Impacts of Australian Commodity Exports and Commodity Terms of Trade on the Australian Dollar 1997–2017

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Abstract

This study examines the impacts of Australian export commodities and commodity terms of trade on the AUD/USD real effective exchange rate over two decades (1997–2017). In this research I address two relationships. First, between commodity terms of trade with real effective exchange rate of the AUD/USD. Second, between the price of Australia's five largest commodities exported overseas (i.e. iron ore, gold, coal, aluminium and natural gas) and the above-mentioned exchange rate. We consider the real interest rate as an exogenous variable for this study. The quantitative method used for testing is time series analysis. The data is tested for stationarity using an Augmented Dickey-Fuller test. Next, a standard VAR and VEC model are employed based on results from the Johansen cointegration test. Finally, the Granger causality test determines the direction of the relationship. The findings show that commodity terms of trade have a strong, positive relationship with the real exchange rate in the long term.

The positive relationship between the commodity terms of trade and the exchange rate has useful policy implications as central banks and large corporations can make informed decisions about how the price index of the Australian commodity import and export sector can impact future foreign exchange shifts. Importers and exporters are directly affected as these data provide insights for the forecasting of future exchange rate prices to guard against shifts in the value of the currency, and therefore the cost to buy and sell goods internationally. The second relationship finds that the iron ore price, aluminium price and coal price also influence the real exchange rate in the long term. The evidence suggests a strong, positive relationship. I attribute the positive relation to their dominance in the export share of Australia, as these commodities add value by means of steel and energy production. As Australia is the world's largest coal exporter, the Australian exchange rate demonstrated 0.3% elasticity with the price of coal. In the short term the coal price caused shifts in the exchange rate. This bidirectional causality results in a cyclical relationship between coal and the exchange rate and poses important policy implications which affect employment in Australia.

Finally, the price of gold and natural gas does not have such a strong relationship with the real exchange rate, however there is evidence of reverse causality between the variables in the short term. These commodities represent a smaller share of exports in

Australia and therefore do not have substantial policy implications. This information contributes to current findings and allows market participants to make well-informed decisions.

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Declaration

This thesis:

- contains no material that has been accepted for the award to the candidate of any other degree or diploma, except where due reference is made in the text of the examinable outcome

- to the best of the candidate's knowledge contains no material previously published or written by another person except where due reference is made in the text of the examinable outcome.

- Diane Brown, Ph. D. edited this thesis. The editing addressed only style and grammar and not its substantive content.

21/07/2020

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List of Abbreviations

ABS	Australian Bureau of Statistics
ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criterion
AUD	Australian Dollar
BIS	Bank of International Settlements
BLS	Bureau of Labour Statistics
CAD	Canadian Dollar
CPI	Consumer Price Index
CTOT	Commodity Terms of Trade
DFAT	Department of Foreign Affairs and Trade
DOLS	Dynamic Ordinary Least Squares
ECM	Error Correction Model
EMH	Efficient Market Hypothesis
GDP	Gross Domestic Product
GFC	Global Financial Crisis
GMM	Generalised Method of Moments
IMF	International Monetary Fund
LOOP	Law of One Price
MUV	Manufacturing Unit Value
NCOMP	Nominal Commodity Price
NEER	Nominal Exchange Rate
OECD	The Organisation for Economic Co-operation and Development
OTC	Over the Counter
OLS	Ordinary Least Squares
PPP	Purchasing Power Parity
RBA	Reserve Bank of Australia
RBNZ	Reserve Bank of New Zealand
RCOMP	Real Commodity Price
AUD/USD REER	Real Effective Exchange Rate
TOT	Terms of Trade
USD	United States Dollar
VAR	Vector Auto Regression
VECM	Vector Error Correction Model

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Chapter 1: Introduction

This chapter is a synopsis for the thesis 'The Impacts of Australian Commodity Exports and Commodity Terms of Trade on the Australian Dollar, 1997-2017'. This chapter is organised in the following order: Background; Objectives and research questions, Research contribution, Underlying theory and Literature of the study. Finally, the chapter will outline the order in which the thesis is presented.

1.1 Background

As a country dependent on primary commodities, Australia's raw materials sector represents a large share of exports. Commodity exporting nations such as Australia, Canada and New Zealand are often noted to be heavily reliant on this sector for economic prosperity. For this reason, understanding the relationship between the exchange rate and export sector is, to say the least, a fascinating subject. Typically, when studying commodity dependent countries and their relationships, many studies focus on terms of trade (TOT) as a measure of international trade (Fornero et al. 2016; Jaaskela & Smith 2013; Otto 2003). Terms of trade can be described as simply an index representing the ratio of exports versus imports. Although this paints an overall picture of a nation's standpoint on international trade activity, it fails to capture which individual components of the index form the basis of change. For this reason, this thesis focuses on the commodity terms of trade (CTOT). This index allows us to capture international trade activity by measuring commodity sector terms of trade, because Australia's commodity sector represents the largest international trade export sector for Australia (DFAT 2017). This informs our learning about the commodity sector, however real commodity prices capture the influence of individual commodities.

