on the *rci* in the long run, which is also supported by existing literature. The effect of a structural break is also significant in the model. Overall, Equation (5.1) represents the long-run relationship between the commodity price index and other macroeconomic variables of Australia.

5.2.4 Vector Error Correction Results

The variables of current model are cointegrated in the long run; therefore, there exists an error correction mechanism that brings together the long-run relationship with its short-run dynamic adjustments. The error correction mechanism combines the long-run equilibrium with short-run dynamics to reach the equilibrium situation. Since we were dealing with a multivariate VAR system, the multivariate counterpart of error correction mechanism was known as the VECM. This VECM can be expressed according to the following matrix form (Table 5.6):

Table 5.6 Matrix Form of VECM

$$\begin{bmatrix}\Delta rci_t\\ \Delta rr_t\\ \Delta rer_t\\ \Delta \mathrm{rip}_t\\ \Delta spr_t\end{bmatrix} = \begin{bmatrix}-0.025\\ -0.010\\ -0.029\\ -0.003\\ -0.072\end{bmatrix}\begin{bmatrix}1.000 & -9.291 & -0.019 & -3.303 & +0.773\end{bmatrix}\begin{bmatrix}rci_{t-1}\\ rr_{t-1}\\ rer_{t-1}\\ ip_{t-1}\\ spr_{t-1}\end{bmatrix} + \begin{bmatrix}+0.514 & +0.765 & +0.092 & -1.144 & -0.013\\ -0.024 & -0.019 & +0.031 & -0.085 & -0.042\\ -0.269 & -0.384 & +0.043 & +2.079 & -0.008\\ -0.000 & -0.022 & +0.002 & +0.891 & +0.002\\ -0.202 & -0.486 & +0.111 & -1.737 & -0.214\end{bmatrix}\begin{bmatrix}\Delta rci_{t-1}\\ \Delta rr_{t-1}\\ \Delta rer_{t-1}\\ \Delta \mathrm{ip}_{t-1}\\ \Delta spr_{t-1}\end{bmatrix}$$

$$+\begin{bmatrix}-0.046 & +0.210 & +0.083 & -0.345 & -0.021\\ +0.059 & +0.115 & +0.098 & +0.083 & -0.030\\ +0.088 & +0.043 & -0.130 & -1.584 & +0.006\\ -0.011 & +0.029 & -0.022 & -0.106 & -0.001\\ +0.209 & +0.433 & +0.532 & -1.250 & -0.117\end{bmatrix}\begin{bmatrix}\Delta rci_{t-2}\\ \Delta rr_{t-2}\\ \Delta rer_{t-2}\\ \Delta \mathrm{ip}_{t-2}\\ \Delta spr_{t-2}\end{bmatrix} + \begin{bmatrix}+0.103 & +0.516 & +0.200 & +1.651 & +0.042\\ +0.036 & -0.130 & -0.066 & +0.322 & -0.001\\ -0.030 & +0.216 & +0.025 & -0.967 & -0.020\\ -0.003 & -0.069 & +0.003 & -0.323 & -0.004\\ -0.012 & +0.064 & -0.360 & +1.549 & +0.017\end{bmatrix}\begin{bmatrix}\Delta rci_{t-3}\\ \Delta rr_{t-3}\\ \Delta rer_{t-3}\\ \Delta \mathrm{ip}_{t-3}\\ \Delta spr_{t-3}\end{bmatrix}$$

$$+\begin{bmatrix}+0.033 & +0.315 & -0.008 & -0.954 & +0.061\\ -0.031 & -0.068 & -0.003 & +0.008 & +0.001\\ -0.073 & +0.220 & -0.209 & +1.109 & -0.032\\ -0.002 & +0.018 & -0.009 & +0.202 & -0.004\\ -0.221 & -0.075 & -0.083 & -1.403 & -0.092\end{bmatrix}\begin{bmatrix}\Delta rci_{t-4}\\ \Delta rr_{t-4}\\ \Delta rer_{t-4}\\ \Delta \mathrm{ip}_{t-4}\\ \Delta spr_{t-4}\end{bmatrix} + \begin{bmatrix}u1_t\\ u2_t\\ u3_t\\ u4_t\\ u5_t\end{bmatrix}$$

The estimates of parsimonious dynamic error correction models from the above matrix form (Table 5.6) are reported in the following equations:

Equation (5.2):

$\Delta rci_t = \mathbf{-0.025\ ECT_{t-k}} + \mathbf{0.514\Delta rci_{-1}} - 0.046\Delta rci_{-2} + 0.103\Delta rci_{-3} + 0.033\Delta rci_{-4} + \mathbf{0.765\Delta rr_{-1}} + 0.210\Delta rr_{-2} + \mathbf{0.516\Delta rr_{-3}} + 0.315\Delta rr_{-4} + 0.092\Delta rer_{-1} + 0.083\Delta rer_{-2} + 0.200\Delta rer_{-3} - 0.008\Delta rer_{-4} - 1.144\Delta ip_{-1} - 0.345\Delta ip_{-2} + 1.651\Delta ip_{-3} - 0.954\Delta ip_{-4} - 0.013\Delta spr_{-1} - 0.021\Delta spr_{-2} + 0.042\Delta spr_{-3} + 0.061\Delta spr_{-4} + u1_t$ --------- *(5.2)*

Equation (5.3):

$\Delta rr_t = \mathbf{-0.010\ ECT_{t-k}} - 0.024\Delta rci_{-1} + \mathbf{0.059\Delta rci_{-2}} + 0.036\Delta rci_{-3} - 0.031\Delta rci_{-4} - 0.019\Delta rr_{-1} + 0.115\Delta rr_{-2} - 0.130\Delta rr_{-3} - 0.068\Delta rr_{-4} + 0.031\Delta rer_{-1} + \mathbf{0.098\Delta rer_{-2}} - 0.066\Delta rer_{-3} - 0.003\Delta rer_{-4} - 0.085\Delta ip_{-1} + 0.083\Delta ip_{-2} + 0.322\Delta ip_{-3} + 0.008\Delta ip_{-4} - \mathbf{0.042\Delta spr_{-1}} - \mathbf{0.030\Delta spr_{-2}} - 0.001\Delta spr_{-3} + 0.001\Delta spr_{-4} + u2_t$ ---------------------- ---------------------------------- *(5.3)*

Equation (5.4):

$\Delta rer_t = \mathbf{-0.029\ ECT_{t-k}} - \mathbf{0.269\Delta rci_{-1}} + 0.088\Delta rci_{-2} - 0.030\Delta rci_{-3} - 0.073\Delta rci_{-4} - \mathbf{0.384\Delta rr_{-1}} + 0.043\Delta rr_{-2} + 0.216\Delta rr_{-3} + 0.220\Delta rr_{-4} + 0.043\Delta rer_{-1} - 0.130\Delta rer_{-2} + 0.025\Delta rer_{-3} - \mathbf{0.209\Delta rer_{-4}} + \mathbf{2.079\Delta ip_{-1}} - \mathbf{1.584\Delta ip_{-2}} - 0.967\Delta ip_{-3} - \mathbf{1.109\Delta ip_{-4}} - 0.008\Delta spr_{-1} - 0.006\Delta spr_{-2} - 0.020\Delta spr_{-3} - 0.032\Delta spr_{-4} + u3_t$ ------ -- *(5.4)*

Equation (5.5):

$\Delta rip_t = \mathbf{-0.003\ ECT_{t-k}} - 0.000\Delta rci_{-1} - 0.011\Delta rci_{-2} - 0.003\Delta rci_{-3} - 0.002\Delta rci_{-4} + 0.022\Delta rr_{-1} + 0.029\Delta rr_{-2} - \mathbf{0.069\Delta rr_{-3}} + 0.018\Delta rr_{-4} + 0.002\Delta rer_{-1} - \mathbf{0.022\Delta rer_{-2}} + 0.003\Delta rer_{-3} - 0.009\Delta rer_{-4} + \mathbf{0.891\Delta ip_{-1}} - 0.106\Delta ip_{-2} - \mathbf{0.323\Delta ip_{-3}} + \mathbf{0.202\Delta ip_{-4}} + 0.002\Delta spr_{-1} - 0.001\Delta spr_{-2} - 0.004\Delta spr_{-3} - 0.004\Delta spr_{-4} + u4_t$ --------------- *(5.5)*

Equation (5.6):

$\Delta spr_t = \mathbf{-0.072\ ECT_{t-k}} - 0.202\Delta rci_{-1} + 0.209\Delta rci_{-2} - 0.012\Delta rci_{-3} - 0.221\Delta rci_{-4} - 0.486\Delta rr_{-1} + 0.433\Delta rr_{-2} + 0.064\Delta rr_{-3} - 0.075\Delta rr_{-4} + 0.111\Delta rer_{-1} + \mathbf{0.532\Delta rer_{-2}} - 0.360\Delta rer_{-3} - 0.083\Delta rer_{-4} - 1.737\Delta ip_{-1} - 1.250\Delta ip_{-2} + 1.549\Delta ip_{-3} - 1.403\Delta rip_{-4} - \mathbf{0.214\Delta spr_{-1}} - 0.117\Delta spr_{-2} + 0.017\Delta spr_{-3} - 0.092\Delta spr_{-4} + u5_t$ -- *(5.6)*

The above five equations are the VEC equations of our commodity price system. Among all these equations, the sign of the error correction terms or the sign of αs are the expected negative (-) sign for all VEC equations (5.2), (5.3), (5.4), (5.5) and (5.6). Moreover, equation (5.2) is statistically significant with t = -1.783 and p = 0.0750. Equation (5.3) is significant with t = -2.053 and p = 0.0403. Equation (5.4) is statistically significant with t = -2.736 and p = 0.0063. Equation (5.5) is significant with t = -2.218 and p = 0.0268. Finally, equation (5.6) is statistically significant with t = -2.491 and p = 0.0129. These error terms measure the speed of adjustments in the rci to the equilibrium level after following a shock in the system. Thus, the model shows that all the variables helped to restore the divergence from the long-run equilibrium in the Australian commodity price model.

It is clear from the previous econometric model discussion that the VEC has cointegration relations built into the specification so that it restricts the long-run behaviour of the endogenous variables to converge to their cointegrating relationships while allowing for short-run adjustment dynamics. The cointegration term is known as the error correction term since the deviation from long-run equilibrium is corrected gradually via a series of partial short-run adjustments. The first coefficients on the right hand side of equations (5.2), (5.3), (5.4), (5.5) and (5.6) are the error correction terms. In long-run equilibrium, these terms are zero. However, if *rci, rr, rer, ip* and *spr* deviate from the long-run equilibrium, the error correction terms would become non-zero and each variable adjusts to partially restore the equilibrium relation. The first coefficient of each equation measured the speed of adjustment of that particular endogenous variable towards the equilibrium. The summary of the significant VEC equations including some diagnostic checks is shown in Table (5.7).

Table 5.7 Significant Vector Error Correction Equations

Equations	Eq. (5.2)	Eq. (5.3)	Eq. (5.4)	Eq. (5.5)	Eq. (5.6)
Endogenous Variables	Δrci	Δrr	Δrer	Δip	Δspr
Error Correction	$\mathbf{-0.025}$ [−1.783]	−0.010 [−2.053]	−0.029 [−2.736]	−0.003 [−2.218]	−0.072 [−2.492]
$\mathbf{\Delta rci_{-1}}$	$\mathbf{+0.514}$ [5.474]	-	−0.269 [−3.674]	-	-
$\mathbf{\Delta rci_{-2}}$	-	+0.059 [1.601]	-	-	-
$\mathbf{\Delta rr_{-1}}$	+0.765 [3.382]	-	−0.384 [−2.185]	-	-
$\mathbf{\Delta rr_{-3}}$	-	-	-	−0.069 [−3.471]	-
$\mathbf{\Delta rer_{-2}}$	-	+0.098 [1.932]	-	−0.022 [−1.892]	+0.532 [1.839]
$\mathbf{\Delta rer_{-4}}$	-	-	−0.209 [−1.938]	-	-
$\mathbf{\Delta ip_{-1}}$	-	-	+2.079 [2.783]	+0.891 [10.896]	-
$\mathbf{\Delta ip_{-2}}$	-	-	−1.584 [−1.681]	-	-
$\mathbf{\Delta ip_{-3}}$	-	-	-	−0.323 [−3.357]	-
$\mathbf{\Delta ip_{-4}}$	-	-	+1.109 [1.705]	+0.202 [2.843]	-
$\mathbf{\Delta spr_{-1}}$	-	−0.042 [−2.604]	-	-	−0.214 [−2.337]
R-squared	0.4679	0.1941	0.3189	0.6332	0.2162
Adj. R-squared	0.3853	0.0690	0.2131	0.5762	0.0945
F-statistic	5.66	1.55	3.02	11.12	1.78
Log likelihood	416.34	603.01	463.32	876.98	277.00
Akaike AIC	-4.17	-6.17	-4.68	-9.10	-2.68
Schwarz SC	-3.73	-5.72	-4.23	-8.65	-2.24

Note: *t* statistics in [ ].

From Table 5.7 the expected signs of all the error terms of our model are negative and the coefficients are statistically significant. Equation (5.2) shows that if there is a shock in the system, the actual rci would adjust to its equilibrium level at approximately the 2.5 per cent rate in every month. This is confirmed with t = -1.783 and p = 0.0750. This 2.5 per cent per month is the adjustment speed to disequilibrium in the long run. All the error correction terms show that the shocks in any of the variables would converge them towards the long-run equilibrium significantly.

Table 5.7 represents the summary of Equation (5.2), (5.3), (5.4), (5.5) and (5.6) and shows statistical results based on the VEC model having endogenous variables (*rci, rr, rer, ip* and *spr*) with lag specification '1 4'. The regression function of the VECM of equation (5.2) has an estimated cointegrating equation ($rci_{-1} - 9.29rr_{-1} - 0.019rer_{-1} - 3.303ip_{-1} + 0.773spr_{-1} + 0.1916dummy_{-1}$), and the shock in real commodity prices with one month lag has significant positive impact in the short run in this model. This is true for the real interest rate with one month's lag as well. However, we cannot delete the insignificant variables from the error correction model. Agung (2009) stated that even though some of the variables in the VECM have an insignificant effect on all of the endogenous variables, those insignificant variables cannot be deleted since the VECM should have all these variables to measure the appropriate short-run dynamics. Therefore, we need to retain all the variables in every VEC equation even though they have insignificant effects on the endogenous variables of the system.

We have checked the stability of our VECM with the assistance of an AR Roots table (Table 8.8) and a graph of the AR Roots of a characteristic polynomial (Figure 5.5).

Table 5.8 AR Roots Table

Roots of Characteristic Polynomial
Endogenous variables: RCI RR RER IP SPR DUMMY
Lag specification: 1 4

Root	Modulus
1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
1.000000 - 7.49e-16i	1.000000
1.000000 + 7.49e-16i	1.000000
0.812992 + 0.227721i	0.844282
0.812992 - 0.227721i	0.844282
0.812908	0.812908
0.417416 + 0.559753i	0.698254
0.417416 - 0.559753i	0.698254
0.281900 + 0.626783i	0.687258
0.281900 - 0.626783i	0.687258
-0.414965 - 0.542554i	0.683052
-0.414965 + 0.542554i	0.683052
-0.650435	0.650435
0.509541 + 0.385548i	0.638967
0.509541 - 0.385548i	0.638967
-0.498543 - 0.377639i	0.625425
-0.498543 + 0.377639i	0.625425
0.298471 - 0.511319i	0.592057
0.298471 + 0.511319i	0.592057
-0.026638 - 0.574386i	0.575004
-0.026638 + 0.574386i	0.575004
-0.364116 - 0.436129i	0.568145
-0.364116 + 0.436129i	0.568145
-0.529697 - 0.175791i	0.558106
-0.529697 + 0.175791i	0.558106
0.270910 + 0.327363i	0.424922
0.270910 - 0.327363i	0.424922
0.355431	0.355431

VEC specification imposes 5 unit root(s).

Table 5.8 shows 12 pairs of complex roots and 6 real roots. The first pair of complex roots 1.000000 - 7.49e-16i and 1.000000 + 7.49e-16i has an equal modulus of 1.000000. In the same way, the second pair to twelfth pair of complex roots have an equal modulus for each pair. Among the other six real roots, three of them have the equal modulus of 1.000000. Thus, with these 12 pairs of complex roots and the other 6 real roots, our VECM showed that no roots lie outside the unit circle. Actually, all inverse roots smaller than 1 indicates that our model is stable. Therefore, it satisfies the stability condition of our model with the lag-length of 4.

This result can also be seen in Figure 5.5,which uses a complex coordinate system.

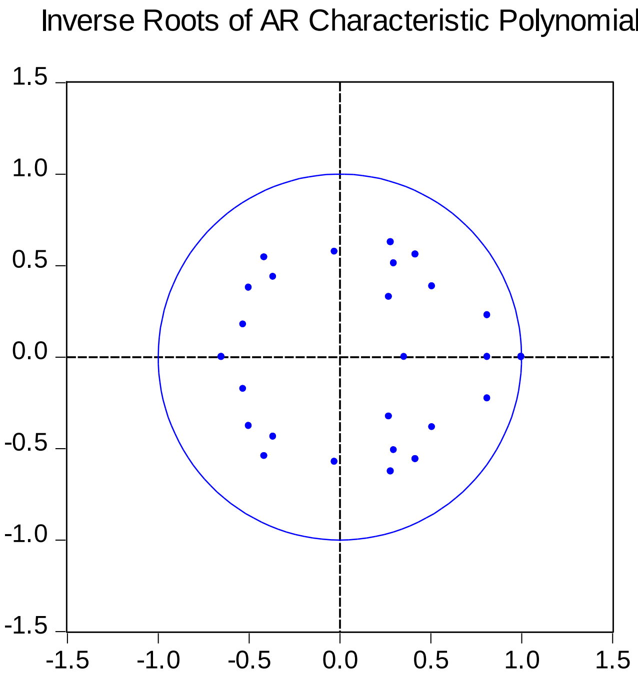


Figure 5.5 Graph of the AR Roots of the VEC Model

Figure 5.5 confirms the stability of the VECM by showing the short-run dynamics of the commodity price model. The graph shows both the real as well as complex roots within the unit circle, and thus confirms the stability of the VECM.

According to Agung (2009), we can also utilise the system equation to conduct Wald coefficient tests to measure multivariate hypothesis of the cointegration equation influence on endogenous variables of the system. This process cannot be achieved using the VECM. However, this special Wald test can be performed to compare the VECM results with the null hypothesis of $H_0: \alpha_{11} = \alpha_{21} = \alpha_{31} = \alpha_{41} = \alpha_{51} = \alpha_{61} = 0$. The results are given in the following table (Table 5.9):

Table 5.9 Wald Test of the System Equation

Test Statistic	Value	df	Probability
Chi-square	55.00893	6	0.0000

Null Hypothesis: $\alpha_{11} = \alpha_{21} = \alpha_{31} = \alpha_{41} = \alpha_{51} = \alpha_{61} = 0$
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
α_{11}	-0.025	0.0128
α_{21}	-0.010	0.0047
α_{31}	-0.029	0.0099
α_{41}	-0.003	0.0011
α_{51}	-0.072	0.0269
α_{61}	+0.011	0.0307

Restrictions are linear in coefficients.

Thus, a multivariate hypothesis of the cointegration equation effect can be tested on all endogenous variables by imposing the restriction on the adjustment coefficients to compare the VECM results. This null hypothesis is rejected based on the chi-squared statistic of 55.0089 with df = 6 and a p-value 0.0000. Therefore, it can be concluded that the cointegrating equation ($rci_{-1} - 9.29rr_{-1} - 0.019rer_{-1} - 3.30ip_{-1} + 0.773spr_{-1} + 0.191dummy_{-1}$) has a significant effect on ($\Delta rci_t, \Delta rr_t, \Delta rer_t, \Delta ip_t, \Delta spr_t$).

The above discussion suggests that the commodity price model constitutes the true cointegrating relationship in the first cointegrating vector. Our conclusion is supported by the plot in Figure 5.6 showing the first vector in the cointegrating space, which appears to be stationary.

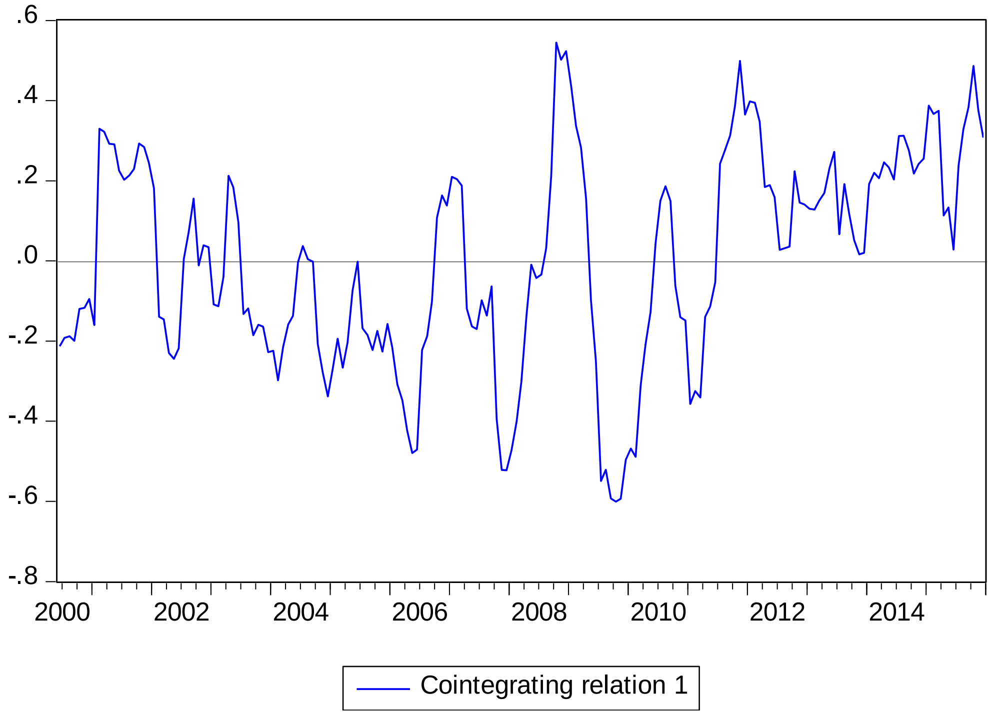


Figure 5.6 Cointegration Graph of Commodity Price Model

5.2.5 Granger Causality

A causality test examines whether the lags of one variable enter into the equation for another variable. To explain the causality simply, Gujarati (2009) stated that since the future cannot predict the past, if variable z (Granger) causes variable y, then changes in z should precede changes in y. Therefore, in a regression of y on other variables, including its own past values, if we include past or lagged values of z and it significantly improves the prediction of y, then we can say that z (Granger) causes y. A similar definition applies if y (Granger) causes z.

Enders (2008) clarified Granger causality with a two-equation model:

$$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} b_{10} - b_{12}b_{20} \\ b_{20} \end{bmatrix} + \begin{bmatrix} \gamma_{11} - b_{12}\gamma_{21} & \gamma_{12} - b_{12}\gamma_{22} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{bmatrix} \epsilon_{yt} - b_{12}\epsilon_{zt} \\ \epsilon_{zt} \end{bmatrix} \quad \text{--} \ (5.7)$$

Estimating the system using OLS yields the theoretical parameter estimates:

$$y_t = a_{10} + a_{11}y_{t-1} + a_{12}z_{t-1} + e_{1t}$$

$$z_t = a_{20} + a_{21}y_{t-1} + a_{22}z_{t-1} + e_{2t}$$

where,

$$a_{10} = b_{10} - b_{12}b_{20}$$

$$a_{11} = \gamma_{11} - b_{12}\gamma_{21}$$

$$a_{12} = \gamma_{12} - b_{12}\gamma_{22}$$

$$a_{20} = b_{20}$$

$$a_{21} = \gamma_{21}$$

$$a_{22} = \gamma_{22}$$

In the case of Equation (5.7), it is possible to test the hypothesis that $a_{21} = 0$ with a t-test. In that model with p lags, $[y_t]$ does not Granger cause $[z_t]$ if and only if all the coefficients of $A_{21}\ (L)$ are equal to zero. Thus, if $[y_t]$ does not improve the forecasting performance of $[z_t]$, then $[y_t]$ does not Granger cause $[z_t]$. The direct way to determine Granger causality is to use a standard F-test to test the restriction:

$$a_{21}(1) = a_{21}\ (2) = a_{21}\ (3) = \cdots = 0$$

In the n variable case in which $A_{ij}(L)$ represents the coefficients of lagged values of variable j on variable i, variable j does not Granger cause variable i if all coefficients of the polynomial $A_{ij}(L)$ can be set equal to zero.

However, according to Granger (1988) if the variables are non-stationary and cointegrated, the adequate method to examine the causal relations is the VECM. Therefore, the condition for exogeneity can be checked. Enders (2008) stated that Granger causality is a weaker condition than the condition for exogeneity. A necessary condition for the exogeneity of $[z_t]$ is for current and past values of $[y_t]$ to not affect $[z_t]$. In our case, we utilised a block exogeneity test, which is a multivariate generalisation form of the Granger causality test and can actually be called a 'block causality' test. In any event, the issue was to determine whether lags of one variable, say, w_t, Granger cause any other of the variables in the system. In the three variables case (w_t, y_t and z_t), the test is whether lags of w_t Granger cause either y_t or z_t. In essence, the block exogeneity restricts all lags of w_t in the y_t and z_t equations to be equal to zero. This cross-equation restriction is properly tested utilising the likelihood ratio test given by:

$$(T - c)(log|\sum_r| - log|\sum_u|) \qquad \text{----------------------------- (5.8)}$$

where,

T = number of usable observations,

c = maximum number of regressors contained in the longest equation.

$\sum_r$ and $\sum_u$ = variance/covariance matrices of the unrestricted and restricted system, respectively.

Therefore, the process is to estimate the y_t and z_t equations utilising p lagged values of (y_t), (z_t) and (w_t) and calculate $\sum_u$. Then, the two equations can be re-estimated excluding the lagged values of (w_t) and $\sum_r$calculated. Next, the likelihood ratio statistics could be determined using Equation (5.8).

This likelihood ratio statistic has a χ^2 distribution with degrees of freedom equal to 2p, since p lagged values of (w_t) are excluded from each equation. Hence, c = 3p + 1 since the two unrestricted y_t and z_t equations contain p lags of (y_t), (z_t), and (w_t) plus a constant.

5.2.5.1 VEC Granger Causality/Block Exogeneity Results

After considering the issues in the previous section, we conducted VEC Granger causality tests during the present study to determine the relationship between Australian commodity prices and the other considered macroeconomic variables. The present study has one cointegrating vector in the model; therefore, a VAR-based Granger causality would be misleading (Enders, 2008; C. W. Granger, 1988; Parsva & Lean, 2011). Thus, the sources of causality could be identified from the significance test of the coefficients of independent variables in the VECM. We divided our results for both short-run (Table 5.10) and long-run (Table 5.11) causality. The null hypothesis was that the lagged explanatory variables of the model and also their joint significance do not Granger cause the dependent variable.

Regarding the causality of the short run, we tested the nullity of the parameters associated with independent variables in each equation of VECM (Equations 5.2, 5.3, 5.4, 5.5 and 5.6) using the χ^2 – Wald statistics. Gujarati (2009) showed that the direction of causality might depend critically on the number of lagged terms included; therefore, we conducted the tests for different lagged terms as undertaken by Brahmasrene, Huang, and Sissoko (2014).

Table 5.10 Short-run Granger Causality Tests

Sources of Causation → Dependent Variable	**Number of Lags**	**Chi-sq**
$\Delta rr \rightarrow \Delta rci$	4 months	8.033***
$\Delta rr \rightarrow \Delta rci$	5 months	12.267*
$\Delta rr \rightarrow \Delta rci$	6 months	11.774***
$\Delta rci \rightarrow \Delta rr$	1 month	5.875*
$\Delta rci \rightarrow \Delta rr$	4 months	10.044*
$\Delta rci \rightarrow \Delta rr$	5 months	10.473***
$\Delta rer \rightarrow \Delta rci$	1 month	2.997***
$\Delta rci \rightarrow \Delta rer$	2 months	5.452***
$\Delta rci \rightarrow \Delta rer$	3 months	10.088*
$\Delta rci \rightarrow \Delta rer$	4 months	8.027***
$\Delta rci \rightarrow \Delta ip$	2 months	4.488***
$\Delta rci \rightarrow \Delta ip$	3 months	7.359***
$\Delta rci \rightarrow \Delta ip$	10 months	16.036***
$\Delta rci \rightarrow \Delta ip$	11 months	19.641*
$\Delta spr \rightarrow \Delta rci$	2 months	5.911**
$\Delta spr \rightarrow \Delta rci$	3 months	7.137***
$\Delta spr \rightarrow \Delta rci$	7 months	16.060*

Notes: → Implies Granger cause, e.g. $\Delta spr \rightarrow \Delta rci$ implies stock price Granger causes commodity price index. *, ** and *** denotes statistical significance at the 1 per cent, 5 per cent and 10 per cent levels, respectively.

Table 5.10 helps to analyse the causal relationships between *rci* and other variables of interest of the commodity price model. Based on the Granger

(1969) approach, Granger's concept of causality does not imply a cause-effect relationship, but rather is based only on 'predictability' or 'forecastability'. Therefore, the short-run causality tests from the VECM equation (5.2) shows that the current and past information on interest rate helps improve the forecasts of commodity prices in four to six months. Only the four and sixth month lags had a statistical significance level of 10 per cent, while the fifth lag had a 1 per cent significance level. The null hypothesis was rejected in these months. Therefore, according to the data, interest rate Granger caused commodity price index in the short run. This finding supports the study of Frankel (2006).

Table 5.10 also shows that the Australian trade weighted real exchange rate's current and past information helps improve the forecasts of commodity prices immediately (one month) and this lag has a statistical significance level of 10 per cent with $\chi^2 = 2.997$. Thus, the null hypothesis of the Granger causality tests is rejected for this VECM equation with a significant error correction term. The author also observed that commodity price index Granger caused the real exchange rate in between two and four-month lags. However, the error correction term of the VECM equation with real exchange rate as the dependent variable (Equation 5.4) was also significant. Our findings are consistent with Simpson and Evans (2004a). This result is also consistent with Bashar and Kabir (2013) who conducted their research on Australian quarterly data for over 30 years. They showed a two-way Granger causality between exchange rate and commodity prices. However, our result shows stronger causality from commodity prices to real exchange rates in the short run than the other way around.

The VECM short-run Granger causality tests also showed that the current and past information on S&P/ASX 200 resources index improved the forecast ability of commodity prices in two to three months as well as in seven months' time. The seven-month lag had a statistical significance level of 1 per cent with $\chi^2 = 16.060$. However, the null hypothesis was rejected in two months at 5 per cent and in three months at the 10 per cent level of significance. Thus, the result showed that real stock price index Granger caused commodity price index in the short run. Our findings are consistent with Rossi (2005, 2012).

Table 5.10 also represents unidirectional causality from commodity price to *ip* in two, three, ten and eleven months. In all these four cases the null hypotheses were rejected with significant statistics. This is consistent with the outcomes of Labys and Maizels (1993). In the present study, *ip* is the dependent variable of the VECM Equation (5.5), which has the significant error correction term.

The VECM Granger causality for the long run is reported in Table 5.11. The causality in the long run can be tested by the significance of the speed of adjustment. This study utilised the t-statistics of the coefficients of the error correction term, which indicated whether there were long-run causal effects. In Table 5.11 only the long-run Granger causality for Equation (5.2) are shown, which also has the significant error correction term with appropriate sign and shows the main objective of our research, i.e. to identify the impacts of other macroeconomic variables on Australian commodity prices.

Table 5.11 Long-run Granger Causality Tests

Sources of Causation → Dependent Variable	**Number of Lags**	**t-statistics**
$ECT \nrightarrow \Delta rci$	1 month	4.057 (0.5412)
$ECT \nrightarrow \Delta rci$	2 months	14.99 (0.1321)
$ECT \rightarrow \Delta rci$	3 months	22.408 (0.0975)
$ECT \nrightarrow \Delta rci$	4 months	27.8203 (0.1137)
$ECT \rightarrow \Delta rci$	5 months	39.9825 (0.0370)
$ECT \rightarrow \Delta rci$	6 months	44.0355 (0.0473)
$ECT \rightarrow \Delta rci$	7 months	68.2139 (0.0007)
$ECT \rightarrow \Delta rci$	8 months	77.6911 (0.0003)
$ECT \rightarrow \Delta rci$	9 months	82.1915 (0.0006)
$ECT \rightarrow \Delta rci$	10 months	84.0004 (0.0018)
$ECT \rightarrow \Delta rci$	11 months	82.7956 (0.0091)
$ECT \rightarrow \Delta rci$	12 months	86.8572 (0.0133)

Notes: $\nrightarrow$ implies does not Granger cause and $\rightarrow$ implies Granger cause.

Parentheses show the probabilities of the relevant t-statistics.

Table 5.11 shows the results for the causality tests for VECM equation (5.2) for different lag lengths. The long-run causality test results show that error correction term does not Granger causes commodity price during the first and second months. However, the results explain that current and past information of the adjustment speed of the cointegrating vector of our long-run model helps improve forecasts of commodity prices in three to twelve months, except during the fourth month that has the statistical significance level close to 10 per cent. Thus, we can conclude that the elasticity of the cointegration vector Granger caused commodity price index in the long run.

5.3 The Dynamic Behaviour of the Vector Error Correction Model

The dynamic behaviour of the VECM was analysed using the IRF and variance decomposition.

5.3.1 Impulse Response Functions (IRFs)

IRFs actually show the effects of shocks on the adjustment path of the variables. For that reason, this process can be utilised to analyse the dynamic relations between the endogenous variables of a VAR(p) process. Impulse response analysis in the framework of VAR models were pioneered by Sims (1980, 1981). These impulse responses are sometimes called forecast error impulse responses because the innovations are the 1-step ahead forecast errors (Lutkepohl, 2005).

However, the econometric process may contain I(1) variables and r cointegrating relations, where $0 < r < K$. This is exactly the case in our study and, therefore, the process can be written as a VECM:

$$\Gamma_0 \Delta y_t = \alpha \acute{\beta} y_{t-1} + \Gamma_1 \Delta y_{t-1} + \cdots + \Gamma_{p-1} \Delta y_{t-p+1} + u_t \ldots\ldots\ldots\ldots \quad (5.9)$$

where, Γ_j $(j = 0, 1, \ldots, p-1)$ are the short-run parameter matrices, α is the $(K \times r)$ loading matrix and β is a $(K \times r)$ matrix containing r linearly independent cointegration relations. The above VECM form Equation (5.9) of the model and shows the instantaneous and intertemporal relations between the variables. According to Benkwitz and Lutkepohl (2001), the exact form of these relations among the variables is usually difficult to see directly from the coefficients, especially if they are only identifying restrictions on the short-term parameters Γ_j $(j = 0, 1, \dots, p - 1)$. Therefore, the researchers compute IRFs so that the analysis can represent the marginal responses if the endogenous variables of the system to an impulse in one of the endogenous variables. These may be considered as restricted forecasts of the endogenous variables given that they have been zero up to time 0 when an impulse in one of the variables occurred. Various kinds of impulse responses are used to understand the models and it depends on the kind of impulse striking the system. The important property of these impulse responses is that they are nonlinear functions of the parameters of the model (5.9):

$$\phi_{ij,h} = \phi_{ij,h}\left(A_0, A_1, \dots, A_p\right) = \phi_{ij,h}\left(\alpha, \beta, \Gamma_0, \Gamma_1, \dots, \Gamma_{p-1}\right) \text{ ---- } (5.10)$$

where, $\phi_{ij,h}$ represents the response of variable i to an impulse in variable j, h periods previously.

Usually the coefficients of the VECM in equation (5.9) are estimated by maximum likelihood or feasible GLS. Estimators of the impulse responses are then obtained as:

$$\hat{\phi}_{ij,h} = \phi_{ij,h}\left(\hat{\alpha}, \hat{\beta}, \hat{\Gamma}_0, \hat{\Gamma}_1, \dots, \hat{\Gamma}_{p-1}\right) \text{ ------- } \quad (5.11)$$

where, $\hat{\alpha}, \hat{\beta}, \hat{\Gamma}_0, \hat{\Gamma}_1, \dots, \hat{\Gamma}_{p-1}$ are the estimated VECM parameter matrices. Under general assumptions, the resulting impulse responses have asymptotic normal distributions and confidence intervals (CIs) can be constructed from these. In practice, bootstrap methods are often utilised for constructing CIs and in the present study we applied bootstrap methods. Bootstrap approaches sometimes lead to more consistent small sample inference than CIs founded on standard asymptotic theory (Benkwitz & Lutkepohl, 2001).

A series of bootstrap datasets were produced for our study and the IRF statistic was calculated for all sets of variables. The following algorithm proposed by Benkwitz and Lutkepohl (2001) was applied:

1. Estimate the parameters of the VECM. The parameters of the models of our study were estimated in the previous section of this chapter.
2. Generate bootstrap residuals $u_1^*, \ldots\ldots, u_t^*$ by randomly drawing with replacement from the set of estimated and re-centred residuals, $(\hat{u}_1 - \bar{u}_., \ldots, \hat{u}_T - \bar{u}_.)$, where $\hat{u}_t = \hat{\Gamma}_0 \Delta y_t - \hat{\alpha}\hat{\beta}' y_{t-1} - \hat{\Gamma}_1 \Delta y_{t-1} - \cdots - \hat{\Gamma}_{p-1} \Delta y_{t-p+1}$, and $\bar{u}_. = T^{-1} \sum \hat{u}_t$.
3. After the bootstrap residuals were created, they were utilised to produce a bootstrap dataset by including them in the data generating process. This process consists of the components; eigenvectors, variables in levels, coefficients, regressors (first differences of the time series and deterministic terms) and bootstrap residuals. Thus, set $(y_{-p+1}^*, \ldots, y_0^*) = (y_{-p+1}, \ldots, y_0)$ and construct bootstrap time series recursively using the levels representation of basic VAR model: $y_t^* = \hat{A}_0^{-1} (\hat{A}_1 y_{t-1}^* + \cdots + \hat{A}_p y_{t-p}^* + u_t^*), t = 1, \ldots, T$.
4. Re-estimate the parameters $\Gamma_0, \Gamma_1, \ldots, \Gamma_{p-1}, \alpha, \beta$ from the generated data and there are two alternative ways to do so. The first possibility is to use the same estimation method in each bootstrap replication that was

utilised in estimating the VECM coefficients from the original data. Alternatively, one may argue that the β matrix is estimated super-consistently from the original data and therefore is treated as known and fixed in the bootstrap replications.

5. Calculate a bootstrap version of the statistic of interest. The purpose of the bootstrapping was to see the certainty we can attach to the impulse response analysis conducted. The CI bands were an appropriate tool for measuring certainty of the analysis in this position. The most commonly applied method in setting up CIs for impulse responses in practice proceeds by using $\gamma/2$ –and $(1-\gamma/2)$-quantiles.

   Hall (1992) presented several modifications of the above process in the bootstrap literature in the following way: let $t^*_{\gamma/2}$ and $t^*_{(1-\gamma/2)}$ be the $\gamma/2$ and $(1-\gamma/2)$ quantiles of $\mathcal{L}\,(\hat{\phi}^*_T - \hat{\phi}_T \,|y_{-p+1}, \dots, y_0, \dots, y_T\ ;\ x_1, \dots, x_T)$, respectively. According to the usual bootstrap analogy, $\mathcal{L}\left(\hat{\phi}_T - \phi\right) \approx \mathcal{L}\,(\hat{\phi}^*_T - \hat{\phi}_T \,|y_{-p+1}, \dots, y_0, \dots, y_T\ ;\ x_1, \dots, x_T)$, one obtains the interval:

   $CI_H = [\,\hat{\phi}_T - t^*_{(1-\gamma/2)}, \hat{\phi}_T - t^*_{\gamma/2}$. Here, we use the symbols $\phi\,, \hat{\phi}_T\ and\ \hat{\phi}^*_T$ to denote a general impulse response coefficient, its estimator implied by the estimators of the model coefficients and the corresponding bootstrap estimator, respectively. The subscript T indicates the sample size.

The CI_H labelled in the last stage is described as the 'percentile interval' by Hall (1992) and Hall's percentile method is asymptotically correct (Benkwitz & Lutkepohl, 2001). In our study, we applied this bootstrap method and for reliable CIs the number of bootstrap replications has to be large, approximately a few thousand. In our study, the number of bootstrap replications was set to 1,500 similar to Akram (2009), although Akram (2009) suggested that it does not matter if one uses fewer replications.

5.3.2 Robustness of the Dynamic Results of VECM and Ordering of the Variables

The estimation results of IRFs and variance decomposition are sensitive to different orderings of the variables of the model (Lutkepohl, 2005; Sims, 1981). Therefore, Sims (1981) and Brooks (2002) suggested investigating the sensitivity of the results to the ordering of the variables.

Brooks (2002) stated that impulse responses refer to a unit shock to the errors of one vector autoregressive equation alone. This means in the system that the error terms of all other equations are held constant. However, the fact is that the error terms are likely to be correlated across equations of the system to some degree. Therefore, assuming that the error terms are entirely independent would lead to a distortion of the model dynamics. In fact, the errors would have a common element that cannot be linked with a single variable alone.

According to Brooks (2002), the standard solution to this problem is to create orthogonalised impulse responses, which we have done for the present study. In the case of a bivariate vector autoregressive system, the entire mutual element of the errors is attributed somewhat randomly to the first variable in the VAR. For the multivariate case, the calculations are more difficult but the explanation is similar. Such a restriction in effect implies an ‘ordering’ of variables, i.e. the equation for y_{1t} would be estimated first and then that of y_{2t}, which is similar to a recursive or triangular system.

A specific ordering is therefore assumed to be essential to calculate the impulse responses and variance decompositions, although the constraint underlying the ordering utilised might not be supported by the data. Again, ordering of all the variables should be supported by financial theories (Brooks, 2002). Therefore, to ensure the robustness of the dynamic results of the model, researchers follow the trend of the literature in selecting the orderings of the variables of the model.

To identify the shocks, the author ordered the variables in current model following the relevant literature and thereby the corresponding shocks were $(ip, rr, rer, spr, rci)'$. This implies:

$$B\ matrix = \begin{bmatrix} * & 0 & 0 & 0 & 0 \\ * & * & 0 & 0 & 0 \\ * & * & * & 0 & 0 \\ * & * & * & * & 0 \\ * & * & * & * & * \end{bmatrix} \begin{bmatrix} \bar{u}_{ip} \\ \bar{u}_{rr} \\ \bar{u}_{rer} \\ \bar{u}_{spr} \\ \bar{u}_{rci} \end{bmatrix}$$

where, B is a lower diagonal matrix consistent with the Cholesky decomposition. The '*' entries in the matrix represent unrestricted parameter values. The zeros suggest that the associated fundamental shock did not contemporaneously affect the corresponding endogenous variable. Specifically, the first row in matrix B implies that ip might respond contemporaneously to only its own shocks, while the other four shocks do not have a contemporaneous effect on ip. The second row suggests that the rr might respond contemporaneously to both shocks to ip and shocks directly to its own, while the third row implies that the rer may respond contemporaneously to shocks to ip and rr, in addition to shocks directly to rer. Finally, the B matrix confirms our assumption that real commodity prices in Australia respond contemporaneously to all of the shocks.

The ordering of *ip* and hence of the shocks to *ip* followed by the *rr*, *rer* and then by the *spr* is more consistent with previous studies, e.g. Akram (2009), Eichenbaum and Evans (1995), Favero (2001) and Klotz, Lin, and Hsu (2014) and the references therein. In our study, the main focus was on the response of commodity prices to other macroeconomic variables. Therefore, we deviated from of the majority of previous studies and placed Australian real commodity prices after all other variables by following Akram (2014).

Several researchers have given importance to variables 'ordering' after analysing the correlation among the residuals of the variables. Borozan (2011) showed that if the error terms of the VEC equations were not correlated, employing different orderings would not change the results of IRFs as well as variance decompositions. In our study, we have checked the serial correlation of the residuals of the VECM and found 'no serial correlation' among the residuals of VEC equations. When the residuals were almost uncorrelated, the ordering of the variables would make little difference (Lutkepohl, 2005). However, we also followed the trend of existing literature for ordering the variables before computing IRFs and variance decompositions. Thus, the results of the IRFs and variance decompositions represent the true dynamic behaviour of our model.

The non-orthogonalised general IRFs show the cumulative effect. For our analysis we utilised orthogonalised IRFs, which measure the isolated effect from a shock in one variable to another.