Thus, real commodity prices of Australia's largest commodities will be the second focus. This will allow the reader to understand how the real price of commodities (measured in USD) influences the real effective exchange rate in Australia. Australia's five largest commodities exported (from 1997-2017) are coal, iron ore, natural gas, gold and aluminium (DFAT 2017). The demand and prices for these commodities have changed dynamically over the course of 20 years due to a myriad of factors such as globalisation, the mining boom, and industrialisation of trading partners in Asia. Understanding these relationships contributes significantly to the participants in the financial market, government decision-makers, liquidity makers and liquidity takers (see section 1.3).

In accordance with the Purchasing Parity Puzzle (PPP) the exchange rate is determined by the price of goods. Small, open economies such as Australia, Canada and New Zealand have much in common. One such commonality is that their exports make up a large percentage of their Gross Domestic Product (GDP). Numerous studies confirm a positive relationship between terms of trade in these countries and their domestic exchange rates. Terms of trade, however, encompass a range of goods and services. Many past studies have further concluded the weighting of commodities in terms of trade figures, and this is particularly relevant for Australia as a large player in global commodity exports. Here, exports also make up a large percentage of Australia's GDP. This thesis extensively studies related literature which contributes toward an understanding of the determinants of the exchange rate. Globally, commodities such as iron ore, copper and other industrial raw materials generate more than just their intrinsic value. When plugged into industrialised nations, these products have multiple economic effects, both on a microeconomic and macroeconomic scale.

1.2 Objectives and research questions

International trade is becoming increasingly advanced and globalised. With the range and volume of both exports and imports increasing (see figures 1.1 and 1.2) over the last two decades in Australia, the ever-changing dynamic of this sector poses the question of what is truly affecting the domestic currency and how it is doing so. This question has been answered by many studies, which confirm strong correlations between terms of trade of a nation and the strength of its local currency (Barhoumi 2008; Campa & Goldberg 2008; Jaaskela & Smith 2013; Kulish & Rees 2014). The Australian context also indicates a noteworthy relationship between the exchange rate and trade interactions similar to other OECD nations such as New Zealand, Canada and Chile. This study extends these findings by examining the relationship of Australian terms of trade with the real effective exchange rate of Australia against the USD.

Figure 1.1 Australia volume of imports, 1997-2017

Figure 1.2 Australia volume of exports, 1997-2017

As a driver of terms of trade shocks in the OECD, the commodity sector in small, open economy models confirm a robust co-movement with the exchange rate (Kulish & Rees 2014). These findings serve as a strong foundation and understanding for the basis of this research and its motivation. Once I understand the elasticity of the relationship between commodity terms of trade and the real effective exchange rate, the findings will allow me to further comprehend which components affect the price in relation to Australian currency, and to what extent. This research, most importantly, extends the robust research of the 'commodity currency' (Chen & Rogoff 2003) nature of the AUD by offering empirical evidence in relation to the five largest (by percentage share) commodity exports and import prices and its effect on the Australian real effective exchange rate. Under the rubric of small, open commodity export economies there has been increasing research surrounding the impact and shocks seen by changes in the price and volume of raw material exports in relation to currency.

In this research there are four objectives. The first objective is to understand the nexus between commodity terms of trade in Australia and the real effective exchange rate. This objective will determine whether a long-term relationship exists between these variables. This objective is fulfilled by answering both RQ1 and RQ2. The hypothesis will deduce where such a relationship exists. If such a relationship exists, I will investigate the significance and extent of the relationship by performing time series analysis (see section 3.3). Lastly, the thesis addresses the Granger causality of the variables. This test determines whether the real effective exchange rate is influenced by movements in commodity terms of trade or vice versa.

The second objective of this research is to understand the nexus between the real commodity price of Australia's five largest exports and the real effective exchange rate. As above, this objective will explore the strength of the relationship, elasticity, and Granger causality of the long term relationship using a time series analysis approach. This is addressed by RQ2. The commodities have been selected for their prominence in Australia's exports. Understanding the nexus of the relationship provides insight into the role a prominent export commodity plays in the strength of the domestic currency.

Based on findings from the first two objectives, the third objective is to explore macroeconomic fundamentals which explain the findings. If there is a significant long term relationship, this thesis also explores the reasons. For this, I also consider the real interest rate as a variable in this study. Studies have found the interest rate indicated a relationship both with the strength of a currency, and the price of commodities (Akram 2009, Ready et al 2017). Where no relationship is discovered, this thesis also discusses the reasons why. The fourth and final objective notes the implications of the Global Financial Crisis (GFC) on the results. The GFC represents a critical moment in financial market history over the last twenty years. Although this is a long-term study, it is important to consider whether there is an impact on the result from the GFC.

The research questions addressed in this thesis are:

1. Do the Australian commodity terms of trade influence the AUD/USD real effective exchange rate over the long term?
(RQ1)

2. Do the price of Australia's five largest raw materials commodity exports influence the AUD/USD real effective exchange rate over the long term?
(RQ2)

For both questions, where there is evidence of a long-term relationship, the thesis discusses both the significance of that relationship and the Granger causality between independent and dependent variables. The independent variable in both cases is the real effective exchange rate. The dependent variable is commodity terms of trade for RQ1, and the real price of commodities for RQ2. As previously mentioned, the commodities assessed are iron ore, coal, natural gas, gold and aluminium. Furthermore, the thesis will discuss whether there is any significance pre and post the Global Financial Crisis (GFC) period (2008-2009). The inclusion of the GFC allows us to study the impact of the post-financial crisis long term. The potential impact enables us to reflect on the long term effects of components before, during and after the crisis. This will add an in-depth understanding of the long term impacts of interest rates and trade at this time.

Achieving these objectives will contribute significantly to the current understanding of how the Australian Dollar (AUD) reacts to changes in the structure of Australian cross border trade as a commodity currency (Cashin et al. 2004; Chen & Rogoff 2003). It will simultaneously highlight how changes in monetary policy impact the domestic currency over a long period and will further understanding of components which determine the value of the AUD at a deeper level. Advancing and reinforcing the existing analysis between these variables is vital for policymakers to forecast the consequences and outcomes of their decisions (Sensoy & Sobaci 2014) (see further discussion in section 1.3).

Manalo, Perera and Rees' (2015) study emphasises the need to determine the source of real effective exchange rate movements, as well as their size and magnitude, to accurately measure the factors that affect exchange rates. The most recent finding provides evidence that countries which focus on raw commodity exports generally have higher interest rates; however, those which specialise in finished goods exports tend to exhibit lower interest rates as a mean (Ready, Roussanov & Ward 2017). This study understands the importance of real interest rates in relation to both the real effective exchange rate and price of goods and takes this into account in the methodology and results section (see Chapter 3, section 3.5).

1.3 Contributions of thesis

The findings of this thesis are significant. The purpose of this study is to further the understanding of factors which cause changes in the AUD/USD real effective exchange rate. A sharp rise in globalisation and international trade, and a surge in mining investment as a result of Australia's mining boom in the early 2000s are major dynamic changes felt by all financial markets. With more emphasis on short term studies (Haque & Lilford 2014, Kumar 2011, Otto 2003) evaluating the impact that the Australian commodity terms of trade and individual commodities have on the exchange rate, this study provides further insights regarding the long term relationship. This is beneficial for many financial market participants in order to understand these relationships in greater depth. These participants include market makers, liquidity takers, central bank decision-makers and various businesses that import and export their goods or services and are reliant on the exchange rate market. The studies which focus on the short term relationship (Haque & Lilford 2014; Kumar 2011; Otto 2003) are important as they provide insight on more speculative participants in the market. However most market participants, especially when concerning the nature of commodities being traded, hold long term contracts for their delivery. I address this limitation by selecting long term quarterly data which spans 20 years for this thesis. The short term studies mentioned previously do provide insight and an analytical framework to identify where the variables are not cointegrated in the long term, allowing also for observation of short term relationships.

The liquidity takers in Australia are the Reserve Bank of Australia (RBA), and its policymakers. In order to correctly control money supply the RBA, or any central bank for that matter, must meet its inflation requirements through fundamental procedures. To control the money supply central banks use various measures. The RBA often uses quantitative easing structures to introduce new money into the economy or to increase or decrease the interest rate to promote saving or spending respectively. The RBA considers the status of unemployment, spending, the manufacturing index and GDP, among other factors. International trade plays an immense role as increased trade can influence employment, especially in the mining sector, if the demand is high. GDP takes into account net exports as part of its measurement. For the RBA to be able to confidently control money supply and have a clear oversight of the nation's economic wellbeing, this thesis will aid understanding of how commodity terms of trade and prices may impact its policy making. Hedge funds and trading firms also comprise liquidity takers and they are entities which allow professional traders to use spot and derivative products in order to perform speculative trading. Risky and also complex, hedge fund traders trade high volumes of currencies and rely on accurate information to build their strategies, using many factors: interest rate differentials, historical price patterns, fundamental news events, business earning reports, and volatility and correlations between different asset classes of tradeable products (King et al. 2011). Big banks generally have large teams dedicated to monitoring and holding their foreign currency positions using these strategies. These market participants will also benefit from understanding the relationships discussed in this thesis.