5.3.3 Impulse Response Results of Australian Commodity Prices

The explanation of the VECM coefficients in the earlier segment of this chapter does not offer much understanding to the interrelation and association of the variables in the model. There were numerous coefficients in each regression and several of them were insignificant. Therefore, IRFs were investigated to learn more about how the Australian commodity prices responded to other macroeconomic variable changes in a shock environment. This computation was useful for this research in assessing how shocks to economic variables reverberate through our specific model.

To report statistical significance, the author drew confidence bands around the impulse response function. If zero lies outside the confidence band, then it is statistically distinguishable from zero (R. H. Murphy, 2015). We analysed impulse responses based on the VECM and present 95 per cent CIs obtained by bootstrapping suggested by Hall (1992) together with the impulse responses to different shocks.

In the present study, to analyse the IRFs we constructed 95 per cent Hall percentile CIs and conducted orthogonal impulse responses analysis. To obtain the orthogonal impulse response the Cholesky decomposition of the covariance matrix of the residuals was applied.

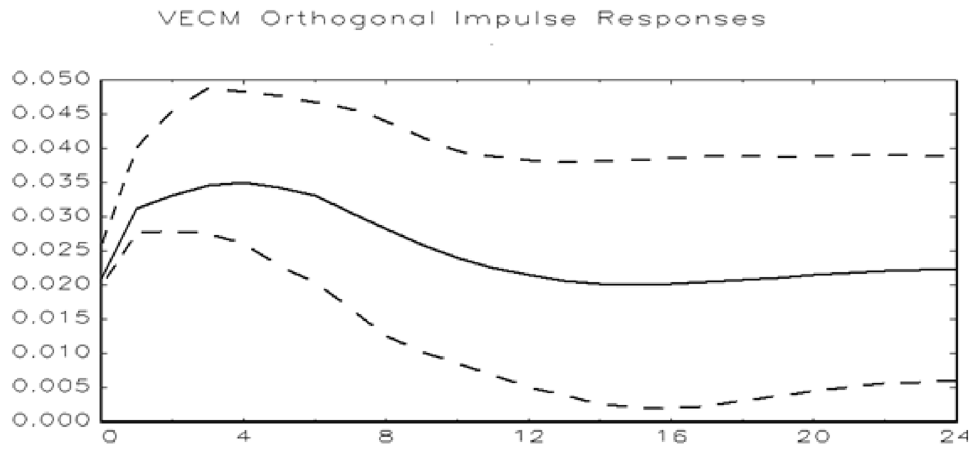


Figure 5.7 Responses of Real Commodity Price (rci) to Real Commodity Price (rci)

In Figure 5.7, the immediate reaction to a commodity price shock is shown as an increase in *rci*, which increases sharply up to the first month. Then, it starts to rise at a lower rate and continuing to its peak during the third month. Thus, a one standard deviation shock to commodity prices causes commodity prices to peak at approximately 3 months and then start to fall gradually.

Table 5.12 Significant VECM Orthogonal Impulse Responses: Responses of rci to rci

TIME	ESTIMATE	CONFIDENCE INTERVAL (CI)*
00 Month	0.0209	[0.0198, 0.0257]
03 Month	0.0346	[0.0274, 0.0489]
06 Month	0.0331	[0.0204, 0.0467]
09 Month	0.0259	[0.0103, 0.0417]
12 Month	0.0215	[0.0051, 0.0383]
15 Month	0.0200	[0.0020, 0.0384]
18 Month	0.0208	[0.0030, 0.0389]

21 Month	0.0218	[0.0051, 0.0390]
24 Month	0.0224	[0.0059, 0.0388]

Note: * This is the 95 per cent Hall percentile CI (B = 1,500; h = 24)

Eventually a continuous decrease in commodity price is observed for at least a year and half before increasing a small amount (Table 5.12). In Figure 5.7 we see that around the IRF, the confidence interval bands followed the same direction, which means that the IRF is relatively reliable. The effect of the shock on commodity price is statistically significant.

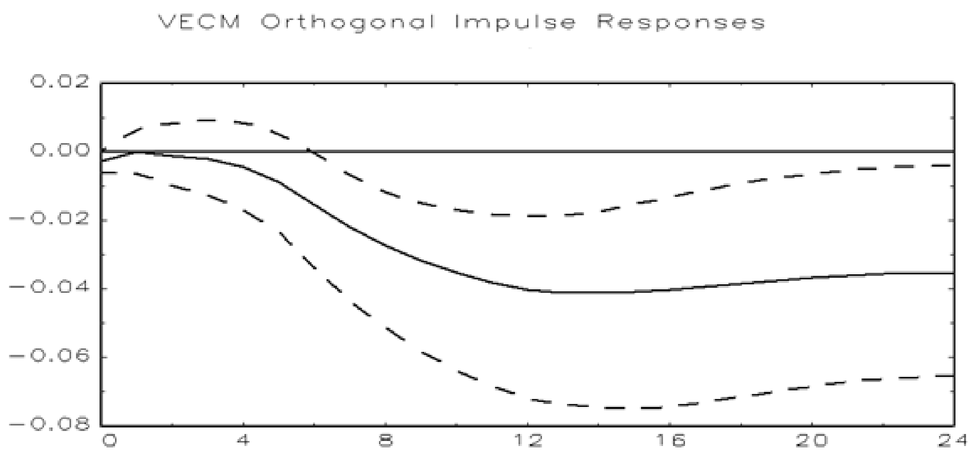


Figure 5.8 Responses of Real Commodity Price (rci) to Real Interest Rate (rr)

Figure 5.8 shows the responses of *rci* because of an impulse in *rr*. The graph shows that a one standard deviation shock to *rr* causes the *rci* to increase by a small amount and then decrease at a slower rate up to the fourth month and then reduces at a sharp rate before it becomes almost constant after one year of the initial shock. The responses of *rci* from the impulse of *rr* is always negative and the effects are statistically significant at the 5 per cent level from the medium term at approximately sixth months after the initial shock. This can also be seen in Table 5.13.

TIME	ESTIMATE	CONFIDENCE INTERVAL (CI)*
00 Month	-0.0028	[-0.0063, 0.0001]
03 Month	-0.0022	[-0.0127, 0.0091]
06 Month	-0.0156	[-0.0339, -0.0002]
09 Month	-0.0317	[-0.0583, -0.0152]
12 Month	-0.0402	[-0.0722, -0.0188]
15 Month	-0.0409	[-0.0749, -0.0154]
18 Month	-0.0384	[-0.0715, -0.0093]
21 Month	-0.0362	[-0.0672, -0.0054]
24 Month	-0.0354	[-0.0653, -0.0042]

Note: * This is 95 per cent Hall percentile CI (B = 1,500; h = 24)

Table 5.13 Significant VECM Orthogonal Impulse Responses: Responses of rci to rr

Figure 5.8 also shows that the CIs widen out from the beginning, which indicates that the shock has a permanent negative effect on *rci*. This negative impact on *rci* becomes significant at approximately the sixth month mark when the CI upper band crosses the zero line. This result is consistent with the long-run relationship among *rci* and *rr* that is shown in the previous segment of this chapter. It is also consistent with the economic theories that suggest a negative relationship between the commodity price and interest rate.

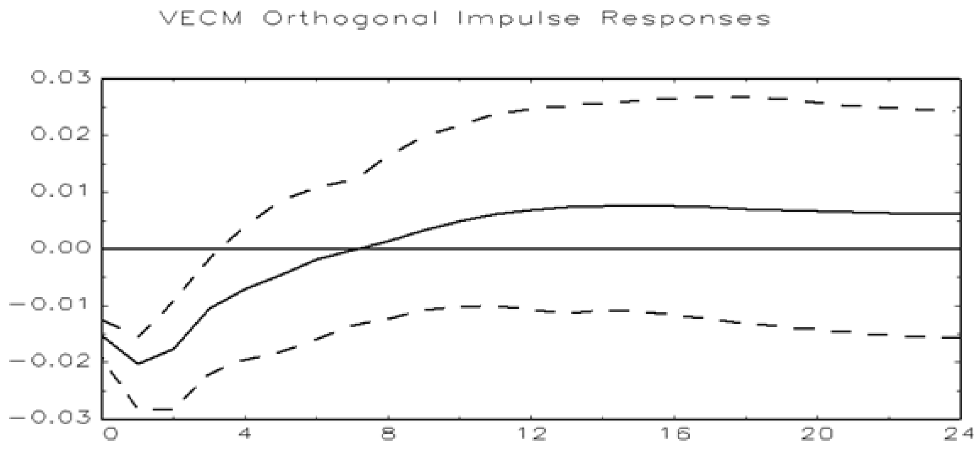


Figure 5.9 Responses of Real Commodity Price (rci) to Real Exchange Rate (rer)

Figure 5.9 displays the responses of the *rci* in Australia from an impulse in the real trade weighted exchange rate. From the graph, a one standard deviation shock to *rer* decreases the Australian *rci* at the beginning and then overshoots. However, the overall responses of the *rci* to the shock of *rer* is insignificant.

Table 5.14 Significant VECM Orthogonal Impulse Responses: Responses of rci to rer

TIME	ESTIMATE	CONFIDENCE INTERVAL (CI)*
00 Month	-0.0154	[-0.0193, -0.0126]
03 Month	-0.0104	[-0.0216, -0.0015]
06 Month	-0.0017	[-0.0158, 0.0109]
09 Month	0.0034	[-0.0107, 0.0199]
12 Month	0.0069	[-0.0107, 0.0248]
15 Month	0.0076	[-0.0110, 0.0263]
18 Month	0.0071	[-0.0131, 0.0268]

21 Month	0.0064	[-0.0148, 0.0253]
24 Month	0.0061	[-0.0157, 0.0242]

Note: * This is 95 per cent Hall percentile CI (B = 1,500; h = 24)

Table 5.14 also shows that the impulse in the *rer* keeps the *rci* as a negative for two quarters and after that the *rci* increases to the positive region. However, Figure 5.9 shows that the response of the *rci* remains insignificant.

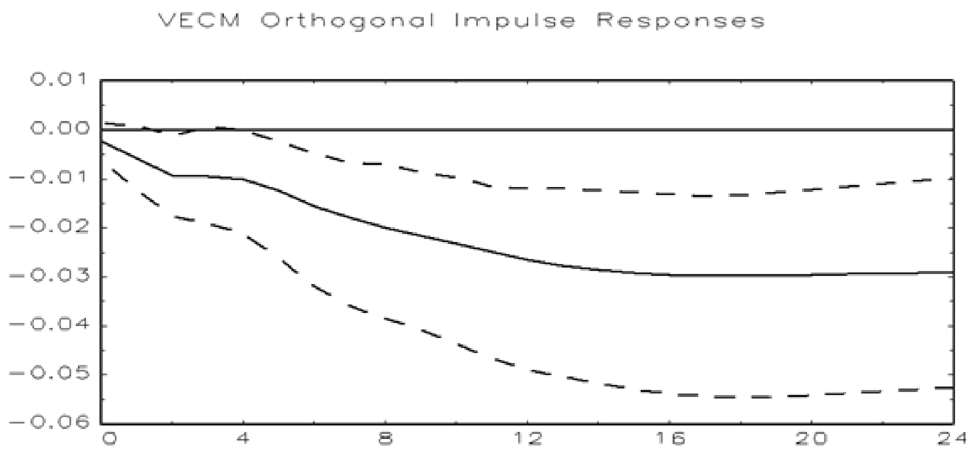


Figure 5.10 Responses of Real Commodity Price (rci) to Industrial Production (ip)

Figure 5.10 shows the response of *rci* from a shock in real economic variable—the *ip*. The graph shows that a one standard deviation shock to *ip* decreased the *rci* from the very beginning and then dropped sharply until the second month. After that, the *rci* remained almost steady before beginning to fall sharply again from approximately the sixth month. The effect of this shock becomes almost constant in the negative region after almost a year of the initial shock in *ip*.

Table 5.15 also shows that after one year the *rci* becomes almost stagnant of the initial shock in economic activity variable within Australia. Thus, the shock of *ip* on *rci* remains negative at all time in the short, medium and long run. This impact also becomes statically significant at the 5 per cent level from the first month of the initial shock in *ip*. The long-run nature of this relationship is consistent with the long-run relationship results of the present study, which is shown as the cointegrating equation of our *rci* model in the earlier section of this chapter.

Table 5.15 Significant VECM Orthogonal Impulse Responses: Responses of rci to ip

TIME	ESTIMATE	CONFIDENCE INTERVAL (CI)*
00 Month	-0.0022	[-0.0063, 0.0015]
03 Month	-0.0095	[-0.0190, 0.0007]
06 Month	-0.0157	[-0.0320, -0.0047]
09 Month	-0.0217	[-0.0408, -0.0085]
12 Month	-0.0264	[-0.0488, -0.0119]
15 Month	-0.0293	[-0.0530, -0.0127]
18 Month	-0.0298	[-0.0547, -0.0133]
21 Month	-0.0295	[-0.0538, -0.0115]
24 Month	-0.0290	[-0.0527, -0.0099]

Note: * This is the 95 per cent Hall percentile CI (B = 1,500; h = 24)

This type of long-run negative relationship between *ip* and *rci* can be described based on findings by Ghura (1990). If a sudden increase in industrial output causes unexpected economic growth, then an ambiguous effect on commodity price can be expected. This completely depends on how investors respond to this ‘good news’, which can be viewed in two ways and depends on the stage of the economic cycle.

First, news of a strengthening of economic activity might increase investors’ confidence about future growth in the economy. In such a case, investors will increase their demand for short-run investments causing short-term nominal and hence real interest rates to rise, assuming inflation expectations do not change. Therefore, the commodity prices would be expected to fall.

Second, investors might view the strengthening of economic activity as a result of a sudden increase in industrial production as a sign of an ‘overheating’ economy. If traders assume that the central bank will respond by contracting money supply, real rates should go up. In this case, investors will amend their portfolio by selling commodity contracts, stocks and foreign currencies and by retaining more money. Hence, commodity prices would be expected to fall. Thus, our findings of the relationship between *ip* and *rci* are consistent with the existing literature (J. Frankel, 1986; J. Frankel, 2014; Hamilton & Wu, 2014).

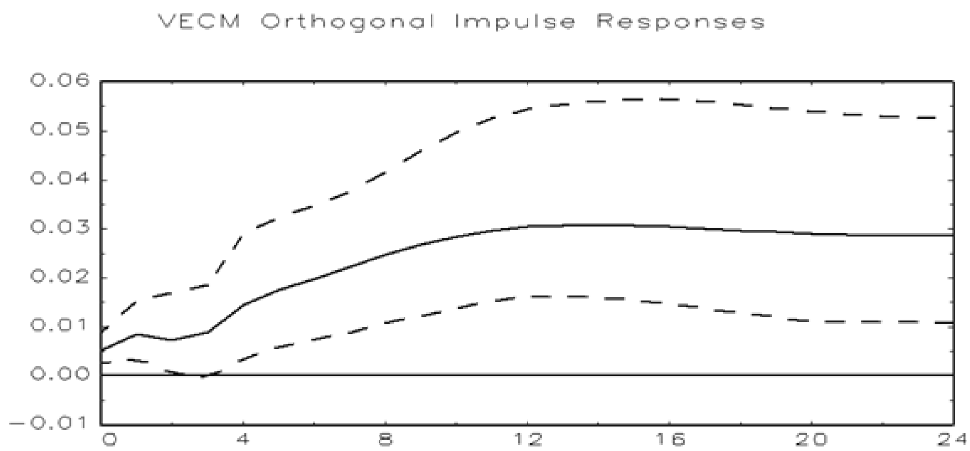


Figure 5.11 Responses of Real Commodity Price (rci) to Real Resource Stock Price (spr)

Figure 5.11 shows that the immediate reaction to *spr* is an increase in *rci*. Because of the shock, the *rci* increases in the first month and then decreases in the next month. After that the *rci* shows the overshooting response and a rapid growth rate in *rci* is visible up to a year after the initial shock in stock price. This effect on *rci* remains statistically significant at 5 per cent. Thus, a standard deviation shock to the *spr* increases the *rci* and the shock remains positive even in the long run. This positive relationship is consistent with the long-run relationship results of our model, which is shown in the earlier section of this chapter. Table 5.16 shows the same relationship between *spr* and *rci*.

Table 5.16 Significant VECM Orthogonal Impulse Responses: Responses of rci to spr

TIME	ESTIMATE	CONFIDENCE INTERVAL (CI)*
00 Month	0.0051	[0.0025, 0.0089]
03 Month	0.0090	[-0.0004, 0.0186]
06 Month	0.0198	[0.0074, 0.0348]
09 Month	0.0268	[0.0123, 0.0460]
12 Month	0.0304	[0.0162, 0.0545]
15 Month	0.0307	[0.0154, 0.0566]
18 Month	0.0297	[0.0129, 0.0554]
21 Month	0.0289	[0.0110, 0.0535]
24 Month	0.0285	[0.0107, 0.0526]

Note: * This is the 95 per cent Hall percentile CI (B = 1,500; h = 24)

Our results about the relationship between stock price and commodity price supports the findings of Rossi (2012), which showed that stock prices can predict future commodity prices in commodity exporting countries such as Australia.

5.3.4 Forecast Error Variance Decomposition

Variance decompositions offer a dissimilar method for examining the dynamic behaviour of our commodity price model. They provide the information on the proportion of movements in dependent variables that are due to their 'own' shocks versus shocks to the other variables. A shock to the ith variable will directly affect that variable; however, it will also be transmitted to all the other variables in the system via the dynamic structure of the VAR. Variance decompositions define how much of the s-step-ahead forecast error variance of a given variable is clarified by innovations to each explanatory variable for s = 1, 2, ... It is generally observed that own series shocks clarify the majority of the forecast error variance of the series in a VAR model. To some degree, impulse responses and variance decompositions suggest very related information (Brooks, 2002).

However, forecast error variance decompositions (FEVD) provide different properties of the model compared to VECM and Granger causality. FEVD provides the dynamic properties of the system during the post-sample period (Shahbaz, Lean, & Shabbir, 2010).

To define FEVD, Lutkepohl (2005) stated that the innovations that actually drive the system could be identified with a FEVD tool for any VAR. Suppose a recursive identification scheme is available so that the following moving average representation with orthogonal white noise innovations may be considered:

$$y_t = \mu + \sum_{i=0}^{\infty} \Theta_i \ \omega_{t-i} \ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \ (5.12)$$

with $\sum_{\omega} = I_K$, the error of the optimal h-step forecast is:

$$y_{t+h} - y_t(h) = \sum_{i=0}^{h-1} \Phi_i \ u_{t+h-i} = \sum_{i=0}^{h-1} \Phi_i \ P \ P^{-1} \ u_{t+h-i} = \sum_{i=0}^{h-1} \Theta_i \ \omega_{t+h-i} \ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \ (5.13)$$

Denoting the mn-th element of Θ_i by $\theta_{mn,i}$ as before, the h-step forecast error of the j-th component of y_t is:

$$y_{j,t+h} - y_{j,t}(h) = \sum_{i=0}^{h-1} (\theta_{j1,i} \ \omega_{1,t+h-i} + \cdots + \theta_{j,K,i}\omega_{K,t+h-i}) = \sum_{K=1}^{K} (\theta_{jK,0} \ \omega_{K,t+h} + \cdots + \theta_{j,K,h-1}\omega_{K,t+1}) \dots\dots\dots\dots\dots\dots\dots\dots \ (5.14)$$

Thus, the forecast error of the j-th component potentially consists of all the innovations $\omega_{1t}, \dots, \omega_{Kt}$. Of course, some of the $\theta_{mn,i}$ may be zero so that some components may not appear in Equation (5.14). Because the $\omega_{K,t}$'s are uncorrelated and have unit variances, the mean squared error (MSE) of $y_{j,t}(h)$ is:

$$E \ (y_{j,t+h} - y_{j,t} \ (h))^2 = \sum_{k=1}^{k} (\theta_{jk,0}^2 + \cdots + \theta_{jk,h-1}^2) \ \dots\dots\dots\dots\dots\dots. \ (5.15)$$

Therefore,

$$\theta_{jk,0}^2 + \theta_{jk,1}^2 + \cdots + \theta_{jk,h-1}^2 = \sum_{i=0}^{h-1} (e_j' \ \Theta_i \ e_k)^2 \ \dots\dots\dots\dots\dots\dots\dots \ (5.16)$$

is sometimes interpreted as the contribution of innovations in variable k to the forecast error variance or MSE of the h-step forecast of the variable j. Here, e_k is the k-th column of I_K. Dividing equation (4.51) by:

$$MSE[y_{j,t}(h)] = \sum_{i=0}^{h-1} \sum_{k=1}^{K} \theta_{jk,i}^2$$

gives

$$\omega_{jk,h} = \sum_{i=0}^{h-1}(e_j' \ \Theta_i \ e_k)^2 \ / \ MSE[y_{j,t}(h)] \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \ (5.17)$$

which is the proportion of the h-step forecast error variance of variable j, accounted for by ω_{kt} innovations. If ω_{kt} can be associated with variable k, $\omega_{jk,h}$ represents the proportion of the h-step forecast error variance accounted for by innovations in variable k. Thereby, the forecast error variance is decomposed into components accounted for by innovations in the different variables of the system. From Equation (5.17), the h-step forecast MSE matrix is seen to be:

$$\sum_y (h) = MSE[y_t \ (h)] = \sum_{i=0}^{h-1} \Phi_i \ \sum_u \Phi_i' \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (5.18)$$

The diagonal elements of this matrix are the MSEs of the y_{jt} variables, which may be applied in Equation (5.18).

Lutkepohl (2005) also discussed that the Granger causality and FEVD are quite different concepts. Moreover, the forecast error variance components are conditional on the system under consideration. They may change if the system is expanded by adding further variables or if variables are deleted from the system. In addition, measurement errors, seasonal adjustment and the use of aggregates may contaminate FEVD.

5.3.5 Results of VECM Forecast Error Variance Decomposition

The variables involved in our study were rci, rr, rer, ip and spr in Australia. Because *rci* was in the centre of our interest, we analysed the VECM FEVD of *rci* in Australia, which is reported in Table 5.17 below.

Table 5.17 VECM Forecast Error Variance Decomposition (FEVD) of Real Commodity Price (rci)

	Proportions of forecast error in *rci* accounted for by:				
Forecast Horizon	(1) *ip*	(2) *rr*	(3) *rer*	(4) *spr*	(5) *rci*
1	0.01	0.01	0.33	0.04	0.61
3	0.03	0.00	0.25	0.04	0.67
6	0.05	0.01	0.13	0.09	0.71
9	0.09	0.10	0.07	0.15	0.58
12	0.12	0.21	0.05	0.19	0.43
15	0.15	0.28	0.04	0.20	0.33
18	0.17	0.32	0.03	0.21	0.27
21	0.18	0.33	0.03	0.22	0.25
24	0.19	0.33	0.03	0.22	0.23

The reported numbers in Table 5.17 indicate the percentage of the forecast error in each variable that can be attributed to innovations in other variables at 24 different horizons from 1 to 24 months ahead. Therefore, these numbers show the percentage of the forecast error from short run to long run.

The above table, under column (5) shows that during the first month, 61 per cent of the variability in *rci* changes is explained by its own innovations. Most of the forecast error variance of *rci* at the beginning is accounted for by own innovations. Even after 9 months, 58 per cent of the variability in *rci* changes is described by its own innovation. This finding supports the fact that *rci* in the current period is closely related to its future pricing decisions in the short to medium run. However, after two years approximately a quarter of the variability in *rci* changes are described by its own innovation.

The results of FEVD in column (1) of Table 5.17 shows that only 1 per cent of the variability in *rci* changes is explained by *ip* in Australia during the very first month and the impact increases at a very slow rate over time. Even after one year, only 12 per cent of the variability in *rci* change can be explained by economic activity of Australia. However, in the long run, *ip* has a significant impact on *rci* and after two years almost one fifth of the *rci* variability can be explained by *ip*.

Indicated under column (2), *rci* are not affected by the shock in the *rr* at the very beginning. Even after half a year only 1 per cent of the variability in *rci* changes can be explained by innovations in *rr*, with this increasing dramatically to more than 20 per cent by the end of the first year. After two years, during the long-run period, approximately one third of the *rci* changes can be explained by the shocks in *rr*. Thus, the result confirms that *rci* are affected by *rr* in the medium to long run.

In column (3) of Table5.17, we see that shocks in the *rer* affect the *rci* significantly during the first quarter, with the impact being 33 per cent in the first month. However, it drops sharply in the medium term and approximately 5 per cent of the variability in *rci* changes can be explained by the innovation in *rer* during the 12 month period. It becomes only 3 per cent after 2 years. Therefore, FEVD results confirm that *rci* are affected by *rer* marginally in the long run and significantly in the short run.

Table 5.17 also shows that approximately 22 per cent of the variability in *rci* changes can be explained by innovation of *spr* in the long run. However, any changes in the *rci* in the first month can be explained marginally by innovation in stock prices (only 4 per cent). However, at 1 year during the medium-run period, 19 per cent of *rci* variations are due to stock price changes. Therefore, in the medium-run and long-run, *spr* shocks have significant impact on *rci* changes and it impacts the *rci* marginally in the short run.

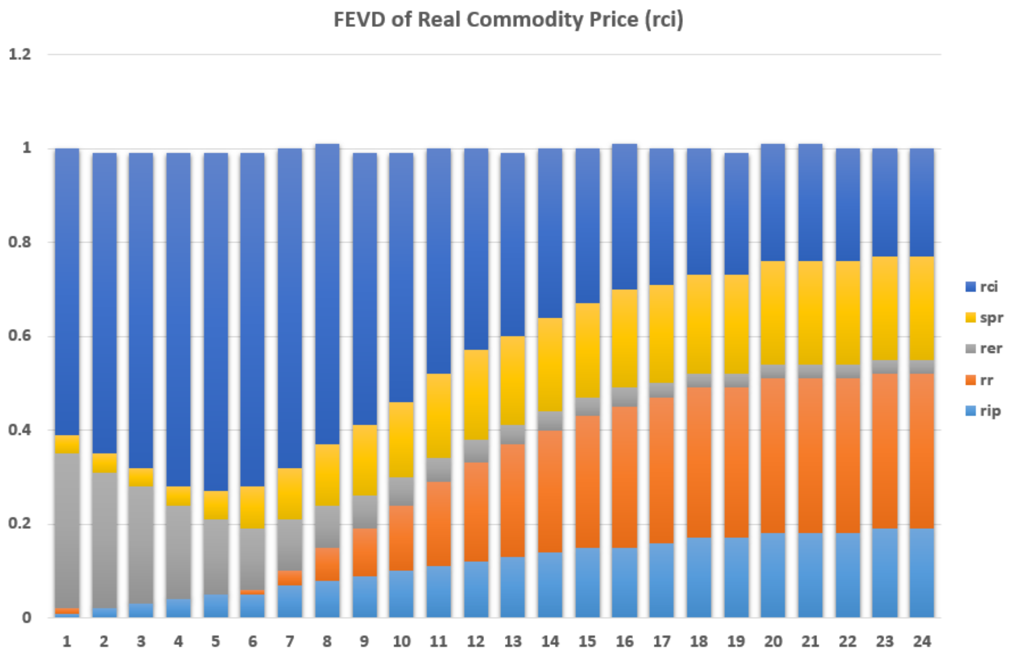


Figure 5.12 Proportions of Forecast Error in Real Commodity Price

Figure 5.12 represents the percentage of the forecast error in *rci* that can be attributed to innovations in other macroeconomic variables at 24 different horizons.

5.4 Concluding Remarks

This chapter analysed the commodity price model to show the outcomes of Australian commodity price dynamics. The whole empirical findings were presented in several sub-sections. The first sub-section showed the stationarity tests of the variables of our commodity price model. The present study employed ADF, DFGLS, KPSS and modified ADF tests with a breakpoint. These tests revealed all the variables of our model as first difference stationary $I(1)$, except for the *rr*, which is a level stationary $I(0)$ series.

This chapter then employed the Johansen (1988, 1991) cointegration procedure to determine whether there was a long-run equilibrium relationship between the commodity price and other macroeconomic variables of our model. The results show the expected sign of all the variables according to the literature. However, *rr, ip* and *spr* were significant in our model. The results reveal that the *rr*, *rer* and *ip* in Australia have an adverse effect on the *rci*. However, the effect of the *rer* on *rci* in the long run is not significant. On the other hand, the *spr* showed a significant favourable effect on the *rci* in the long run.

The variables of our model are cointegrated in the long run; therefore, there exists an error correction mechanism, which is shown in the following section of this chapter. This VEC mechanism combines the long-run equilibrium with short-run dynamics to reach the equilibrium situation. The signs of the error correction terms of our model have the expected negative (-) sign with statistical significance. Thus, the model showed that all the variables helped restore the divergence from the long-run equilibrium in the commodity price model of Australia.

The next section of this chapter presented the VEC Granger causality test results. We divided the results for both short and long run. The results showed that the Australian interest rate Granger caused *rci* in the short run and the same was true for the opposite direction. However, the Australian trade weighted RER current and past information helped improve the forecasts of commodity prices immediately and the opposite was true between two to four months lags. Moreover, the current and past information on S&P/ASX 200 resources index helped improve the forecast ability of *rci* mostly in the short run. Another unidirectional causality has been found from *rci* to *ip* in the short to medium term.

The VECM Granger causality for the long run was also reported in this section, which was tested by the significance of the speed of adjustment. This result in our study explained that current and past information of the adjustment speed of the cointegrating vector of our long-run model helped improve forecasts of commodity prices over 3 to 12 months. Thus, we can conclude that the elasticity of the cointegration vector Granger caused *rci* in the long run.

The next section of this chapter explained the dynamic behaviour of the VECM of our study via IRFs and FEVD. The IRFs actually showed the effects of shocks on the adjustment path of the variables of our model. The orthogonal IRF showed a one standard deviation shock to commodity price causes commodity price to peak immediately and to stay in the positive territory significantly. The significant long-run negative response of *rci* from a shock in *ip* was also observed from IRFs. The opposite significant response was seen from the shock of the Australian *spr*. However, the responses of *rci* from the shock of *rr* was always negative and effects were statistically significant at the 5 per cent level from the medium term at around sixth months after the initial shock. This effect of monetary shock on Australian commodity price is consistent with Frankel's (1986, 2010) overshooting model of commodity price and also consistent with seminal empirical work of Akram (2009).

The last section of this chapter presented the FEVD of the model, which provides information on the proportion of movements in dependent variables that are due to their 'own' shocks versus shocks to the other variables. The first finding supported the fact that the *rci* in the current period is closely related to its future pricing decisions in the short to medium run. Australian *ip* can explain very little of the variability of the *rci* changes in the short run. However, in the long run *ip* can describe almost a quarter of the inconsistency in *rci*. Similarly, the *rr* as well as *spr* did not have much impact on commodity prices in the short run. In the medium to long run, both these variables could explain the *rci* changes significantly. Thus, the *rer* affects the *rci* marginally in the long run, but significantly during the first quarter.

Thus, this chapter showed the analytical framework utilised to evaluate the commodity price dynamics of Australia, which is consistent with Frankel's (1986, 2010) overshooting model of commodity price and it presents the interaction between commodity price as well as other major Australian macroeconomic variables.

Chapter 6 RESPONSES OF MACROVARIABLES TO COMMODITY PRICES SHOCK

6.1 Introduction

The shocks on various Australian macroeconomic variables and their effects on commodity prices are analysed in the last section of the previous chapter. However, analysis of the shocks the other way around would give the complete picture of the Australian economy and its response from the shock of volatile commodity prices.

This research utilised orthogonalised IRFs to analyse the responses of Australian macroeconomic variables in case of a shock in Australian commodity prices. These particular IRFs measure the isolated effect from a shock in one variable to another in this commodity price model.

6.2 Reasons for Finding the Responses of Macroeconomic Variables

The short-run dynamic model of Australian commodity prices in the previous chapter has several coefficients in each regression and many of them were insignificant. Thus, the model does not offer much understanding to how the variables in the model interconnected and their relations. Therefore, the IRFs of this chapter could help to learn more about how the Australian macroeconomic variables respond to commodity price volatility in a shock environment and enable us to compare the responses of commodity prices.

6.3 Impulse Responses of Australian Macroeconomic Variables

The analysis of this chapter starts with the impulse responses based on the VECM ofthe commodity price in the previous chapter. We have maintained the same ordering of the variables as the estimation results of IRFs and variance decomposition are sensitive to different orderings of the variables of the model (Lutkepohl, 2005; C. A. Sims, 1981).

This study applied 95 per cent CIs achieved by bootstrapping together with the impulse responses to diverse shocks of the Australian macroeconomic variables. We employed the bootstrap method suggested by Hall (1992) and the number of bootstrap replications was set to 1,500 to maintain consistency with other empirical literature of the same type. However, as mentioned previously, Akram (2009) suggested that it does not matter greatly if fewer bootstrap replications are applied.

The existing theories regarding the relationship between real interest rates and commodity prices suggest a negative relationship. However, the influence is generally from monetary policy to commodity prices. The literature from a viewpoint based on reverse causality is rare. Frankel (2006) discussed the possible influence of commodity prices on monetary policy when determining what price index to utilise for the nominal anchor. The results of the responses of commodity prices from other macroeconomic variables also support the relevant economic theories including the evidence of the support for an overshooting feature of Australian commodity prices.

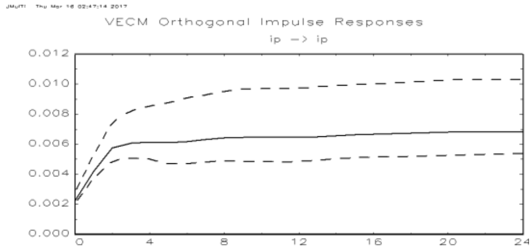
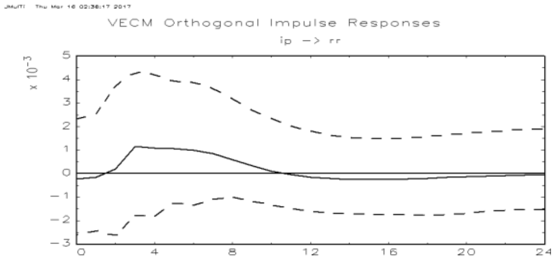
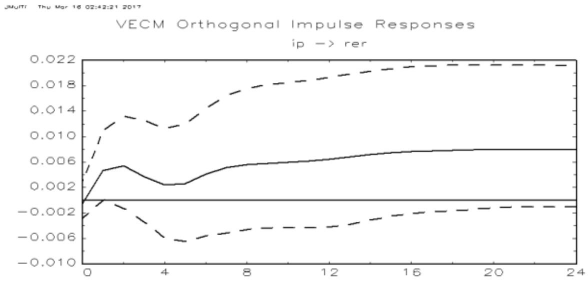
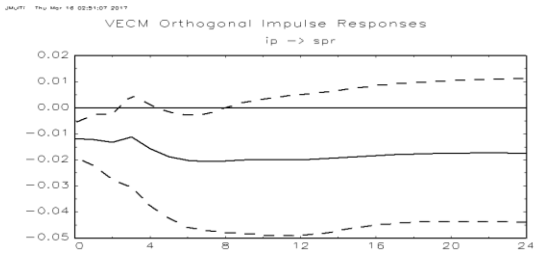
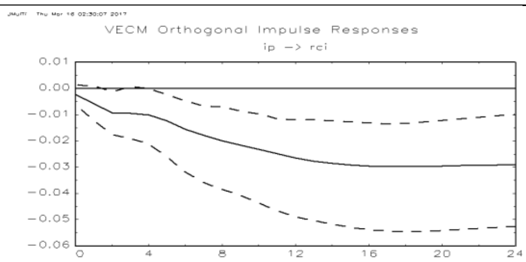
	Impulse Variable ----- > Response Variable
ip -> ip	
ip -> rr	
ip -> rer	
ip -> spr	
ip -> rci	

Figure 6.1 VECM Orthogonal Impulse Responses to One Standard Error Shocks to Industrial Production (ip).

Dashed lines: 95 per cent confidence intervals.

Figure 6.1 shows the responses of different macroeconomic variables in Australia caused by an exogenous increase in Australian economic activity. The shock from *ip* represented by *ip* to *ip* is positive and significant throughout every time horizon. This is consistent with the existing literature (e.g. Akram 2009).

The one standard deviation shock from *ip* to *rr* is initially negative, but mixed in the future. However, the overall impact is statistically insignificant. Moreover, the shock from *ip* sharply appreciates the *rer* at the beginning and then depreciates in the medium term before gradual appreciation. However, the impact is briefly significant only in the short run, although the 95 per cent confidence interval curves were close to the significant level in the long run.

The response of Australian *spr* remains statistically significant until the third month of the initial shock on *ip*. The *spr* decreases at a very slow rate and then increases a small amount. After that, the *spr* decreases sharply before it becomes almost constant after the eighth month of the initial shock. It remains statistically significant for almost a quarter of the time even in the medium-run.

However, the most significant result can be observed in the case of *the rci* of Australia. The shocks on *ip* decreases the *rci* from the beginning and it is statistically significant from the very first month of the initial shock. It decreases the *rci* sharply during the first two months and then remains almost constant for another two months before declining sharply again. Thus, the response of *rci* because of the shocks in *ip* remain statistically significant from the short to long run.

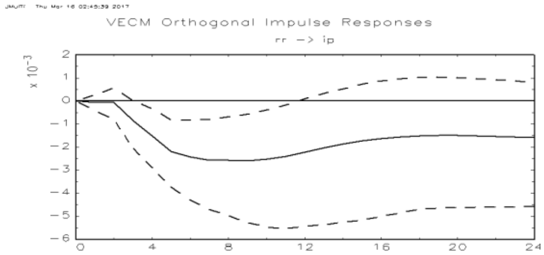
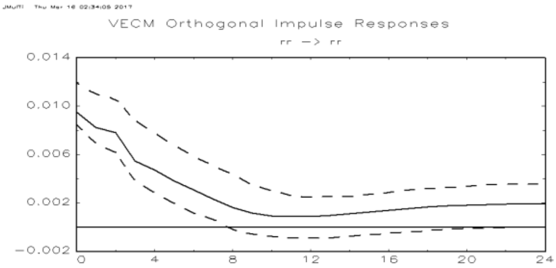
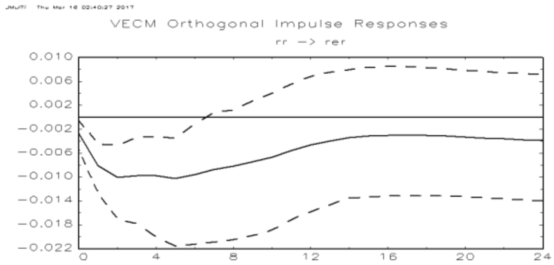
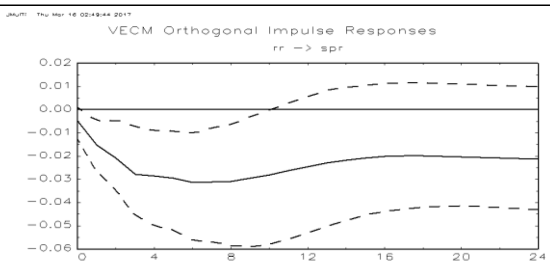
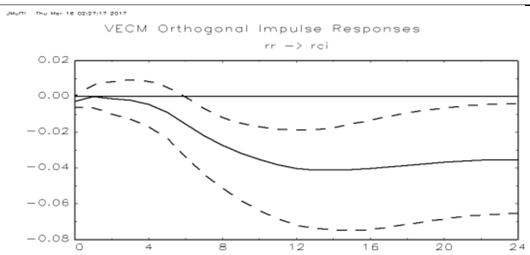
	Impulse Variable ----- > Response Variable
rr -> ip	
rr -> rr	
rr -> rer	
rr -> spr	
rr -> rci	

Figure 6.2 *VECM Orthogonal Impulse Responses to One Standard Error Shocks to Real Interest Rates (rr).*

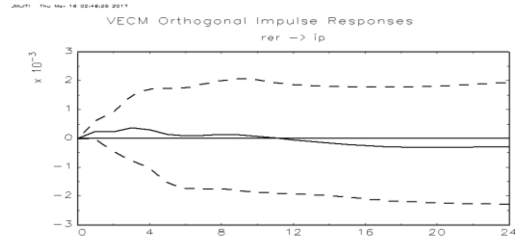
Dashed lines: 95 per cent confidence intervals.

Figure 6.2 shows that a shock to *rr* depresses economic activity, which is similar to the findings of Akram (2009). The *ip* remained non-responsive to *rr* shocks at the beginning, but dropped sharply and in statistically significant way until the second quarter and then began rising slowly. The response remained statistically significant for almost a year.

The shock on the *rr* to its own remained statistically significant for the first eight months. However, a one standard deviation shock to *rr* depreciates the *rer* for approximately two months of the initial shock and then it remains almost constant for the same period before appreciating gradually. The responses remained statistically significant for greater than two quarters of the initial shock.

The shock to *rr* decreased Australian *spr* for the very first quarter. Then, it remained almost constant until the eighth month before a gradual increase. The responses remained statistically significant for greater than three quarters of the initial shock.

An exogenous increase in *rr* affected the *rci* negatively, which supports Frankel's (1986, 2010) overshooting model of commodity price and was also consistent with the seminal work of Akram (2009). The initial shock in the *rr* lifted the *rci* a small amount before starting to decrease throughout the whole time horizon and the response remained statistically significant from the second quarter onward.

<table>
<tr><th></th><th>Impulse Variable ----- > Response Variable</th></tr>
<tr><td>rer -> ip</td><td>
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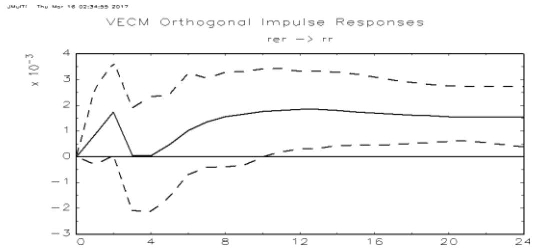
<tr><td>rer -> rr</td><td>
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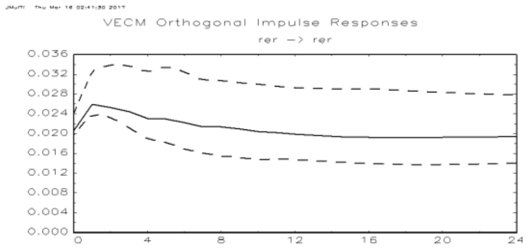
<tr><td>rer -> rer</td><td>
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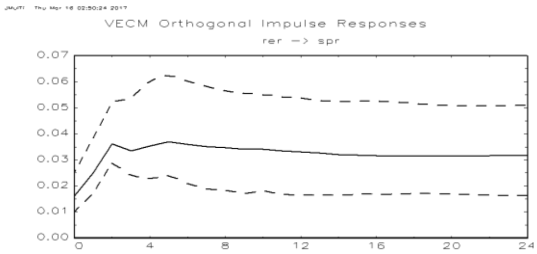
<tr><td>rer -> spr</td><td>
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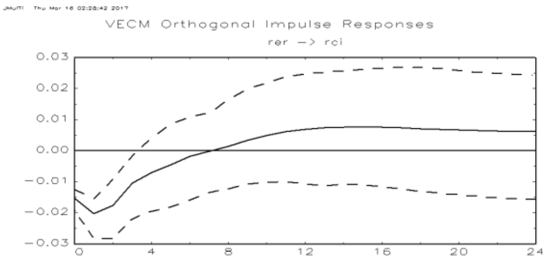
<tr><td>rer -> rci</td><td>
</td></tr>
</table>

Figure 6.3 *VECM Orthogonal Impulse Responses to One Standard Error Shocks to Real Exchange Rate (rer).*

Dashed lines: 95 per cent confidence intervals.

Figure 6.3 shows the shock from *rer* appreciation briefly increased *ip* in the short run and the response remained marginally significant only in the very first month of the initial shock. However, for the most part it remained statistically insignificant. This short-lived significance of the shock is consistent with Akram (2009).

The impulse of *rer* to *rr* is mixed. It remained brief and increased immediately after the initial shock before coming down until the first quarter. It then overshoots again after the fourth month. However, mostly the response remained statistically insignificant. On the other hand, the responses of *rer* from its own shocks remained statistically significant for the whole forecast horizon.