Finally, there are corporations and retailers who export and import their goods, products and services. Many corporations need access to the foreign exchange market to fulfil currency requirements needed to pay overseas manufacturers and suppliers. In order to protect their bottom line and profit margins, corporations may need to hedge in order to mitigate their exposure to volatile or adverse currency movements. These incorporate currency movements which they need to be aware of and understand as they can impact the wellbeing of businesses. These are the key liquidity takers. Next, I discuss the market makers.

The market makers are the ones who create liquidity. These are reporting dealers, custodians such as non-reporting banks, Electronic Communication Network (ECN) brokers and exchanges. These are speculative market participants who enter the market to adjust quotes and buy and sell underlying assets in the financial market. They are governed by regulators, such as the Australian Securities and Investments Commission (ASIC) in Australia. These participants maintain market liquidity. These buyers and sellers are charged for holding currencies based on interest rate differential. They profit from holding currencies which appreciate or depreciate. If these currencies act in the opposite direction to which the investor selected, this results in financial loss. Market makers rely heavily on the understanding of market influencers and they decide whether to buy or sell a particular asset based on the information available. For RQ2, all commodities can be traded on the exchange. This thesis contributes to information for market makers as it will establish the causality of variables, and this will help market makers by providing a deeper understanding of tradeable asset classes so they can make more informed decisions.

Not only will the findings from this thesis contribute to these market participants locally, but they will also provide greater understanding to traders and investors worldwide who have invested in trading the relevant commodity prices or the AUD/USD currency. This also stimulates the conversation for similar small, open economies to explore their largest commodities and how these commodity prices can influence their exchange rate. Furthermore, in addition to acknowledging and measuring the relationship (RQ1 and RQ2), RQ2 provides a comparison of influence. The following section summarises the approach this thesis adopts to understand both research questions.

1.4 Approach

This thesis is based on some key theoretical foundation from the previous literature, which includes Akram (2009), Haque & Lilford (2014), Haque & Lilford (2014b), Jaaskela and Smith (2013), Demirer & Belasen (2019), Ma & Wang (2019) and Lof & Nyberg (2017). This thesis adopts time series analysis, panel data correlation and regression analysis. First, the thesis conducts a simple correlation analysis between variables, followed by a Log-linear test for long term elasticity as used in Akram (2009) and Ali & Rahman (2012). Next, time series analysis involves the Augmented Dickey-Fuller (ADF) stationarity test for a unit root (Apergis 2014, Dauvin 2014). This is followed by the Johansen cointegration test in order to determine whether a Vector Auto-Regression (VAR) or Vector Error Correction Model (VECM) is suitable to test the strength of the relationship (Kumar 2011, Haque & Lilford 2014). The final step of time series analysis implements a Granger causality test which allows me to understand the direction of the relationship between the independent and dependent variables (Haque et al. 2014, Ready et al. 2017). The third analysis is regression analysis. For regression analysis I use a standard ordinary least squares (OLS) model. I also note that there are limitations with using a univariate OLS regression model. I use the OLS to generate a general snapshot of the regression between individual commodities. To answer the research questions, I place more importance on time series analysis of the data. (The model and process for these methods is discussed in Chapter 3.) The study uses eViews for statistical analysis and time series analysis as it is an advanced and reliable econometrics software. SPSS is used occasionally where eViews is unable to capture the method.

1.5 Research motivation

The motivation to undertake this research stems from two areas. Firstly, to extend current findings within the Australian context in relation to international trade composition and its effect on the economy. This provides further understanding on how the AUD real effective exchange rate reacts to these factors and what that means for market participants who are impacted, as outlined in the contributions section. It also furthers understanding of how the AUD currency market dynamic works, which on average turns over USD348 billion every day (BIS 2016). There are many studies, as discussed in Chapter 2, which clarify the relationship between individual commodities such as gold and oil, or a commodity index. However, I am motivated to study commodities based on their importance in the export sector in Australia.

Secondly, the components of Australian trade have shifted dramatically over the last 20 years. This shift has occurred as a result of the mining boom, increased demand from trading partners, and rapid globalisation. Initially, agricultural products were dominant in Australia's exports with wool, beef, sugar and butter being the major products which the country exported. It was in the 1970s that the agricultural export industry began to experience a decline, and the structure of Australia's primary exports shifted to the natural resources and raw materials sector. Precious metals, coal, natural gas and other such resources became more imperative to the exports sector (DFAT 2016). Many of these resources saw a significant growth in the early 2000s. This motivated me to study the impacts of these changes over the long term. Due to the large number of buyers and sellers, and therefore high market liquidity, commodities have a floating marketplace of their own. Changes in commodity prices and volumes traded based on buyers and sellers in the market have a dynamic and complex relationship with the currency itself, and I am motivated to find out more about this complex relationship.