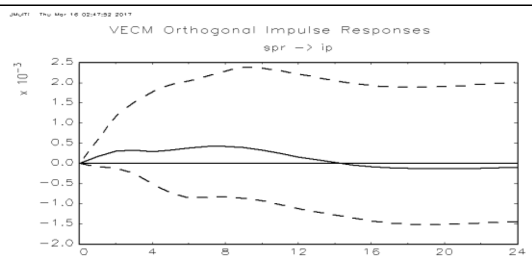
The appreciation of *rer* increased the *spr* sharply within the first two months of the initial shock. Then, the *spr* stumbled a little bit before becoming almost constant from the second quarter onwards. The response of *real resources stock price due* to the shock of *real exchange raterer* remained statistically significant for the entire forecast perspective.

An appreciation of *rer* reduced the *rci* immediately after the shock and then it increased gradually. It remained statistically significant until the first quarter from the initial shock to the *rer*. Thus, this result indicated a link from the *rer* to commodity prices, which was statistically significant in the short run. This supports the results of Groenewold and Paterson (2013) on the Australian commodity currency. They showed that the link from the exchange rate to commodity prices is stronger and more consistent than that in the opposite direction.

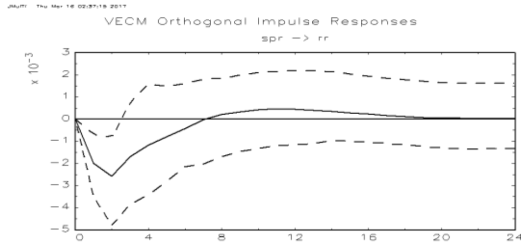
Figure 6.4 shows the responses of various macroeconomic variables because of the shock from the Australian *spr*. An exogenous increase in *spr* leads to increased economic activity for more than a year and increased the *rer* briefly just after the first month of the initial shock before dying out within an additional quarter. However, both of these responses were statistically insignificant.

A one standard deviation shock from the *spr* to *rr* reduced it sharply during the very first quarter from the initial shock. Then, the *rr* started rising rapidly until the eighth month and the response was statistically significant for approximately a quarter from the primary shock.

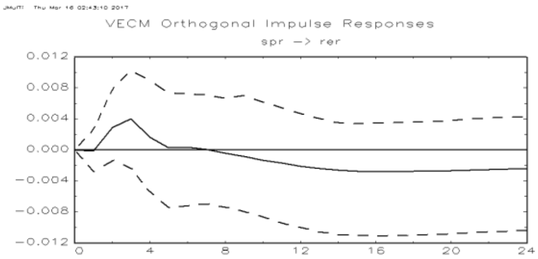
Finally, the impulse from *spr* affected the *rci* most significantly. The shock increased the *rci* from the beginning and during the first quarter it stumbled a little bit before gradual increase until one year and then the response became almost constant. This supports the results of Sarkar et al. (2015) who showed that the Australian *spr* were positively correlated to the *rci*, especially the iron ore prices.

	Impulse Variable -----> Response Variable
spr -> ip	

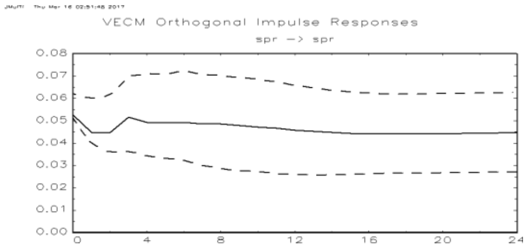
spr -> rr



spr -> rer



spr -> spr



spr -> rci

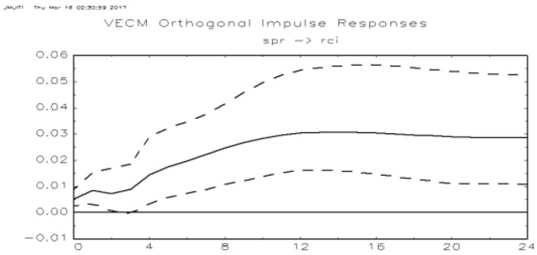


Figure 6.4 *VECM Orthogonal Impulse Responses to One Standard Error Shocks to Real Resources Stock Price Index (spr).*

Dashed lines: 95 per cent confidence intervals.

	Impulse Variable ----- > Response Variable

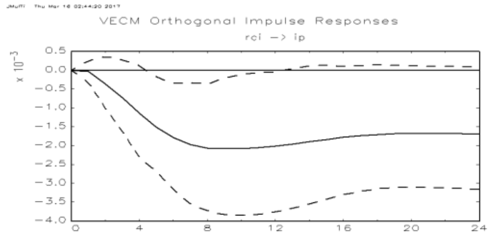
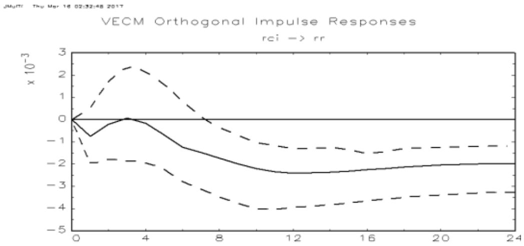
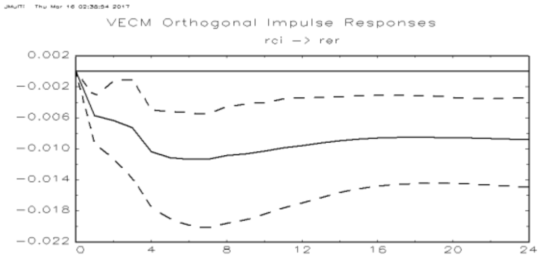
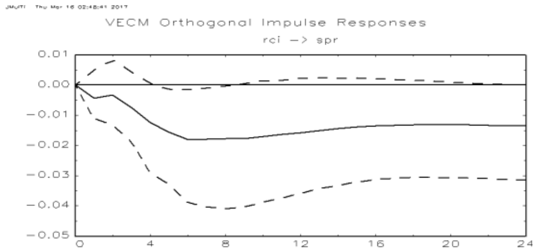
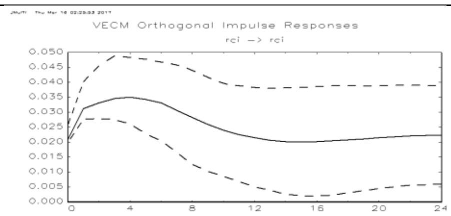
rci -> ip	
rci -> rr	
rci -> rer	
rci -> spr	
rci -> rci	

Figure 6.5 *VECM Orthogonal Impulse Responses to One Standard Error Shocks to Real Commodity Prices (rci).*

Dashed lines: 95 per cent confidence intervals.

Figure 6.5 shows an exogenous increase in *rci* can affect various macroeconomic variables. This particular shock depressed *ip* from the very first month of the initial shock and it reduced the economic activity very sharply until the third quarter. This negative response remained statistically significant from the beginning of the second quarter to greater than a year. It also remained marginally significant even in the long run. This outcome is similar to Hamilton (1983) and the important empirical work of Akram (2009).

A one standard deviation shock in the *rci* showed immediate negative response from *rr* and it continued to increase until the fourth month before decreasing again. The response of the *rr* remained statistically significant just after the second quarter of the initial shock in commodity prices. This result is consistent with Akram (2009) as well as the study on the Australian economy by Jaaskela and Smith (2011). Akram (2009) showed this characteristic as being normal for many OECD countries. Thus, it is still a argumentative matter in the literature whether monetary policy authorities under inflation targeting regimes such as in Australia react to commodity prices (Chadha, Sarno, & Valente, 2004; Clarida, Gali, & Gertler, 1998).

The shocks of *rci* on *rer* show one of the most interesting results. The initial shock depreciated the *rer* sharply at the beginning, which slowed down a small amount for approximately one quarter. Then, the *rer* depreciated again until approximately the second quarter before starting to increase gradually. However, the response of the *rer* remained statistically significant for the whole forecasting period. This result is similar to Akram (2009) who explained the possible reason for this outcome was because of the fall in *rer* in the economy.

He also suggested the influence of the terms of trade on the *rer* might explain the depreciation of it due to *rci* shock. We also saw a downward trend of Australian *rr* for our sample period, which could be one of the possible explanations of having depreciation in the *rer*. This result is similar to the outcomes from the Australian economy study by Jaaskela and Smith (2011).

The above result in the response of the *rer* because of the shock in *rci* can also be explained by the traded-nontraded productivity differentials as suggested by S. Edwards (1989). The same explanation was provided recently by Dumrongrittikul (2012) to explain the puzzle of the *rer* of China. According to that study, this effect is possible if productivity growth has positive supply effects that more than offset demand effects (income effects), which in turn exceed supply in nontraded goods. This excess supply of nontraded goods in the economy will push the price down and will cause depreciation in the *rer*. This process also appears true in the case of the Australian economy.

Figure 6.5 also shows the shock of *rci* on the *spr*. It shows negative responses from the beginning, which become statistically significant just after the fourth month and remained significant until the nine month. After that period, the decrease in *spr* remained marginally significant throughout the whole long-run period.

6.4 Forecast Error Variance Decomposition of Australian Macroeconomic Variables

In this sub-section, this study explores influences of diverse structural shocks to variations in the modelled variables. This section shows FEVD of different macroeconomic variables over diverse forecasting horizons, which are shown in months in the Tables 6.1, 6.2, 6.3, 6.4 and 6.5 as well as in Figures 6.6, 6.7, 6.8, 6.9 and 6.10.

Table 6.1 Forecast Error Variance Decomposition of Real Commodity Price (rci)

Forecast Horizon	*ip*	*rr*	*rer*	*spr*	*rci*
1	0.01	0.01	0.33	0.04	0.61
3	0.03	0	0.25	0.04	0.67
6	0.05	0.01	0.13	0.09	0.71
9	0.09	0.1	0.07	0.15	0.58
12	0.12	0.21	0.05	0.19	0.43
15	0.15	0.28	0.04	0.2	0.33
18	0.17	0.32	0.03	0.21	0.27
21	0.18	0.33	0.03	0.22	0.25
24	0.19	0.33	0.03	0.22	0.23

Table 6.1 and Figure 6.6 show that *rr*, *spr* and *ip* account for an increasing share of *rci* fluctuations over the forecast horizon. The share attributable to *rr* shocks increases to approximately 33 per cent while the share attributable to *spr* and *ip* increases to 22 per cent and 19 per cent, respectively, in the long run. In the short run, a major share of *rci* fluctuations is accounted for by *rci* shocks, which could be seen as an indication of the low explanatory power of the other shocks in the short run. However, *rer* shocks explain 33 per cent of the variation in the *rci* in the short run and, in the long run, it has very negligible influence on the variation of *rci*. This result supports the claim made by Chen et al. (2010) and Rossi (2012) that exchange rates are a better prediction of commodity prices than equity markets are.

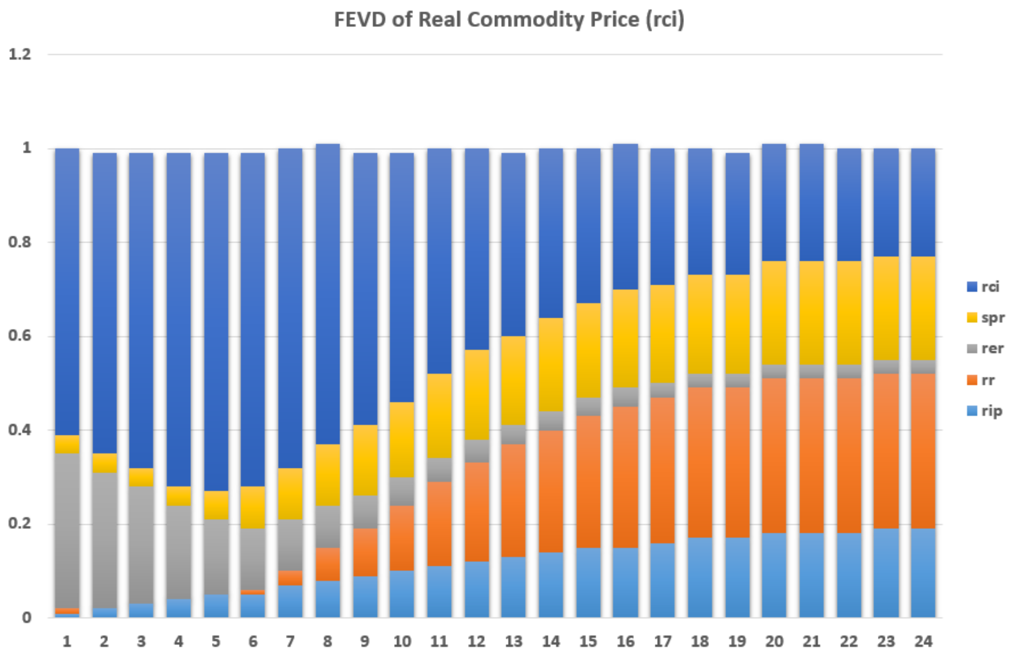


Figure 6.6 FEVD of Real Commodity Price (rci)

Table 6.2 and Figure 6.7 show that the *rer* accounts for an increasing share of *spr* fluctuations over the forecast horizon. The *rer* can explain about a quarter of the variation in the *spr* in the long run. The combined long-run shocks of *rci*, *rr* and *ip* are almost the same as the *rer* shock for explaining the fluctuation in *Spr*.

Table 6.2 Forecast Error Variance Decomposition of Real Resources Stock Price Index (spr)

Forecast Horizon	ip	rr	rer	spr	rci
1	0.04	0.01	0.08	0.87	0
3	0.05	0.07	0.22	0.67	0
6	0.05	0.13	0.24	0.57	0.02
9	0.06	0.15	0.24	0.52	0.04
12	0.07	0.15	0.24	0.51	0.04
15	0.07	0.15	0.24	0.5	0.04
18	0.07	0.14	0.24	0.5	0.04
21	0.07	0.14	0.24	0.5	0.04

24	0.07	0.13	0.24	0.5	0.04

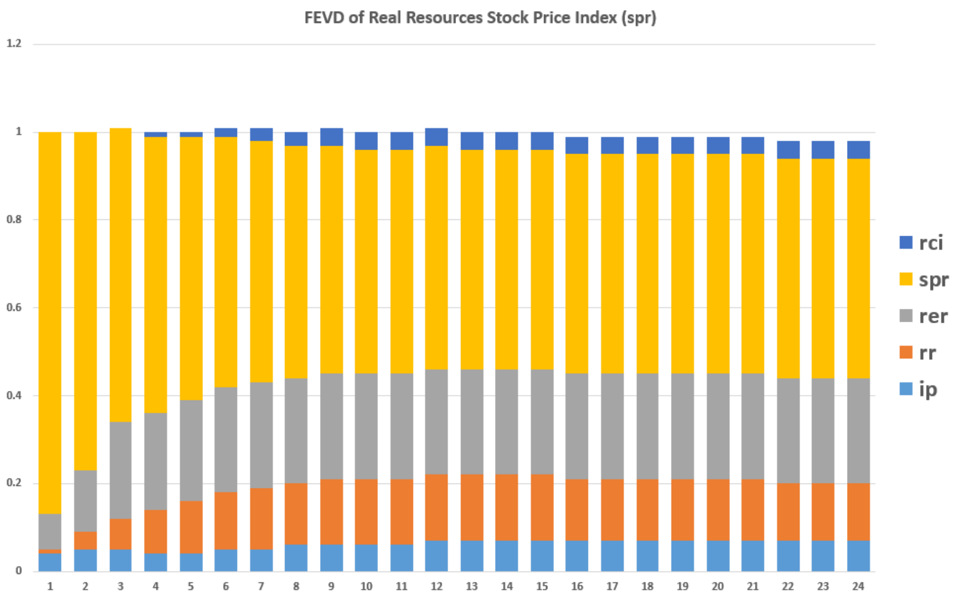


Figure 6.7 FEVD of Real Resources Stock Price Index (spr)

In the short run, the *rer* has very little influence; however, from the medium term onward it has almost constant predictability power about the variation in *spr*.

Table 6.3 Forecast Error Variance Decomposition of Real Exchange Rate (rer)

Forecast Horizon	ip	rr	rer	spr	rci
1	0	0.02	0.98	0	0
3	0.03	0.09	0.85	0	0.04
6	0.02	0.11	0.78	0.01	0.08
9	0.02	0.11	0.75	0	0.11
12	0.03	0.1	0.74	0	0.13
15	0.04	0.09	0.73	0	0.13
18	0.05	0.08	0.73	0.01	0.13
21	0.06	0.07	0.73	0.01	0.13
24	0.07	0.07	0.72	0.01	0.14

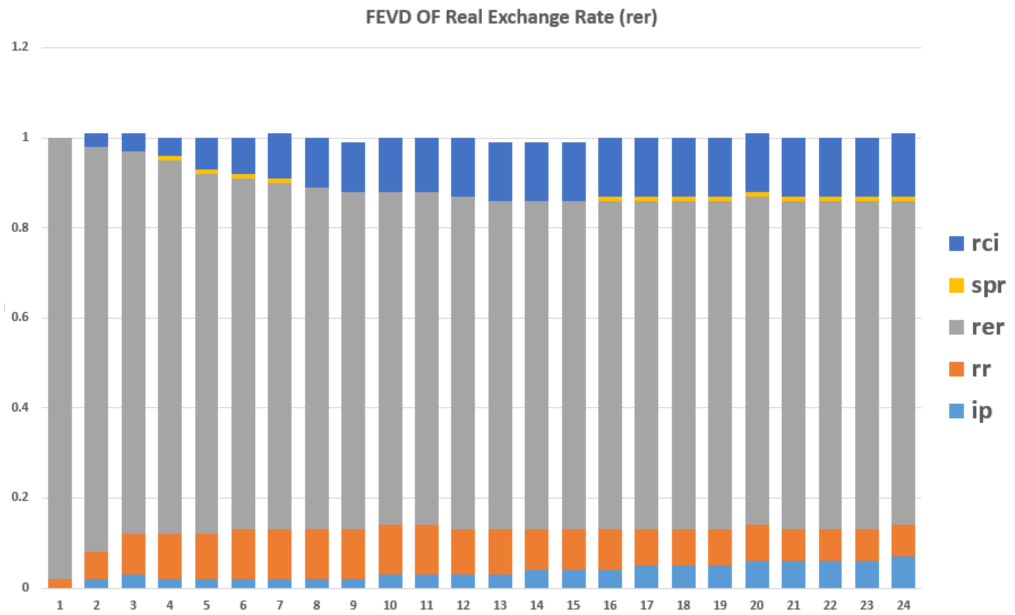


Figure 6.8 For FEVD of Real Exchange Rate (rer)

Table 6.3 and Figure 6.8show that the shocks in the *rci* can explain only about 15 per cent of the fluctuations in the *rer* in the long run. However, in the very first quarter after the shock, *rr* had more predicting power than *rci* for explaining the fluctuations in *rer*. The *spr* has almost zero explaining capability in case of a fluctuation in *rer*. Therefore, fluctuations in the *rer* are mostly due to shocks of its own and the *rr*. The other shocks do not support *rer* variations, particularly in the short run. This is consistent with the exchange rate disconnect puzzle and the empirical evidence suggesting that, apart from own shocks, *rer* mostly move in reaction to interest rate fluctuations (Alquist & Chinn, 2008).

Table 6.4 Forecast Error Variance Decomposition of Real Interest Rate (rr)

Forecast Horizon	ip	rr	rer	spr	rci
1	0	1	0	0	0
3	0	0.94	0.02	0.05	0
6	0.01	0.92	0.01	0.05	0
9	0.02	0.89	0.03	0.05	0.02
12	0.02	0.83	0.05	0.04	0.06
15	0.02	0.77	0.07	0.04	0.1
18	0.01	0.73	0.09	0.04	0.13
21	0.01	0.7	0.1	0.04	0.15
24	0.01	0.68	0.11	0.03	0.16

Table 6.4 and Figure 6.9 show that *rci* can explain the majority of the variation in *rr* in the long run. The *rer* has slightly less predicting power in explaining the variation in the *rr*. None of the variables has any significant influence in the short run. However, the *spr* has almost constant explaining power of the variation in *rr*

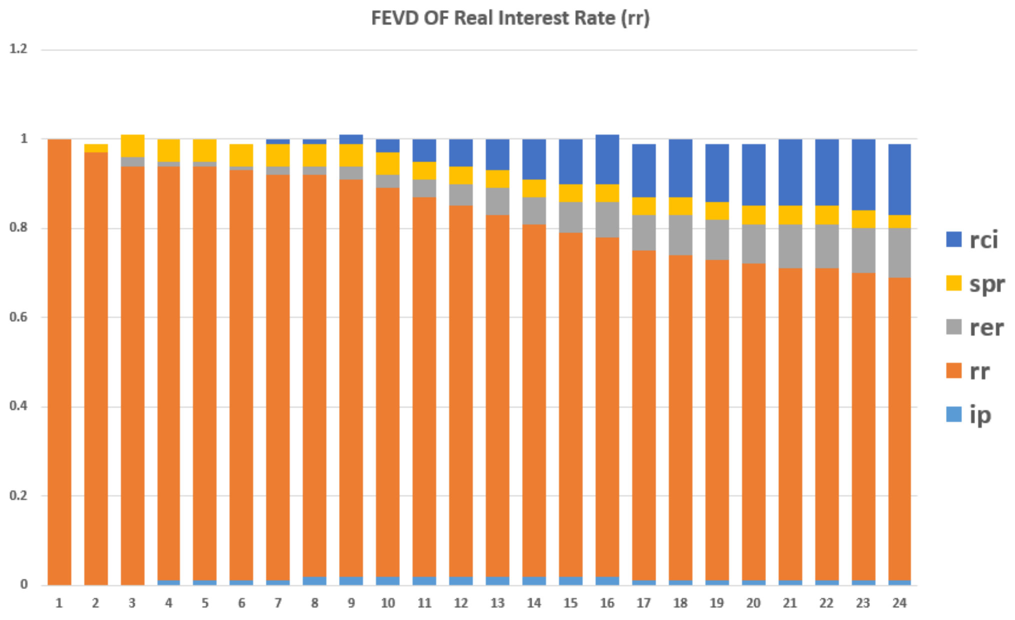


Figure 6.9 FEVD of Real Interest Rate (rr)

Table 6.5 Forecast Error Variance Decomposition of Industrial Production (ip)

Forecast Horizon	*ip*	*rr*	*rer*	*spr*	*rci*
1	1	0	0	0	0
3	0.99	0	0	0	0
6	0.93	0.04	0	0	0.02
9	0.87	0.08	0	0	0.05
12	0.84	0.09	0	0	0.06
15	0.84	0.09	0	0	0.06
18	0.85	0.08	0	0	0.06
21	0.86	0.08	0	0	0.06
24	0.86	0.07	0	0	0.06

Table 6.5 and Figure 6.10 show that *rr* and *rci* account for a very small share of *ip* fluctuations over the forecast horizon. In the long run, both the *rr* and *rci* can explain only 7 per cent and 6 per cent fluctuations in *ip*, respectively.

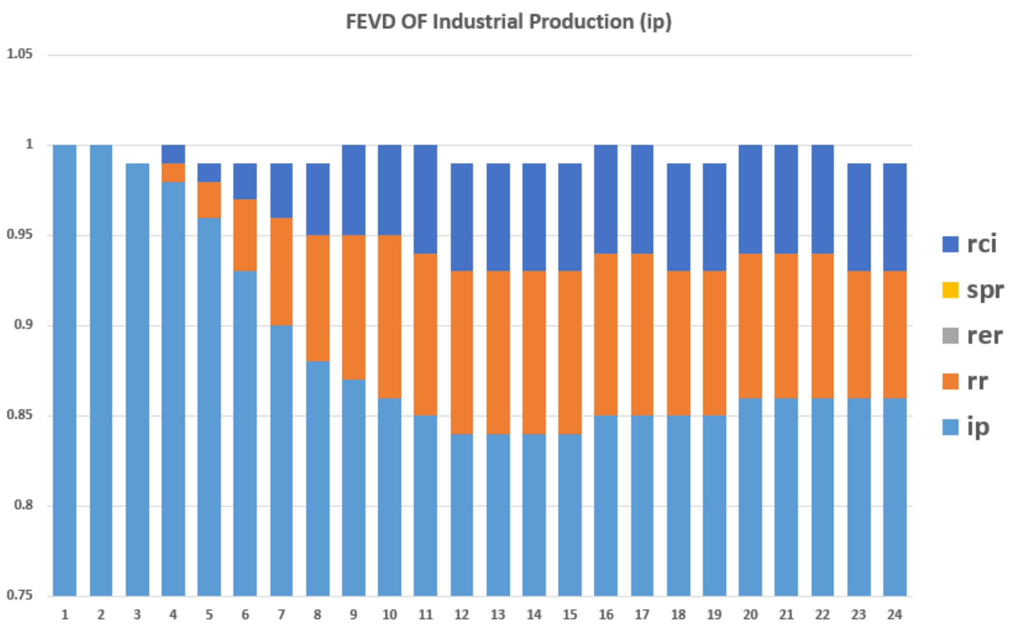


Figure 6.10 FEVD of Industrial Production (ip)

Interestingly, the *spr* and *rer* do not have any explaining power of the variation in *ip.*

6.5 Concluding Remarks

This chapter utilised orthogonalised IRFs to analyse the responses of Australian macroeconomic variables in case of a shock in Australian commodity prices. The dynamic interactions among these variables are very important for policy makers in such a commodity dependent economy. This chapter presented 95 per cent CIs obtained by bootstrapping together with the impulse responses to different shocks. FEVD results revealed the dynamic explanation ability of one variable in case of a variation in another variable in all time horizons.

Chapter 7 CONCLUSIONS, POLICY RECOMMENDATIONS AND LIMITATIONS

7.1 Introduction

This chapter concludes the investigation of a simple model to analyse the interaction among commodity price fluctuations and various relevant macroeconomic variables in open economies with particular reference to Australia, one of the major commodity exporters in the Asian region. Australia has experienced unprecedented swings in commodity prices during the twenty-first century. Hence, explanations behind these soaring commodity prices as well as investigating the reasons for falling commodity prices have become vital for policy makers. Therefore, the objectives of the present study was to investigate the empirical relationship between *rci*, *rr* and *rer* as well as *ip* and *spr*

The present study employed the Johansen (1988, 1991) cointegration and VECM approach first, followed by the Granger causality along with impulse responses and variance decomposition techniques to evaluate Australian commodity price dynamics. The econometric models of the present study utilised seasonally adjusted monthly time series data from January 2000 to December 2015 for five Australian macroeconomic variables. These variables were *rci, rr, rer, ip* and *spr*. Econometric tests revealed that 1 October 2008 was the breakpoint in the time series for most of the variables of the commodity price model in the present study, which can be justified by the influence of the GFC on the Australian economy. The present study employed a dummy variable in the model to include this structural break, which was shown to be highly significant.

The necessary adjustments of the considered variables in this commodity price model were guided by the literature, especially to construct the *rci* and Australian *rr*. Extra caution was taken as suggested by Richards and Rosewall (2010) who indicated that the introduction of the New Tax System increased the Australian CPI between June 2000 and September 2001. The impact on the September quarter in 2000 was the worst. Therefore, Richards and Rosewall (2010) suggested to view this fluctuation cautiously as a brief instability in the CPI. These swings may not essentially reflect changes to the fundamental inflationary trend. For that reason, the present study applied deflated monthly commodity price index as well as monthly interest rates by average annual inflation for only 2000 and 2001. Thereafter, the present study followed the usual process of calculating the *rci* and *rr* of Australia. This important modification assists the present study to capture more accurate interactions among relevant macroeconomic variables and the Australian *rci*.

7.2 Summary of the Findings of the Study

An empirical analysis was conducted to shed light on the recent fluctuations in Australian commodity prices. In the long run, the analysis showed a significant negative relationship between *rr* and *rci*. This result supports Frankel's (1986, 2006) view, which is resounded in Akram (2009) that the negative relationship arises if commodity prices are considered to be flexible asset prices traded in efficient markets. Impulse response results of the present study did not show any immediate responses to commodity prices because of an increase in *rr*. However, it did show a significant negative response of commodity prices after six months of the initial shock. Thus, the real commodity prices in Australia display delayed response to *rr* shocks and it displays no evidence of overshooting behaviour in Australia. This result is almost similar to the results of the relationship of commodity prices and *rr* by Akram (2009). However, the results of the present study show the importance of interest rate information to predict commodity prices in the long run. In two years' time, approximately one third of the commodity price changes will be explained by the shocks in *rr*.

The results of the present study for the shocks from the opposite direction showed support from various empirical studies such as Akram (2009) and Jaaskela and Smith (2011). These studies demonstrated significant negative response of *rr* after having shocks from Australian commodity prices in the medium term. Akram (2009) showed this characteristics as beingnormal for many OECD countries. Thus, it is still a matter of debate in the literature whether monetary policy authorities under inflation targeting regimes such as Australia react to commodity prices (Chadha et al., 2004; Clarida et al., 1998).

The results of the present study also show immediate decrease in Australian commodity prices and thereafter increases at a higher rate significantly in response to the *rer* shock, which is consistent with Frankel's (1986) overshooting model of commodity prices. This finding raises the question as to whether *rer* shocks are a significant factor of Australian macroeconomic instability as commodity export plays an important role in its economy. The present study revealed the answer to this query as being no, especially in the long run. This can be observed from the variance decomposition results of the present study, which showed no significant contribution of *rer* shocks to the variance of other macroeconomic variables in the long run. Thus, the present study confirms that *rer* are not a long-run source of shocks. This result supports the findings of Manalo, Perera, and Rees (2014) for Australia.

The interaction of these two variables from opposite directions shows more interesting results in the present study. The separate commodity-related driver of exchange rates result of the present study demonstrates that the Australian *rer* movements are not purely random, which supports the findings of Kohlscheen, Avalos, and Schrimpf (2017) for Australia. VEC-based Granger causality tests of the present study indicates strong support of causality from commodity prices to *rer* in the short run. It shows that Australian commodity prices help improve forecasting *rer* in two to four months. This finding supports the study undertaken by Bashar and Kabir (2013); however, their study found two-way Granger causality between exchange rate and commodity prices.

Impulse response results in this same regard showed the most curious results. The shocks from Australian commodity prices showed immediate significant depreciation in *rer* and the index remain depreciated significantly at all horizons, which shows the opposite result to many previous studies (Connolly & Orsmond, 2011; Minifie et al., 2013; Plumb et al., 2013; Sheehan & Gregory, 2013). However, this finding matches the theoretical explanation provided by Dumrongrittikul (2012) to explain the puzzle that while China experiences unprecedented export expansion, there is not a tendency for its *rer* to appreciate. This explanation is actually based on the S. Edwards (1989) *rer* model, which predicts that productivity growth in traded sectors compared to nontraded sectors will push the *rer* to depreciate. According to Dumrongrittikul (2012), this is possible if productivity growth has positive supply effects that more than offset demand effects (income effects), which in turn exceed supply in nontraded goods. This excess supply of nontraded goods in the economy will push the price down and will cause depreciation in *rer*. This interesting feature of the Australian economy may have helped it to remain safe from the Dutch disease effects during the commodity boom period. Moreover, to the best of the knowledge of the author, there is no other study on the Australian economy that found this interesting feature, and thus this might have significant policy implications in a commodity export dependent open economy.

The results of the present study also show that the shock to industrial production has negative effects on Australian commodity prices and these effects remain significant in all time horizons. In the long run, Australian industrial production represents almost one-fifth variation in its *rci.* Thus, this relationship can play a vital role in policy recommendation. It is also consistent with the long-run relationship shown in our study utilising Johansen (1988, 1991) cointegration. This result supports the theoretical explanation given by Ghura (1990) and the empirical findings of Akram (2009), Bloch et al. (2012) and Hamilton (1983).

The results of the present study also show the commodity price fluctuation predictive ability of the resources stock prices. It shows that the shock in resources stock price has significant positive response of Australian commodity price. This positive response is significant in all time horizons, which is also shown by the cointegration relationship in the present study. This result is consistent with Rossi (2012) who showed that stock prices can predict future commodity prices in commodity exporting countries such as Australia.

7.3 Policy Implications and Recommendations

The fluctuation in commodity prices during recent times has conveyed new momentum to ample discussion between academics and policy makers on large swings in commodity prices and their causes. The present study attempted to investigate the dynamic interactions between commodity prices and other fundamental macroeconomic variables in Australia.

Results endorse the consequence of the real interest rate for commodity prices and are stable with the view that monetary easing may lead to higher commodity prices in the medium to long term. Hence, to the extent that prices are important for stabilisation policies as suggested by Byrne (2013), monetary policy should therefore be aware of its influence on commonalities in commodity prices. Moreover, as the present study showed the evidence of having short to medium run causal link from interest rate to commodity price, our policy makers need to be aware of Frankel's (2006) view. The author suggested that the case of high interest rates decrease inventory demand, and thus reduce the demand for storable commodities or increase the supply, which depresses the commodity price. Akram (2009) suggested that policy makers consider another indirect channel, exchange rate, to observe the effect of interest rate on commodity prices. According to uncovered interest parity, the exchange rate deviation depends on the interest rate differential between an economy and its international standard. Thus, the interest rate influences the exchange rate and the exchange rate in turn has an effect on the price of commodities.

The author of the present study can echo the concern of some implications for Australian monetary policy makers suggested by Frankel (2008) as the results showed evidence in support of his model. As he advocates, commodity prices should be on the list of Australian monetary conditions indicators because real commodity prices mirror monetary ease, in particularly real interest rates. No one can directly see expected inflation, which means that no one can ever be certain what the real interest rate means. Thus, it is advantageous to have further information, including data on real commodity prices, which are thought to reveal real interest rates.

Australia has adopted an inflation targeting feature in monetary policy regimes. Frankel (2008) stated that targeting CPI was the usual choice of the central banks of these types of countries. The author of the present study proposes to change the target to an index of export prices for monetary policy of commodity exporters such as Australia.

On the exchange rate and commodity price issue, the present study observed a strong effect from the commodity prices to its real exchange rates but little effect in the opposite direction. Because the present study showed significant influences of Australian commodity prices on its real exchange rate for all time horizons, policy makers should provide attention to the factors that can influence the movements of the real exchange rate along with the commodity price. However, the present study suggests the depreciating influence of commodity prices on real exchange rates. Therefore, policy makers should take a closer look to the factors of traded-nontraded productivity differentials as suggested by S. Edwards (1989). Appropriate productivity differential policies after considering this particular relationship would help Australia tackle the economy from the Dutch disease effect during the boom or increase its ability to sell those goods in which it is internationally competitive during the bust.

The real economic activity and resources stock prices represent almost half of the commodity price volatility in the long run; therefore, Australian policy makers should allocate more importance to measuring the impacts of these variables. Policies related to influencing investors' confidence is very important to manipulate industrial productions effect on commodity prices as suggested by Ghura (1990). Policymakers should emphasis measuring the influence of commodity prices on aggregate price level to induce people's confidence and they should consider the policies suggested by Bloch et al. (2006b; 2012).

All policy suggestions given above belong to the macroeconomic field. The other segment of the policy suggestions can be related to structural measures that should try to deal with the declining trend in commodity prices. Increasing diversification in commodity exports in Australia should be considered to protect the economy in hostile situation. Enhancing production chains for each raw material via an industrialisation process would help to reduce price volatility as suggested by Bastourre et al. (2007). Other fronts of policy should be postured in building and developing infrastructure. Moreover, coordination between producer countries could be another best alternative to stabilise markets.

7.4 Limitations and Areas for Further Research

The present study has been predominantly structured on linear VAR models. Using nonlinear VAR models can investigate the interactions among Australian commodity prices and macroeconomic variables as shown in Kyrtsou (2008).

The technological change in an economy should have an important impact on a commodity exporter's total supply, and thus a significant impact on world prices for an export dominant country such as Australia. It may be worthwhile to model the commodity price after considering this important variable.

It is regularly debated that the breakdown of numerous vital international commodity agreements has added significantly to the weakness in commodity prices (Reinhart & Borensztein, 1994). Therefore, it is sensible to attempt to consider these types of breakdown of treaties or new trade agreements when modelling Australian commodity prices.

The present study has found that the commodity price volatility significantly affected the Australian *rer*. In addition, it might be possible that there are other *rer* determinants such as government consumption, terms of trade, openness of the economy, net foreign assets and *rr* differentials that influence short-run as well as long-run *rer* movements in Australia. Therefore, further research could be undertaken after considering all these variables along with productivity growth of Australian tradable and non-tradable sectors to obtain the true movement path of the *rer* in all time horizons.

Although the present study reveals that Australian *rer* is not a long-run source of macroeconomic instability, this particular finding needs to be scrutinised from various angles to provide sufficient information to policy makers for them to understand commodity price volatility. Further research should be undertaken to determine the effects of *rer* at an industry level to discover its shocks on manufacturing and other business services sectors to understand the overall commodity price dynamics.

The present study has ignored the role of the terms of trade in the commodity price model. Clements and Fry (2008) suggested that the role of the terms of trade is probably an important element in the story linking the endogenous determination of both exchange rates and commodity prices. Future research should explore this issue further.

The present study has also ignored the role of inventories on commodity prices. Further research should be undertaken by considering all commodities as storable and non-storable as well as stressing the role of flows versus stocks. A cautious empirical treatment of this concern is important.

7.5 Concluding Remarks

Based on results from the present study, various fundamental macroeconomic variables show expected long-run relationships with Australian commodity price. Johansen's (1988, 1991) cointegration technique was applied first to test the proposed commodity price model. After considering significant structural break at the peak of the GFC, the dynamic interactions between commodity prices and other macroeconomic variables show mixed evidence of their relations expected by Frankel's (1986; 2006) overshooting model. The model in the present study also showed that if all these variables deviate from their long-run equilibrium because of shocks, then they congregate to equilibrium level significantly. The VECM shows their significant speed of convergence to its equilibrium. VECM Granger causality is considered for this study willingly to avoid misleading results from a VAR-based Granger causality (Enders, 2008; C. W. Granger, 1988; Parsva & Lean, 2011). This shows the commodity price predictability power of interest rate as expected by Frankel (2006). Similar negative relationships among these two variables because of the shock in interest rate was discovered in our VECM orthogonal impulse response result.

The commodity price model in the present study does not show significant long-run relationships between Australian commodity prices and *rer*. Akram (2009) explained in his empirical analysis that to control certain macroeconomic variables such as interest rates and economic activity can help determine the true connection between commodity price and real exchange rate; therefore, the present study conducted analysis of IRFs. It revealed significant depreciating effects on the *rer* because of shocks in commodity prices in all time horizons. This finding suggests policy makers give more attention to productivity differential of tradable and non-tradable sector of Australia as recommended by S. Edwards (1989).

FEVD results of the present study showed that *rr*, *ip* and *spr* explained two-thirds of the volatility of Australian commodity price in the long run. The impact of the *rr* is the strongest among these variables. Thus, Australian policy makers should consider the interaction of these variables before suggesting appropriate monetary policy for Australia.

APPENDIX: SUPPLEMENTARY TABLES AND BASIC DATA

Appendix 01:

Changes in Index of Commodity Price Weights and Commodity Exports (All items index; per cent)

	ICP weights[a]		Change[b] 2008/09 to 2010/11–2011/12	
	Existing (2008/09)	Updated (2010/11–2011/12)	Price[c]	Volume[d]
Rural commodities[e]	**10.3**	**10.9**	**7**	**19**
Wool	1.1	1.4	46	–4
Beef and veal	3.2	2.5	–3	–2
Wheat	3.2	3.2	–18	50
Barley	0.6	0.7	–10	44
Canola	0.4	0.6	4	95
Sugar	0.7	0.7	49	14
Cotton	0.3	1.1	54	189
Milk powder	0.8	na	4	–9
Lamb and mutton	na	0.8	20	–14
Base metals[e]	**6.8**	**5.8**	**7**	**–7**
Aluminium	3.4	2.4	–9	–2
Lead	0.6	0.5	16	–16
Copper	1.8	2.1	29	8
Zinc	0.6	0.5	13	–4
Nickel	0.4	0.3	22	–19
Bulk commodities[e]	**56.5**	**57.5**	**–5**	**22**
Iron ore	21.8	32.7	29	33
Metallurgical coal	23.3	16.4	–28	14
Thermal coal	11.4	8.4	–22	10
Other resources[e]	**26.4**	**25.8**	**9**	**0**
LNG[e]	6.5	6.0	–5	16
Crude oil	5.3	6.0	16	11
Alumina	3.8	2.9	–13	–2
Gold	10.8	8.0	27	–31
Copper ore	na	2.8	48	–1
Total[e]	**100.0**	**100.0**	**0**	**14**

(a) Commodity weights may not sum to subindex weights due to rounding
(b) Changes in prices and volumes do not necessarily accord with changes in export values due to compositional differences
(c) Based on movements of the price measures used for the ICP; A$ terms; average export prices for the bulk commodities
(d) Based on tonnages data from the ABS and Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)
(e) Changes in volumes are calculated as changes in export values divided by changes in the price index for the commodities included in the updated ICP

Source: Robinson and Wang (2013).

Appendix 02:

Sources of the Price Measures Utilised in the Commodity Price Index

Commodity	Sources	Data description
Rural commodities		
Wool	Australian Wool Exchange	National Price
Beef and veal	MLA	Average of beef prices to the United States and Japan
Wheat	ABARES	US Gulf price; HRW No 1
Barley	Confidential	
Canola	Bloomberg	Canada Par Region
Sugar	Bloomberg	Sugar No.11 ICE
Cotton	Bloomberg	Cotlook A Index
Lamb	MLA	Eastern States Trade Lamb Indicator
Base metals		
Aluminium	Bloomberg	London Metal Exchange (LME) spot price
Lead	Bloomberg	LME spot price
Copper	Bloomberg	LME spot price
Zinc	Bloomberg	LME spot price
Nickel	Bloomberg	LME spot price
Bulk commodities		
Iron ore	ABS	Average export price
	Bloomberg	Spot price – 62 per cent Fe Chinese landed price, adjusted for freight
Metallurgical coal	ABS	Average export price
	Energy Publishing	Spot price – Queensland premium hard metallurgical coal
Thermal coal	ABS	Average export price
	Thomson Reuters	Spot price – Newcastle thermal coal
Other resources		
LNG	Confidential	
Crude oil	Bloomberg	European Brent Blend
Alumina	ABS	Average export price
Gold	Bloomberg	Spot price
Copper ore	ABS	Average export price

Source: Robinson and Wang (2013)

REFERENCES

Adam, C. S., & Bevan, D. L. (2006). Aid and the supply side: Public investment, export performance, and Dutch disease in low-income countries. *World Bank Economic Review, 20*(2), 261–290.

Agung, I. G. N. (2009). *Time series data analysis using EViews*. Singapore: John Wiley & Sons (Asia) Pty Ltd.

Ai, C., Chatrath, A., & Song, F. (2006). On the co-movement of Commodity prices. *American Journal of Agricultural Economics, 88*(3), 574–588.

Akram, Q. F. (2004). Oil prices and exchange rates: Norwegian evidence. *Econometrics Journal, 7*, 476–504.

Akram, Q. F. (2009). Commodity prices, interest rates and the dollar. *Energy Economics, 31*, 838–851.

Ali, M. L., & Rahman, S. F. (2013). Investigation of directional and functional relationships of Australian dollar exchange rate, steam coal export, and steam coal price. *Journal of Aisa-Pacific Business, 14*(3), 202–222.

Alquist, R., & Chinn, M. D. (2008). Conventional and unconventional approaches to exchange rate modelling and assessment. *International Journal of Finance and Economics, 13*, 2–13.

Andersen, T. G., Bollerslev, T., Diebold, F. X., & Vega, C. (2003). Micro effects of macro announcements: Real-time price discovery in foreign exchange. *American Economic Review, 93*, 38–62.

Arango, L. E., Arias, F., & Florez, A. (2012). Determinants of commodity prices. *Applied Economics, 44*(2), 135–145.

Ardeni, G., & Wright, B. (1992). The Prebisch-Singer hypothesis: A reappraisal independent of stationarity hypothesis. *Economic Journal*, *102*, 803–812.

Arezki, R., Hadri, K., Loungani, P., & Rao, Y. (2014). Testing the Prebisch-Singer hypothesis since 1650: Evidence from panel techniques that allow for multiple breaks. *Journal of International Money and Finance, 42*, 208–223.

Aruman, S., & Dungey, M. (2003). A Perspective on modelling the Australian real trade weighted index since the float. *Australian Economic Papers, 42*(1), 56–76.

Avendano, R., Reisen, H., & Santiso, J. (2008). The macro management of commodity booms: Africa and Latin America's response to Asian demand. *OECD Development Centre Working Paper No. 270*. Retrieved from http://www.oecd-ilibrary.org/development/the-macro-management-of-commodity-booms_240356635678

Awokuse, T. O., & Yang, J. (2003). The informational role of commodity Prices in formulating monetarypolicy: A reexamination. *Economics Letters, 79*, 219–224.