I am also motivated to learn more about commodity terms of trade. Commodities have a dynamic relationship with currencies. However, learning about commodity terms of trade allows us to capture import and export ratios as a whole. The current literature provides evidence supporting a positive relationship between a country's terms of trade and its domestic currency, particularly for small, open commodity-exporting economies such as Canada, New Zealand and Australia. However, terms of trade cover all components of international trade including travel, education and services. There is scope for further examination of commodity terms of trade, which eliminates all factors other than commodities.

The contributions section mentions many market participants directly impacted by the exchange rate. In only fifteen years, the amount of AUD traded globally has increased from $48 billion to $463 billion in daily average turnover. The market is expanding, and the amount of funds being circulated, and commodities demanded is expanding at a significant rate. It is vital, even more so now, to understand the relationship between these variables. Previously a twenty-year study has not been possible, due to the limitation of data, and commodities not being prominent in Australia in earlier years. Now, this is possible.

1.6 Organisation of research

The research is organised as follows. Chapter 2 discusses relevant and influential literature which has contributed to my understanding of the relationship of commodity terms of trade and commodity prices to date. The literature review discusses pioneering concepts and past findings that examine the relationship of the currency market. As a basis for studying past literature and finding gaps I develop my hypothesis and research questions outlined in Chapter 3. That chapter also outlines the research design, data and methodology implemented in the testing process. The research design further indicates the variables used in the research, and reliability and sources of the data. The methodology highlights different tests and methods implemented in order to test the hypothesis and importance of chosen methodologies. Chapter 4 presents the results with initial analysis. Chapter 5 provides in depth discussion of the results. The implication results have for policymakers is discussed, in conjunction with the contribution this thesis makes to the field of study in financial markets. Finally, the conclusion in Chapter 6 summarises key takeaways of the thesis.

1.7 Chapter summary

The foreign exchange and commodities market are developing at a rapid rate, and this thesis provides up-to-date findings on the relationship between them. Concentrating on the AUD/USD exchange rate, and Australia's five largest commodities and commodity terms of trade, this thesis will be amongst the first to study these variables over a twenty-year period post a significant boom. The findings will assist market participants such as central banks, liquidity takers and market makers to construct better policies, and enhance informed decision making for the wellbeing of Australia's economic prosperity.

Chapter 2: Literature Review

2.1 Introduction

This chapter thoroughly discusses the foreign exchange market, and how this financial market reacts to changes in the dynamics of buyers and sellers, specifically related to the export of commodities. The main purpose of this chapter is to summarise, review previous studies undertaken in this strand of literature, and combine their findings and limitations to add a valuable contribution to this field of research. This chapter discusses and deliberates on noteworthy past literature which formed the basis of the research questions and hypothesis development outlined in Chapter 3. The chapter is structured in five sections. Section 2.2 provides the background to the topic and highlights relevant information in regard to the foreign exchange market. Section 2.3 focuses on the basic theory behind terms of trade and its impact on developed and developing economies, more specifically those which are a part of the OECD and notable commodity currencies. Section 2.4 discusses the consequences and impacts of Australian trade shocks on the domestic foreign exchange market. This is followed by an investigation of Australia's commodity exports and prices as a component of terms of trade in section 2.5. We then focus on Australia's top 5 exports (i.e. iron ore, gold, coal, aluminium and natural gas) and their significance. Section 2.6 summarises key literature findings in a tabular format and section 2.7 concludes the literature review chapter.

2.2 The foreign exchange market

The foreign exchange market is an over the counter (OTC), decentralised global market where market participants can trade different currencies. This financial market dictates and forms the foreign exchange rate of 180 different currencies in total as recognised by the United Nations (UN) (BIS, 2016). More recently currencies were allowed to float freely, being determined by market forces of supply and demand. For a long time, researchers have studied the relationship between the foreign exchange market and factors that may impact the swings and movements of currencies (Dornbusch 1985; Fama 1984; Faust & Rogers 2003; Sweeney 1986). Since this historical event took place in 1975, and its subsequent effect on foreign exchange market dynamics, there has been a larger spotlight on the long term principles of terms of international trade between countries as an indication of exchange rate determination and the consequences of terms of trade. Apart from these principles, there are many factors that can be analysed to study currency market behaviour, such as geopolitical circumstances, central bank activities and even algorithmic trading, to name a few.