Baffes, J., & Savescu, C. (2014). Monetary conditions and metalprices. *Applied Economics Letters, 21*(7), 447–452.

Balagtas, J. V., & Holt, M. T. (2009). The commodity terms of trade, unit roots and nonlinear alternatives: a smooth transition approach. *American Journal of Agricultural Economics, 91*, 87–105.

Balassa, B. (1964). The purchasing power parity doctrine: A reappraisal. *The Journal Of Political Economy,* (72), 231–238.

Banerjee, A., Dolado, J., Galbraith, J. W., & Hendry, D. F. (1993). *Co-integration, error-correction and the econometric analysis of non-stationary data*. Oxford: Oxford University Press.

Banerjee, A., Lumsdaine, R. L., & Stock, J. H. (1992). Recursive and sequential tests of the unit-root and trend-break hypotheses: Theory and international evidence. *Journal of Business & Economic Statistics, 10*, 271–287.

Barnhart, S. W. (1989). The effects of macroeconomic announcements on commodity prices. *American Journal of Agricultural Economics, 17*(2), 389–403.

Barsky, R., & Kilian, L. (2004). Oil and the macroeconomy since the 1970s. *Journal of Economic Perspectives, 18*(4), 115–134.

Barsky, R. B., & Kilian, L. (2002). Do we really know that oil caused the great stagflation? A monetary alternative. *NBER Macroeconomics Annual 2001, MIT Press, 16*, 137–198.

Bashar, O. K. M. R., & Kabir, S. H. (2013). Relationship between commodity prices and exchange rate in light of global financial crisis: Evidence from Australia. *International Journal of Trade, Economics and Finance, 4*(5), 265–269.

Bastourre, D., Carrera, J., & Ibarlucia, J. (2007). Commodity prices in Argentina: What does move the wind? *Buenos Aires, Banco Central de la República Argentina.*

Batten, J. A., Ciner, C., & Lucey, B. M. (2010). The macroeconomic determinants of volatility in precious metals markets. *Resources Policy, 35*, 65–71.

Baxter, M., & King, R. G. (1999). Measuring business cycles: Approximate band-pass filters for economic time series. *The Review of Economics and Statistics, 81*(4), 557–593.

Beck, S. (1993). A rational expectations model of time varying risk premia in commodities futures markets: theory and evidence. *International Economic Review, 34,* 149–168.

Beck, S. (2001). Autoregressive conditional heteroscedasticity in commodity spot prices. *Journal of Applied Econometrics, 16*, 115–132.

Beenstock, M. (1988). An econometric investigation of north-south interdependence. In David Currie & D. Vines (Eds.), *Macroeconomic Interactions Between North and South* (pp. 32–62). New York: Cambridge University Press.

Belke, A., Orth, W., & Setzer, R. (2010). Liquidity and the dynamic pattern of asset price adjustment: Aglobal view. *Journal of Banking and Finance, 34*, 1933–1945.

Belke, A. H., Bordon, I. G., & Hendricks, T. W. (2014). Monetary policy, global liquidity and commodity price dynamics. *North American Journal of Economics and Finance, 28*, 1–16.

Benkwitz, A., & Lutkepohl, H. (2001). Comparison of bootstrap confidence intervals for impulse responses of German monetary systems. *Macroeconomic Dynamics, 5,* 81–100.

Bernanke, B., & Gertler, M. (2000). Monetary policy and asset price volatility. *National Bureau of Economic Research Working Paper*. Retrieved from http://www.nber.org/papers/w7559

Bernanke, B. S., Boivin, J., & Eliasz, P. (2005). Measuring the effects of monetary policy: A factor-augmented vector autoregressive (FVAR) approach. *Quarterly Journal of Economics, 120*, 387–422.

Bernanke, B. S., & Mihov, I. (1998). The liquidity effect and long-run neutrality. *Camegie-Rochester Conference Series on Public Policy*, *49*, 149 –194

Bhar, R. (2015). Commodity export prices and exchange rate: An Australian perspective. *International Journal of Economics and Finance, 7*(1), 1–13.

Bhar, R., & Hamori, S. (2008). Information content of commodity futures Prices for monetary policy. *Economic Modelling, 25*, 274–283.

Bhattacharyya, S., & Williamson, J. G. (2011). Commodity price shocks and the Australian economy since Federation. *Australian Economic History Review, 51*(2), 150–176.

Bhattacharyya, S., & Williamson, J. G. (2016). Distributional consequences of commodity price shocks: Australia over a century. *Review of Income and Wealth*, *62*(2), 223–244.

Bleaney, M. (1996). Primary commodity prices and the real exchange rate: The case of Australia 1900–91. *The Journal of International Trade & Economic Development, 5*(1), 35–43.

Bleaney, M., & Greenaway, D. (1993). Long-runtrends in the relative price of primary commodities and in the terms of trade in developing countries. *Oxford Economic Papers, 45*(3), 349–363.

Bleaney, M., & Greenaway, D. (2001). The impact of terms of trade and real exchange rate volatility on investment and growth in sub-Saharan Africa. *Journal of Development Economics, 65*, 491–500.

Blinder, A. S. (1982). The anatomy of double digit inflation in the 1970s. In R. Hall (Ed.), *Inflation: Causes and Effects*. Chicago: University of Chicago Press.

Bloch, H. (1992). Pricing in Australian manufacturing. *Economic Record, 68*, 365–376.

Bloch, H., Dockery, A. M., & Sapsford, D. (2006a). Commodity prices and the dynamics ofinflation in commodity-exporting nations: Evidence from Australia and Canada. *Economic Record*, *82*, 97–109.

Bloch, H., Dockery, A. M., & Sapsford, D. (2006b). Commodity prices, wages, and U.S. inflation in the twentieth century. *Journal of Post Keynesian Economics*, *26*(3), 523–545.

Bloch, H., Fraser, P., & MacDonald, G. (2012). Commodity prices: how important are real and nominal shocks? *Applied Economics*, *44*, 2347–2357.

Bloch, H., & Olive, M. (1999). Cyclical and competitive influences on pricing in Australian manufacturing. *Economic Record, 75*, 268–279.

Bloch, H., & Sapsford, D. (1997). Some estimates of Prebisch and Singer effects on theterms of trade between primary producers and manufacturers. *World Development, 25*, 1873–1884.

Bloch, H., & Sapsford, D. (2004). Post-war movements in prices of primary products and manufactured goods. In L. R. Wray & M. Forstater (Eds.), *Contemporary Post-Keynesian Analysis* (pp. 87–203). Cheltenham: Edward Elgar.

Borozan, D. (2011). Granger causality and innovation accounting analysis of the monetary transmission mechanism in Croatia. *Post-Communist Economies*, *23*(4), 517–537.

Brahmasrene, T., Huang, J.-C., & Sissoko, Y. (2014). Crude oil prices and exchange rates: Causality, variance decomposition and impulse response. *Energy Economics, 44*, 407–412.

Brana, S., Djigbenou, M. L., & Prat, S. (2012). Global excess l;iquidity and asset prices in emerging countries: A PVAR approach. *Emerging Markets Review, 13*, 256–267.

Brooks, C. (2002). *Introductory econometrics for finance*. Cambridge: Cambridge University Press.

Bruno, M., & Sachs, J. D. (1985). *Economics of worldwide stagflation*. Cambridge: Harvard University Press.

Bunzel, H., & Vogelsang, T. (2005). Powerful trend function tests that are robust to strong serial correlation with an application to the Prebisch-Singer hypothesis. *Journal of Business and Economic Statistics, 23,* 381–394.

Buyuksahin, B., Haigh, M. S., & Robe, M. A. (2010). Commodities and equities: Ever a 'market of one'? *Journal of Alternative Investments, 12*(3), 76–95.

Byrne, J. P., Fazio, G., & Fiess, N. (2013). Primary commodity prices: Co-movements, common factors and fundamentals. *Journal of Development Economics, 101*, 16–26.

Caballero, R., Farhi, E., & Gourinchas, P. (2008a). An equilibrium model of global imbalance and low interest rates. *American Economic Review, 98*, 358–393.

Caballero, R., Farhi, E., & Gourinchas, P. (2008b). Commodity prices and global imbalances. *Brookings Papers on Economic Activity, 2*, 1–55.

Cabrales, C. A., Castro, J. C. G., & Joya, J. O. (2014). The effect of monetary policy on commodity prices: Disentangling the evidence for individual prices. *Hindawi Publishing Corporation, Economics Research International.*

Cagliarini, A., & McKibbin, W. (2009). Global relative price shocks: The role of macroeconomic policies. *RBA Research Discussion Paper*. Retrieved from http://www.rba.gov.au/publications/confs/2009/pdf/conf-vol-2009.pdf#page=310

Cai, J., Cheung, Y. L., & Wong, M. C. S. (2001). What moves the gold market? *Journal of Futures Markets, 21*(3), 257–278.

Calvo, G. (2008). Exploding commodity prices, lax monetary policy, and sovereign wealth funds. *Vox, June 20*. Retrieved from http://www.voxeu.org/index.php?q=node/1244#fn5

Carr, T., Fernandes, K., & Rosewall, T. (2017). The recent economic performance of the States. *RBA Bulletin* (March Quarter), 1–12.

Cashin, P., Cespedes, L. F., & Sahay, R. (2004). Commodity currencies and the real exchange rate. *Journal of Development Economics, 75*, 239–268.

Cashin, P., Liang, H., & McDermott, J. C. (2000). How persistent are shocks to world commodity prices? *IMF Staff Papers, 47*, 177–217.

Cashin, P., & McDermott, C. J. (2002). The long-run behavior of commodity prices: Small trends and big variability. *IMF Staff Papers, 49*(2), 175–199.

Cashin, P., McDermott, J. C., & Scott, A. (2002). Booms and slumps in world commodity prices. *Journal of Development Economics, 69*, 277–296.

Chadha, J., Sarno, L., & Valente, G. (2004). Monetary policy rules, asset prices and exchange rates. *International Monetary Fund Staff Papers, 51*, 529–552.

Chambers, R. G., & Just, R. E. (1979). A critique of exchange rate treatment in agricultural trade models. *American Journal of Agricultural Economics, 61*, 249–257.

Chen, Y. C., & Rogoff, K. (2003). Commodity currencies. *Journal of International Economics, 60*, 133–160.

Chen, Y. C., Rogoff, K., & Rossi, B. (2010). Can exchange rates forecast commodity prices? *Quarterly Journal of Economics, 125*(3), 1145–1194.

Cheung, C., & Morin, S. (2007). The impact of emerging Asia on commodity prices. *Bank of Canada, Working Paper*. Retrieved from http://www.bankofcanada.ca/wp-content/uploads/2010/02/wp07-55.pdf

Chevallier, J., & Ielpo, F. (2013). *The economics of commodity markets*. John Wiley & Sons.

Chowdhury, M. B. (1998). *Resources booms and macroeconomic adjustment: Papua New Guinea.* (Doctor of Philosophy), The Australian National University, Canberra.

Christiano, L., Eichenbaum, M., & Evans, C. L. (1999). Chapter 2: Monetary policy shocks: What have we learned and to what end? In J. B. Taylor & M. Woodford (Eds.), *Hand-Book of Macroeconomics* (Vol. 1, Part A, pp. 65–148). Elsevier.

Christie-David, R., Chaudhry, M., & Koch, T. W. (2000). Do macroeconomics news releases affect gold and silver prices? *Journal of Economics and Business, 52*(5), 405–421.

Clarida, R., Gali, J., & Gertler, M. (1998). Monetary policy rules in practice. *European Economic Review, 42*, 1033–1067.

Clements, K. C., & Fry, R. (2008). Commodity currencies and currency commodities. *Resources Policy, 33*, 55–73.

Cody, B. J., & Mills, L. O. (1991). The role of commodity prices in formulating monetary policy. *Review of Economics and Statistics, 73*(2), 358–365.

Collier, P., & Goderis, B. (2007). Commodity prices and growth: Reconciling a conundrum. *Department of Economics, University of Oxford.* Retrieved from http://users. ox. ac. uk/econpco/research/pdfs/CommodityPricesAndGrowth. pdf

Connolly, E., & Orsmond, D. (2011). *The miningindustry: From bust to boom*. Economic Analysis Department, Reserve Bank of Australia.

Cook, L. H., & Seiper, E. (1984). Minerals sector growth and structural change. In L. H. Cook & M. G. Porter (Eds.), *The minerals sector and the Australian economy; Special study No. 6* (pp. 85–127). Sydney: Centre of Policy Studies, Monash University.

Corden, W. M. (1984). Booming sector and Dutch disease economics: Survey and consolidation. *Oxford Economic Papers, 36*(3), 359–380.

Corden, W. M., & Neary, J. P. (1982). Booming sector and de-industrialisation in a small open economy. *Economic Journal, 92*, 825–848.

Creti, A., Joets, M., & Mignon, V. (2013). On the links between stocks and commodity markets' volatility. *Energy Economics, 37*, 16–28.

Cuddington, J. T. (1992). Long-run trends in 26 primary commodity prices: a disaggregated look at the Prebisch-Singer hypothesis. *Journal of Development Economics, 39*, 207–227.

Cuddington, J. T., & Jerrett, D. (2008). Super cycles in real metals prices? *IMF Staff Papers, 55*(4), 541–565.

Cuddington, J. T., & Urzua, C. M. (1989). Trends and cycles in the net barter terms of trade: A new approach. *Economic Journal, 99*, 426–442.

Cunado, J., & De-Gracia, F. P. (2003). Do oil price shocks matter? Evidence for some European countries. *Energy Economics, 25*(2), 137–154.

Datastream. (2016a). *Thomson Reuters Datastream 5.1*. Retrieved from Subscription Service

Datastream. (2016b). *Thomson Reuters Datastream 5.1*. Retrieved from Subscription Service

Daude, C., Melguizo, A., & Neut, A. (2011). Fiscal policy in Latin America: countercyclical and sustainable? *Economics: The Open-Access, Open-Assessment E-Journal*. Retrieved from http://dx.doi.org/10.5018/economics-ejournal.ja.2011-14

Deaton, A. (1999). Commodity prices and growth in Africa. *Journal of Economic Perspectives, 13*(3), 23–40.

Deaton, A., & Laroque, G. (1992). On the behavior of commodity prices. *Review of Economic Studies, 59*, 1–23.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association, 74*, 427–431.

Dionne, G., Gauthier, G., Hammami, K., Maurice, M., & Simonato, J. G. (2011). A reduced form model of default spreads with Markov-switching macroeconomic factors. *Journal of Banking and Finance, 35*, 1984–2000.

Dooley, M. P., Isard, P., & Taylor, M. P. (1995). Exchange rates, country-specific shocks, and gold. *Applied Financial Economics, 5*, 121–129.

Dornbusch, R. (1976). Expectations and exchange rate dynamics. *Journal of Political Economy, 84*, 1161–1176.

Dornbusch, R. (1985). Policy and performance links between LDC debtors and industrial nations. *Brookings Papers on Economic Activity, 1985*(2), 303–368.

Downes, P., Hanslow, K., & Tulip, P. (2014). The effect of the mining boom on the Australian economy. *Research Discussion Paper; Reserve Bank of Australia.* Retrieved from http://www.rba.gov.au/publications/rdp/2014/pdf/rdp2014-08.pdf

Dumrongrittikul, T. (2012). Real exchange rate movements in developed and developing economies: A reinterpretation of the Balassa-Samuelson hypothesis. *Economic Record, 88*(283), 537–553.

Edison, H., Cashin, P., & Liang, H. (2003). Foreign exchange intervention and the Australian dollar: Has it mattered? *IMF Working Paper; WP/03/99*. Retrieved from https://www.imf.org/external/pubs/ft/wp/2003/wp0399.pdf

Edwards, J. (2014). *Beyond the boom, Lowy Institute paper*. Melbourne: Penguin Special, Penguin Australia.

Edwards, S. (1989). Real exchange rates, devaluation, and adjustment. *Cambridge, Mass:MIT Press*.

Ehrmann, M., & Fratzscher, M. (2005). Exchangerates and fundamentals: New evidence from real-time data. *Journal of International Money and Finance, 24*, 317–341.

Eichenbaum, M. (1983). A Rrtional expectations equilibrium model of inventories of finished goods. *Journal of Monetary Economics, 12*, 259–277.

Eichenbaum, M., & Evans, C. (1995). Some evidence on the effects of monetary policy on real exchange rates. *Quarterly Journal Economics, 110*, 975–1009.

Elliott, G., Rothenberg, T. J., & Stock, J. H. (1996). Efficient tests for an autoregressive unit root. *Econometrica, 64*, 813–836.

Ellis, L. (2001). *Measuring the real exchange rate: Pitfalls and practicalities*. Retrieved from https://ideas.repec.org/p/rba/rbardp/rdp2001-04.html

Enders, W. (2008). *Applied econometric time seeries*. John Wiley & Sons.

Engle, R., & Granger, C. (1987). Cointegration and error correction representation, estimation and testing. *Econometrica, 55*, 251–267.

EViews7. (2009). *EViews 7 User's Guide II* (Vol. 2). USA: Quantitative Micro Software, LLC.

EViews9.5. (2016). EViews9.5 User's Guide: Unit Root Tests With A Breakpoint. Retrieved from http://www.eviews.com/help/helpintro.html#page/EViews%25209%2520Help%2Fadvtimeser.049.3.html%23

Favero, C. A. (2001). *Applied macroeconometrics*. Oxford: Oxford University Press.

Fazle, R. (2011). *Remittances and the Dutch disease: Macroeconomic consequences in Bangladesh.* (Master in Commerce (Honours)), University of Western Sydney, Parramatta, NSW. Retrieved from http://handle.uws.edu.au:8081/1959.7/515513

Ferraro, D., Rogoff, K., & Rossi, B. (2015). Can oil prices forecast exchange rates? An empirical analysis of the relationship between commodity prices and exchange rates. *Journal of International Money and Finance, 54*, 116–141.

Financial, M. H. (2015). Equity S&P/ASX 200 Resources (AUD), S&P Dow Jones Indices. Retrieved from http://au.spindices.com/indices/equity/sp-asx-200-resources

Flood, R. P., & Rose, A. K. (1999). Understanding exchange rate volatility without the contrivance of macroeconomics. *The Economic Journal, 109*(459), 660–672.

Flores, R. G., & Szafarz, A. (1996). An enlarged definition of cointegration. *Economics Letters, 50*, 193–195.

Florez, L. A. (2010). Monetary policy and commodity prices: An endogenous analysis using an SVAR approach. *Banco de la Republica, 610*.

Frankel, J. (1984). Commodity prices and money: Lessons from international finance. *American Journal of Agricultural Economics, 66*(5), 560–566.

Frankel, J. (1986). Expectations and commodity price dynamics: The overshooting model. *American Journal of Agricultural Economics, 68*(2), 344–348.

Frankel, J. (2006). The effect of monetary policy on real commodity prices (No. w12713). *National Bureau of Economic Research*. Retrieved from http://www.nber.org/papers/w12713

Frankel, J. (2008). An explanation for soaring commodity prices. *Vox*. Retrieved from http://www.voxeu.org/index.php?q=node/1002

Frankel, J. (2008). The effect of monetary policy on real commodity prices. In John Campbell (Ed.), *Asset Prices and Monetary Policy* (pp. 291–327). University of Chicago Press.

Frankel, J. (2014). Effects of speculation and interest rates in a "carry trade" model of commodity prices. *Journal of International Money and Finance, 42*, 88–112.

Frankel, J. (2014). Why so many commodity prices are down in the US, yet up in Europe. *VOX*. Retrieved from http://voxeu.org/article/commodity-prices-down-dollars-euros

Frankel, J., & Hardouvelis, G. (1985). Commodity prices, money surprises and Fed credibility. *Journal of Money, Credit and Banking, 17*(4), 427–438.

Frankel, J., & Meese, K. (1987). Are exchange rates too variable? In S. Fischer (Ed.), *NBER macroeconomics annual*, *Volume II* (pp. 117–153). Cambridge: MIT Press.

Frankel, J. A. (2006). The effect of monetary policy on real commodity prices (No. w12713). *National Bureau of Economic Research*. Retrieved from http://www.nber.org/papers/w12713

Frankel, J. A., & Rose, A. K. (2010). Determinants of agricultural andmineral commodity prices. *HKS Faculty Research Working Paper Series RWP10-038* Retrieved from http://nrs.harvard.edu/urn-3:HUL.InstRepos:4450126

Fraser, P., Taylor, M. P., & Webster, A. (1991). An empirical examination of long-run purchasing power parity as theory of international commodity arbitrage. *Applied Economics, 23*, 1749–1759.

Freebairn, J. (1991). Is the $A a commodity currency? In K. Clements & J. Freebairn (Eds.), *Exchange rates and Australian commodity exports*. Australia: Centre of Policy Studies.

Frenkel, J., & Mussa, M. (1980). The efficiency of foreign exchange markets and measures of turbulence. *American Economic Association, 70*(2), 374–381.

Fujita, M., Krugman, P., & Venables, A. J. (1999). *The spatial economy: Cities, regions, and international trade*. Cambridge, MA: MIT Press.

Galati, G., & Ho, C. (2003). Macroeconomic news and the Euro/Dollar exchange rate. *Economic Notes, 32*(3), 371–398.

Ghura, D. (1990). How commodity prices respond to macroeconomic news. *Policy, Research and External Affairs Working Papers, International Economics Department, The World Bank, WPS 354.* Retrieved from http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/1990/02/01/000009265_3960928200056/Rendered/PDF/multi_page.pdf

Gilbert, C. L. (1987). Metals market efficiency in relation to foreign exchange and financial markets. *International Commodity Markets Division, The World Bank, Washington, DC, 1987–9*.

Gilbert, C. L. (1989). The impact of exchange rates and developing country debt on commodity prices. *The Economic Journal*, *99*(397), 773–784.

Gorton, G., & Rouwenhorst, K. G. (2005). Facts and fantasies about commodity futures. *Financial Analysts Journal, 62*(2), 47–68.

Gorton, G. B., Hayashi, F., & Rouwenhorst, K. G. (2013). The fundamentals of commodity futures returns. *Review of Finance, 17*, 35–105.

Gourieroux, C., & Monfort, A. (1990). *Series temporelles et modeles dynamiques (Vol.3)*. Cambridge University Press.

Graham, P., & Waring, T. (1998). The economics of Australian coal supply. *Australian Bureau of Agricultural and Resource Economics (ABARE) Conference Paper; JAPAC International Symposium 98, Tokyo, Japan*. Retrieved from http://trove.nla.gov.au/version/7673810

Granger, C. W. (1988). Some recent development in a concept of causality. *Journal of Econometrics, 39*(1), 199–211.

Granger, C. W. J. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica, 37*(3), 424–438.

Gregory, R. G. (1976). Some implications of the growth of the minerals sector. *The Australian Journal of Agricultural Economics*, *20*(2), 71–91.

Grilli, E., & Yang, M. C. (1988). Primary commodity prices, manufactured goods prices, and terms of trade of developing countries: What does the long-run show. *The World Bank Economic Review, 2*, 1–48.

Grilli, E. R., & Yang, M. C. (1988). Primary commodity prices, manufactured goods, prices and terms of trade of developing countries: What the long run shows. *World Bank Economic Review, 2*(1), 1–48.

Groenewold, N., & Paterson, J. E. H. (2013). Stock prices and exchange rates in Australia: are commodity prices the missing link? *Australian Economic Papers, 52*(3-4), 159–170.

Gujarati, D. N., & Porter, D. C. (2009). *Basic econometrics* (5th ed.). Boston: McGraw-Hill Irwin.

Gujarati, D. N., & Porter, D. C. (2010). *Essentials of econometrics* (4th ed.). New York: McGraw-Hill/Irwin.

Gylfason, T., Herbertsson, T. T., & Zoega, G. (1999). A mixed blessing. *Macroeconomic Dynamics, 03*(02), 204–225.

Hall, P. (1992). *The bootstrap and edgeworth expansion*. New York: Springer.

Hamilton, J. D. (1983). Oil and the macroeconomy since World War II. *Journal of Political Economy, 21*, 228–248.

Hamilton, J. D. (1989). A new approach to the economic analysis of nonstationary time series and the business cycle. *Econometrica, 57*(2), 357–384.

Hamilton, J. D. (1994). *Time series analysis*. Princeton: Princeton University Press.

Hamilton, J. D. (2008). Understanding crude oil prices. *Energy Journal, 30*, 179–206.

Hamilton, J. D., & Wu, J. C. (2014). Risk premia in crude oil futures prices. *Journal of International Money and Finance, 42*, 9–37.

Hammoudeh, S., Nguyen, D. K., & Sousa, R. M. (2014). US monetary policy and commodity sector prices. *Ipag Business School Working Paper Series.* Retrieved from http://www.ipag.fr/fr/accueil/la-recherche/publications-WP.html

Hammoudeh, S., & Yuan, Y. (2008). Metal volatility in presence of oil and interest rate shocks. *Energy Economics, 30,* 606–620.

Hamori, S. (2007). The information role of commodity prices in formulating monetary policy: Some evidence from Japan. *Economics Bulletin, 5*(13), 1–7.

Harri, A., Nalley, L., & Hudson, D. (2009). The relationship between oil, exchange rates, and commodity prices. *Journal of Agricultural and Applied Economics, 41*(2), 501–510.

Harvey, D. I., Kellard, N. M., Madsen, J. B., & Wohar, M. E. (2010). The Prebisch-Singer hypothesis: Four centuries of evidence. *The Review of Economics and Statistics, 92*(2), 367–377.

Hatzinikolaou, D., & Polasek, M. (2005). The commodity-currency view of the Australian dollar: A multivariate cointegration approach. *Journal of Applied Economics, VIII*(1), 81–99.

Hayashi, F. (2000). *Econometrics*. Princeton: NJ: Princeton University Press.

He, Y., Wang, S., & Lai, K. K. (2010). Global economic activity and crude oil prices: A cointegration analysis. *Energy Economics, 32*, 868–876.

Hess, D., Huang, H., & Niessen, A. (2008). How do commodity futures respond to macroeconomic news? *Financial Markets and Portfolio Management, 22*(2), 127–146.

Hicks, J. R. (1946). Value and capital, 1939. *Mathematical Appendix*, 311–312.

Hirschman, A. O. (1958). *The strategy of economic development*. New Haven, CT: Yale University Press.

Hotelling, H. (1931). The economics of exhaustible resources. *Journal of Political Economy, 39*(2), 137–175.

Hua, P. (1998). On primary commodity prices: The impact of macroeconomic/monetary shocks. *Journal of Policy Modeling, 20*(6), 767–790.

Hunter, J., Burke, S. P., & Canepa, A. (2017). *Multivariate modelling of non-stationary economic time series, Palgrave texts in econometrics*. Palgrave Macmillan UK: Springer.

Jaaskela, J., & Smith, P. (2011). Terms of trade shocks: What are they and what do they do. *RBA Research Discussion Paper*. Retrieved from http://www.rba.gov.au/publications/rdp/2011/pdf/rdp2011-05.pdf

Jacobs, D., & Williams, T. (2014). The determinants of non-tradables inflation. *RBA Bulletin*(September Quarter), 27–38.

Jerrett, D., & Cuddington, J. T. (2008). Broadening the statistical search for metal price super cycles to steel and related metals. *Resources Policy, 33*, 188–195.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control*(12), 231–254.

Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica, 59*, 1551–1580.

Johansen, S., & Juselius, K. (1990). The full information maximum liklihood procedure for inference on cointegration. *Oxford Bulletin of Economics and Statistics, 52*, 211–244.

Juselius, K. (1995). Do purchasing power parity and uncovered interest rate parity hold in the long run? An example of likelihood inference in a multivariate time-series model. *Journal of Econometrics, 69*(1), 211–240.

Kabir, S. H., Bashar, O. K. M. R., & Masih, A. M. M. (2014). Is domestic stock price cointegrated with exchange rate and foreign stock price? Evidence from Malaysia. *The Journal of Developing Areas, 48*(3), 285–302.

Kaldor, N. (1939). Speculation and economic stability. *Review of Economic Studies, 7*, 1–27.

Kellard, N. M., & Wohar, M. E. (2005). On the prevalence of trends in primary commodity prices. *Journal of Development Economics, 79*, 146–167.

Keynes, J. M. (1930). *A treatise on money* (pp. 687 –690).

Kilian, L. (2009). Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market. *American Economic Review, 99*(3), 1053–1069.

Kilian, L., & Vega, C. (2011). Do energy prices respond to US macroeconomic news? A test of the hypothesis of predetermined energy prices. *The Review of Economics and Statistics, 93*(2), 660–671.

Kirchner, S. (2009). Commodity prices and the Australian economy: trends versus cycles. *Policy, 24*(04).

Klotz, P., Lin, T. C., & Hsu, S.-H. (2014). Global commodity prices, economic activity and monetary policy: The relevance of China. *Resources Policy, 42*, 1–9.

Knop, S. J., & Vespignani, J. L. (2014). The sectorial impact of commodity price shocks in Australia. *Economic Modelling*, *42*, 257–271.

Kohlscheen, E., Avalos, F., & Schrimpf, A. (2017). When the walk is not random: commodity prices and exchange rates. *International Journal of Central Banking*, *13*(2), 121–158.

Kolb, R. W. (1992). Is normal backwardation normal? *Journal of Futures Markets, 12*, 75–91.

Krichene, N. (2008). Recent inflationary trends in world commodity markets *International Monetary Fund Working Paper* (08/130). Retrieved from https://www.imf.org/external/pubs/ft/wp/2008/wp08130.pdf

Krugman, P. (1981). Trade, accumulation, and uneven development. *Journal of Development Economics, 8*(2), 149–161.

Krugman, P. (1991). Increasing returns and economic geography. *Journal of Political Economy, 99*, 483–499.

Krugman, P., & Venables, A. J. (1995). Globalization and the inequality of nations. *The Quarterly Journal of Economics, 110*(4), 857–880.

Krugman, P. R. (1991). *Geography and trade*. MIT press.

Kurilenko, S. B. (1998). Exchange rate and competitiveness of national economy. Calculation of indices of nominal and real effective exchange rates for Ukraine. *Cybernetics and Systems Analysis, 34*(5).

Kwiatkowski, D., Phillips, P. C. B., Schmidt, P., & Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root. *Journal of Econometrics, 54*, 159–178.

Kyrtsou, C. (2008). Nonlinear features of commodity price comovements. In P. V. Schaeffer (Ed.), *Commodity modeling and pricing*. New York: Wiley and Sons.

Labys, W. C., Achouch, A., & Terraza, M. (1999). Metal prices and the business cycle. *Resources Policy, 25*, 229–238.

Labys, W. C., & Maizels, A. (1993). Commodity price fluctuations and macroeconomic adjustments in the developed economies. *Journal of Policy Modeling*, *15*(3), 335–352.

Lane, K., & Rosewall, T. (2015). Firms' investment decisions and interest rates. *RBA Bulletin* (June Quarter), 1–8.

Lennox, D. (2016). Is it time to buy resource stocks? Retrieved from http://www.asx.com.au/education/investor-update-newsletter/201602-is-it-time-to-buy-resource-stocks.htm

Leon, J., & Soto, R. (1997). Structural breaks and long-run trends in commodity prices. *Journal of International Development*, *9*, 347–366.

Lewis, W. A. (1978). *The evolution of the international economic order*. Princeton, NJ: Princeton University Press.

Lombardi, M. J., Osbat, C., & Schnatz, B. (2012). Global commodity cycles and linkages: A FAVAR approach. *Empirical Economics, 43*(2), 651–670.

Lutkepohl, H. (1991). *Introduction to multiple time series analysis*. Berlin: Springer.

Lutkepohl, H. (2005). *New introduction to multiple time series analysis*. New York: Springer Verlag.

Lutz, M. G. (1999). A general test of the Prebisch-Singer hypothesis. *Review of Development Economics, 3*(1), 44–57.

MacDonald, R., & Ricci, L. (2004). Estimation of the equilibrium real exchange rate for South Africa. *South African Journal of Economics, Vol. 72*(No. 2), 282–304.

MacKinnon, J. G. (1991). Long-run economic relationships. In R. F. A. Engle & C. W. J. Granger (Eds.), *Critical Values for cointegration tests*. Oxford: Oxford University Press.

MacKinnon, J. G. (1996). Numerical distribution functions for unit root and cointegration tests. *Journal of Applied Econometrics, 11*, 601–618.

MacKinnon, J. G., A. Haug, & Michelis, L. (1999). Numerical distribution functions of likelihood ratio tests for cointegration. *Journal of Applied Econometrics, 14*(5), 563–577.

Makin, A. J. (2013). Commodity prices and the macroeconomy: An extended dependent economy approach. *Journal of Asian Economics, 24*, 80–88.

Makin, A. J., & Rohde, N. (2015). Macroeconomic effects of terms of trade fluctuations in commodity exporting advanced economies. *Applied Economics*, 1–12.

Manalo, J., Perera, D., & Rees, D. (2014). Exchange rate movements and the Australian economy. *Research Discussion Paper of Reserve Bank of Australia*. Retrieved from https://www.rba.gov.au/publications/rdp/2014/pdf/rdp2014-11.pdf

Masih, M., Alsahlawi, M., & DeMello, L. (2010). What drives carbon-dioxide emissions: Income or electricity generation? Evidence from Saudi Arabia. *The Journal of Energy and Development, 33*(2), 201–213.

Mimuroto, Y. (2000). *An analysis of steaming coal price trends - Factors behind price fluctuations and outlook*. Washington, DC: Coal Research Group, International Cooperation Department, s194.

Minifie, J., Cherastidtham, I., Mullerworth, D., & Savage, J. (2013). *The mining boom: Impacts and prospects, Grattan Institute Report No 2013-9*. Carlton: Grattan Institute.

Mollick, A. V., Faria, J. R., Albuquerque, P. H., & Leon-Ledesma, M. A. (2008). Can globalisation stop the decline in commodities' terms of trade? *Cambridge Journal of Economics, 32*, 683–701.

Murphy, K., Shleifer, A., & Vishny, R. W. (1989). Industrialization and the big push. *Journal of Political Economy, 97*, 1003–1026.

Murphy, R. H. (2015). Unconventional confidence bands in the literature on the government spending multiplier. *Econ Journal Watch, 12*(1), 72–83.

Muth, J. F. (1961). Rational expectations and the theory of price movements. *Econometrica, 29*(3), 315–335.

Myrdal, G., & Sitohang, P. (1957). *Economic theory and under-developed regions*. London: Duckworth.

Neftci, S. N., & Lu, Y. (2008). *Financial instruments to hedge commodity price risk for developing countries*: International Monetary Fund.

Obstfeld, M., & Rogoff, K. (1996). *Foundations of international macroeconomics*. Cambridge, MA: MIT Press.

Ocampo, J. A., & Parra, M. A. (2003). *Returning to a eternal debate: The terms of trade in the twentieth century*. Santiago, Chile: United Nations Publication.

Office of the Chief Economist (OCE). (2016). Australian Industry Report 2016. Office of the Chief Economist, Department of Industry, Innovation and Science. Retrieved from https://industry.gov.au/Office-of-the-Chief-Economist/Publications/AustralianIndustryReport/index.html

Osterwald-Lenum, M. (1992). A note with quantiles of the asymptotic distribution of the ML cointegration rank test statistics. *Oxford Bulletin of Economics and Statistics*, *54*, 461–472.

Parsva, P., & Lean, H. H. (2011). The analysis of relationship between stock prices and exchange rates: evidence from six middle eastern financial markets. *International Research Journal of Finance and Economics*(66), 157–171.

Perron, P. (1989). The great crash, the oil price shock, and the unit root hypothesis. *Econometrica, 57*, 1361–1401.

Perron, P. (2006). Dealing with structural breaks. In P. A. T. C. Mills (Ed.), *Palgrave handbook of econometrics, Vol.1: Econometric theory* (pp. 278-352). Palgrave Macmillan.

Pieroni, L., & Ricciarelli, M. (2005). Testing rational expectations in primary commodity markets. *Applied Economics*, *37*, 1705–1718.

Pindyck, R. S., & Rotemberg, J. J. (1990). The excess co-movement of commodity prices. *The Economic Journal, 100*(403), 1173–1189.

Plumb, M., Kent, C., & Bishop, J. (2013). Implications for the Australian economy of strong growth in Asia. *RBA Research Discussion Paper*.

Retrieved from http://celestefunds.com.au/Portals/0/Implications%20for%20the%20Australian%20Economy%20of%20Strong%20Growth%20in%20Asia.pdf

Powell, A. (1991). Commodity and developing countries terms of trade: What does the long run show? *Economic Journal*, *101*, 1485–1496.

Prebisch, R. (1950). The economic development of Latin America and its principal problems. *Economic Bulletin for Latin America*, *1962*, 1–22.

Ratti, R. A., & Vespignani, J. L. (2013). Why are crude oil prices high when global activity is weak? *Economics Letters*, *121*, 133–136.

Ratti, R. A., & Vespignani, J. L. (2015). Commodity prices and BRIC and G3 liquidity: A SFAVEC approach. *Journal of Banking and Finance*, *53*, 18–33.

Reserve Bank of Australia (RBA). (1993). Reserve Bank of Australia index of commodity prices. *Reserve Bank of Australia Bulletin*, 24–31.

RBA. (2011). Box A: A comparison of commodity indices. *Statement of Monetary Policy*(November), 14–16.

RBA. (2016). *Index of commodity prices.* Retrieved from http://www.rba.gov.au/statistics/frequency/commodity-prices.html

Reinhart, C., & Borensztein, E. (1994). The macroeconomic determinants of commodity prices. *Staff Papers - International Monetary Fund*, *41*(02), 236–261.

Richards, T., & Rosewall, T. (2010). Measures of underlying inflation. *Bulletin* (pp. 7–12). Australia: RBA.

Ridler, D., & Yandle, C. (1972). A simplified method of analyzing the effects of exchange rates on exports of a primary commodity. *IMF Staff Papers, 19*(3), 559–578.

Roache, S. K., & Rossi, M. (2009). The effects of economic news on commodity prices: Is gold just another commodity? *IMF Working Papers*. Retrieved from https://www.imf.org/external/pubs/ft/wp/2009/wp09140.pdf

Robinson, T., & Wang, H. (2013). Changes to the RBA index of commodity prices:2013. *RBA Bulletin*(March Quarter), 23–28.

Rossi, B. (2005). Optimal tests for nested model selection with underlying parameter instabilities. *Econometric Theory*, *21*(5), 962–990.

Rossi, B. (2012). The changing relationship between commodity prices and equity prices in commodity exporting countries. *IMF Economic Review, 60*(4), 533–569.

Routledge, B., Seppi, D., & Spatt, C. (2000). Equilibrium forward curves for commodities. *Journal of Finance*, *55*, 1297–1338.

Sachs, J. D., & Warner, A. M. (2001). The curse of natural resources. *European Economic Review, 45*(4), 827–838.

Said, S. E., & Dickey, D. A. (1984). Testing for unit roots in autoregressive moving average models of unknown order. *Biometrika, 71*, 599–607.

Samuelson, P. A. (1964). Theoretical notes on trade problems. *Review of Economics and Statistics, 46*, 245–254.

Sari, R., Hammoudeh, S., & Soytas, U. (2010). Dynamics of oil price, precious metal prices, and exchange rate. *Energy Economics, 32*, 351–362.

Sarkar, M., Ratti, R. A., & Westerholm, J. (2015). Does iron ore move Australian equity prices? An investigation of the pricing mechanism by industry sector. *Joakim, Does Iron Ore Move Australian Equity Prices*. Retrieved from http://www.valuewalk.com/wp-content/uploads/2015/11/SSRN-id2676073.pdf

Scrimgeour, D. (2015). Commodity price responses to monetary policy surprises. *American Journal of Agricultural Economics*, *97*(1), 88–102.

Sephton, P. S. (1992). Modelling the link between commodity prices and exchange rates: The tale of daily data. *Canadian Journal of Economics, 25*(1), 156–171.

Shahbaz, M., Lean, H. H., & Shabbir, M. S. (2010). *Environmental Kuznets curve and the role of energy consumption in Pakistan*. Business and Economics: Monash Univerisity.

Sheehan, P., & Gregory, R. G. (2013). The resources boom and economic policy in the longer run. *Australian Economic Review, 46*(2), 121–139.

Sheen, J., & Kim, S. J. (2002). The determinants of foreign exchange intervention by central banks: Evidence from Australia. *Journal of International Money and Finance, 21*, 619–649.

Simpson, J. L., & Evans, J. (2004a). Commodity exporting countries and exchange rates: Australian evidence. *Derivatives Use, Trading & Regulation, 10*(1), 70–84.

Simpson, J. L., & Evans, J. (2004b). Commodity exporting countries and exchange rates: Australian evidence. *Derivatives Use, Trading & Regulation, 10*(1), 70–84.

Sims, C. (1992). Interpreting the maroeconomic time series facts: The effects of monetary policy. *European Economic Review, 36*, 975–1000.

Sims, C. A. (1980). Macroeconomics and reality. *Econometrica*, *48*, 1–48.

Sims, C. A. (1981). An autoregressive index model for the U.S. 1948–1975. In J. K. a. J. B. Ramsey (Ed.), *Large-scale macro-econometric models* (pp. 283–327). Amsterdam: North-Holland.

Singer, H. W. (1950). The distribution of gains between investing and borrowing countries. *American Economic Review, 40*(2), 473–485.

Spraos, J. (1980). The statistical debate on the net barter terms of trade. *Economic Journal, 90*, 107–128.

Stein, J. L. (1986). *The economics of futures markets*. Oxford: Basil-Blackwell.

Svensson, L. E. O. (2008). The effect of monetary policy on real commodity prices: Comment. In J. Y. Campbell (Ed.), *Asset prices and monetary policy*. NBER, University of Chicago, Chicago.

Takaendesa, P. (2006). *The behaviour and fundamental determinants of the real exchange rate in South Africa.* (Masters in Commerce (Financial Markets)), Rhodes University. Retrieved from http://eprints.ru.ac.za/516/1/Takaendesa_MCom.pdf

Tang, K., & Xiong, W. (2010). Index investing and the financialization of Commodities. *NBER Working Paper # 16385*. Retrieved from http://www.nber.org/papers/w16385

Taylor, J. B. (2009). The financial crisis and the policy responses: An empirical analysis of what went wrong. *National Bureau of Economic Research.* Retrieved from http://www.nviegi.net/teaching/taylor1.pdf

Thirlwall, A., & Bergevin, J. (1985). Trends, cycles, and asymmetry in terms of trade. *World Development, 13*, 805–817.

Thomas, R. L. (1997). *Modern econometrics: an introduction*. London: Addison-Wesley.

Thomsen, A., Sandager, R., Logerman, A. V., Johanson, J. S., & Andersen, S. H. (2013). Introduction to EViews 6.0/7.0. Retrieved from http://studerende.au.dk/fileadmin/www.asb.dk/servicekatalog/IT/Analysevaerktoejer/Eviews/Eviews_7.0_Manual.pdf

Torvik, R. (2001). Learning by doing and the Dutch disease. *European Economic Review, 45*(2), 285–306.

Turnovsky, S. J. (1983). The determination of spot and futures prices with storable commodities. *Econometrica, 51*, 1363–1387.

Venables, A. (2007). Trade, location, and development: an overview of theory. In *Naturalresources: Neither curse nor destiny* (pp. 259–288).

Vogelsang, T. J., & Perron, P. (1998). Additional test for unit root allowing for a break in the trend function at an unknown time. *International Economic Review, 39*, 1073–1100.

Webber, A. G. (1997). Australian commodity export pass-through and feedback causality from commodity prices to the exchange rate. *Australian Economic Papers, 36*(68), 55–68.

Wei, P.-Y., & Chang, Y. (2016). The relationship between equity and commodity markets during the credit crisis. *Academia Economic Papers, 44*(1), 93-–125.

Williamson, J. G. (2012). Commodity prices over two centuries: Trends, volatility and impact. *The Annual Review of Resource Economics, 4*, 185-–206.

Wooldridge, J. M. (2003). *Introductory econometrics A modern approach* (2nd ed.). United States of America: Thomson South Western.

Yin, L., & Han, L. (2016). Macroeconomic impacts on commodity prices: China vs the United States. *Quantitative Finance, 16*(3), 489–500.

Zanias, G. P. (2005). Testing for trends in the terms of trade between primary commodities and manufactured goods. *Journal of Development Economics, 78*, 45–59.

Zeng, T., & Swanson, N. R. (1998). Predictive evaluation of econometric forecasting models in commodity futures markets. *Studies in Nonlinear Dynamics and Econometrics, 2*(4), 159–177.

Zivot, E., & Andrews, D. W. K. (1992). Further evidence on the great crash, the oil-price shock and the unit-root hypothesis. *Journal of Business & Economic Statistics, 10*, 251–270.