However, the focus here is on the complex long term relationship of the currency market in relation to terms of trade, commodity specific terms of trade and the major five commodities exported from Australia, as a nation which strongly represents a small, open economy. The rationale for this chosen topic and its relevant hypothesis questions are developed here in the literature review chapter. Recent research work combines empirical literature with large panel datasets in order to evaluate domestic foreign exchange market behaviour in small, open economies (Andries et al. 2017, Charnavoki & Dolado 2014). The findings of this research highlight the need for further understanding of the active role of trade in the foreign exchange market dynamic.

The forces of market supply and demand are actively changing in the Australian market, and as such, there is an existing need to reinforce and supplement the current understanding of the role the commodity market plays in a small, open economy.

This thesis examines two key relationships: the relationship between Australian commodity-specific terms of trade and its relationship with the AUD, and the commodity price of Australia's five largest exports and its long-term impact on the real effective exchange rate.

2.2.1 History of the foreign exchange market

Initially a barter system, the exchange market has advanced extensively. Recently, major global economies were valuing their currency against one ounce of gold. In 1944, when there was not enough gold during the Second World War to fund the money being printed out of Europe, the Bretton-Woods system was born. This system appointed the USD as the national reserve currency, yet problems resurfaced as an excess of trading USDs led to a shortage overseas. It was the beginning of a new era when the United States President Richard M. Nixon announced the end of the Bretton-Woods system of fixed exchange rates in 1971 (IMF 2005). After this, the majority of global economies were allowed to float freely, and other countries followed this path over the following years. Under this post Bretton-Woods regime, currency prices were based on the market forces of supply and demand and were decentralised. This principle of supply and demand stipulates the way in which the market currently shifts in order to find its equilibrium and determine current prices (Devereux & Engel 2003; Mussa 1982). These forces will be discussed in further detail in this chapter.

2.2.2 The foreign exchange market

The foreign exchange market today is a large, globalised online network where market participants can buy and sell currencies worldwide. It is a system that facilitates the flow and organisation of an average of USD5.1 trillion a day in international trade. This is made up of foreign exchange and OTC spot and derivative products such as futures, options and swaps (BIS 2016). It is almost twelve times and twenty-seven times larger than the futures and equities markets respectively.

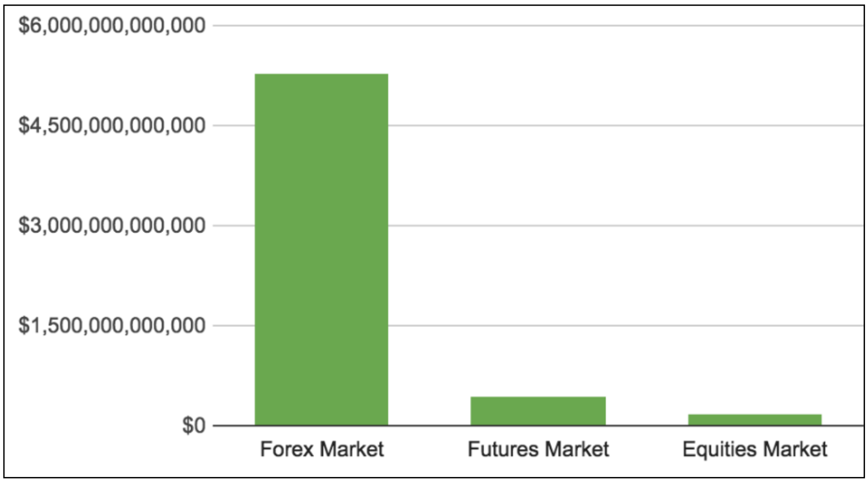


Figure 2.1: Forex market vs futures and equities market

(Source: BIS 2016)

The combined actions of market participants are responsible drivers of the exchange rate. These market participants can be categorised into liquidity makers and liquidity takers and they essentially form the dynamic forces of illustrating the supply and demand of currency through a change in price and equilibrium (BIS 2011; Carron 2015).

The liquidity makers are made up of reporting dealers, exchanges, multi-bank platforms and retail aggregators (BIS, 2011). Liquidity makers (or market makers) are both buyers and sellers, acting at both ends in a transaction. They buy and sell assets or commodities at certain prices which can be evidenced in the daily volume of products traded. The liquidity takers are the central banks, institutional investors, hedge funds and proprietary trading firms. Central banks play a key role in setting the monetary policy of their respective country; not only do they set the inter-bank interest rate, but they also report the ongoing expected short- and long term outlook of the condition of the economy. Over time central banks have had three main objectives: to maintain the nation's currency stability in line with the ongoing monetary regime; to catalyse financial prosperity and maintain economic stability; and to retain full employment and low inflation, all of which they achieve by setting monetary policy (Goodhart 2011; RBA 2014). The central banks achieve these goals by controlling and manipulating money supply. The bottom line remains that there needs to be the correct quantity of money in circulation to ensure a nation's economy remains healthy and sustainable (Gali & Monacelli 2005; Reinhart 2000).

These changes to money supply have many consequences, including the direct effect on the domestic rate of inflation. All else being equal in an efficient economy, if the money supply is increased there is more currency chasing the same quantity of goods, as a result of which the prices of goods increase (Carlin & Soskice 1990, p.90). Subsequently, the change in prices of goods influences the competitiveness of local goods in the international market. With the increase in price of goods being sold internationally, the knock-on effect means it becomes increasingly expensive for other nations to keep up with their import demands, with domestic demand for exports simultaneously experiencing a decline. On a global and macroeconomic scale, this leads to the second topic of international trade.

The need for international trade stems from the comparative advantage of innovation in a plethora of fields available worldwide. There is a vast variation in the availability of resources, and in today's context technology and innovation in many sectors have made cross border trade an essential path to economic prosperity. There is a rich history of trade which has developed extensively over many centuries. In the present day, with advances in technology and the proliferation of trade, countries are importing and exporting goods to maintain economic prosperity for multiple reasons. These include the availability or lack of domestic raw materials, the cost of substitution, cheaper labour, and other factors. It is mentioned by many central banks that net exports of a nation are a key determining factor of a nation's Gross Domestic Product (GDP) (Cayen et al. 2010), which is given by the following equation:

$$GDP = C + I + G + (X - M) \tag{1}$$

where GDP is the sum of consumer spending C, capital investment I, government spending G, and net exports given by exports minus imports $X - M$. GDP is one of the primary indicators used to measure the health of a country's economy, by representing the dollar value of goods and services produced over the specified time range. GDP is also referred to as the size of an economy$(X - M)$ which plays an important role in this measure by illustrating the net exports of a nation. This equation proposes that an increase in exports directly contributes to the wealth of the nation.

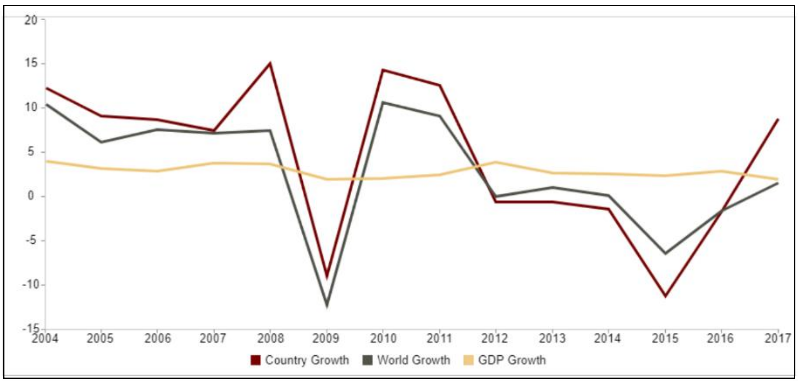


Figure 2.2: Australia's country growth vs world growth vs GDP growth

Source: World Bank Group 2018

In addition, Australia is a small, open economy driven by commodities, especially since the 2000s. The implication of such an economy is that as a participator of international trade, its activities and trade do not hypothetically impact world prices or incomes, as compared to larger open economies such as the United States. Other small, open economies such as Canada and New Zealand exhibit similar economic characteristics, which are also part of the Organisation for Economic Co-operation and Development (OECD). These characteristics include their reliance on commodities and their large degree of openness to both international capital flows and net foreign assets. Furthermore, they all maintain a floating exchange rate and their central banks use formal published inflation targets to set their monetary policies. The similarity in these economies allows this thesis to draw from literature and findings from these nations with a high degree of similarities (Charnavoki & Dolado 2014; Jaaskela & Smith 2013; Zettelmeyer 2004). Furthermore, globalisation relies heavily on exports and imports. The mining boom of the 2000s and expanding growth from Australia's close trading partner, China, has a strong connection to the increase and change in Australia's international trade, and consequently its effect on the Australian economy. For example, there was a significant change in materials exported from Australia to China and the world in comparing pre- and post-mining booms.

It is widely acknowledged that the AUD is a commodity currency and international trade plays a large role in determining its strength. However, in the last twenty years the composition of trade has changed dramatically, leaving this area open to further extended research, interpretation and understanding.

2.2.3 International trade and globalisation

As a result of industrialisation and globalisation, small to medium multinational corporations are finding a growing requirement to outsource their products, labour and raw materials in order to increase their efficiency. In addition to increased efficiency, international trade also gives nations a platform in the global economy to encourage investment in foreign companies and countries, known as Foreign Direct Investment (FDI). This gives exposure to goods and services which are not available domestically in their own nations. On a larger scale, commodities and raw materials such as coal, iron ore and coffee (to name a few) are not available in many nations due to their geographic location. Many nations rely on the global price indices and availability of these commodities for the prosperity of their countries. Australia relies on China's demand for these raw materials which make up most of Australia's exports since 2000. This dependency on China has been studied ever more recently due to this increase in raw materials export. It is one of the key reasons that AUD has been tagged as a commodity currency.

Commodity currencies refer to those currencies which depend highly upon the export and/or import of certain raw materials and commodities for the nations' income (Chen & Rogoff 2003). Generally, the term commodity currency encompasses the following countries: Australia, Canada, New Zealand, South Africa, Norway, Brazil, Russia and Chile (Chen & Rogoff 2003). The significance of the currencies for these countries lies in the fact that the movement of their exchange rates is co-dependent on the world prices of the primary commodities. The figures below represent the growth in exports for Australia and Canada from 1997-2017, and the subsequent figures illustrate the AUD/USD and CAD/USD exchange rates. It is apparent, and as per prior research on the relationship between the export of commodities and the exchange rate. Countries such as Australia and Canada have a singular exported commodity which contributes largely to their export volume portion. For Australia this is iron ore, and for Canada it is oil. Although this study does not focus as heavily on oil prices, as that is a vast topic, it does concentrate on the raw material exports of Australia to further solidify and understand this relationship. These products, iron ore and oil, have added effects on productivity such as cost of manufacturing for iron ore and cost of logistics for oil. This is a subject which I will not address.

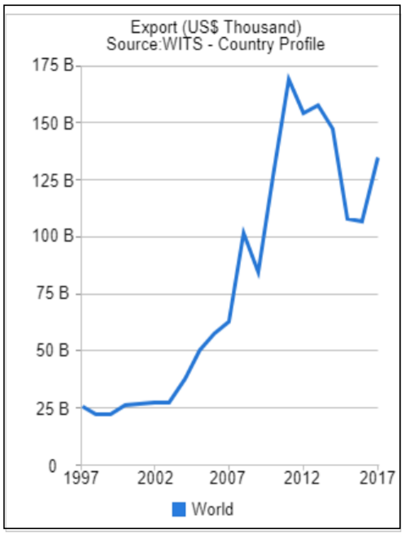


Figure 2.3: Australian exports in USD thousands, 1997-2017

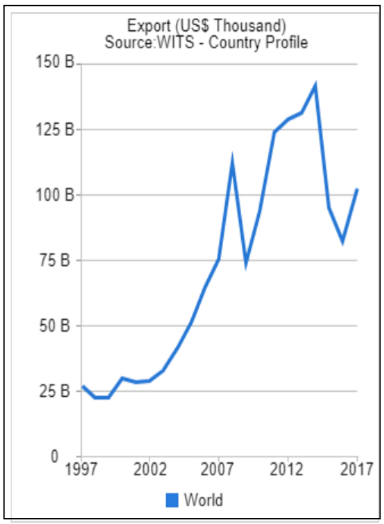


Figure 2.4: Canadian exports in USD thousands, 1997-2017

Source: World Integrated Trade Solutions, 2018

International trade is linked closely to theoretical concepts of PPP which formed the basis of our understanding of foreign exchange markets for many decades. PPP discusses how the price of goods determines the exchange rate. However, although many studies show validity for the PPP, it is well known as the PPP Puzzle as there are also many studies which refute the PPP.

These concepts are highly discussed and debated when studying the determinants of the exchange rates. To summarise, the PPP Model (Dornbusch 1987; Fama 1984; Rogoff 1996) and the Efficient Market Hypothesis (Perron 1985; Sarno & Taylor 2002) give way to the Uncovered Interest Parity (UIP) model. These concepts have shaped the way in which foreign exchange markets are seen today and are the foundation of many current theoretical principles.

The PPP is based on the Law of One Price (LOOP)., states that a good should sell for the same price regardless of its location. Applied in a global context where each country has its own domestic currency, the goods should have the same value when expressed in the home currency (Carron 2015, De Gregorio & Wolf 1994). This is the absolute PPP theory. The relative PPP theory takes into account the relationship between the inflation rates of the two countries. Fama (1984) depicted the PPP using the following formula:

$$PPP = \frac{V\ it}{V\ jt} \tag{2}$$

The PPP index can be illustrated as a function of the price level of country i $V\ it$ divided by the price level of country j $V\ jt$. The equation assumes that the exchange rate will account for the difference of inflation in respective countries i and j (Rogoff, 1996). It is usually expressed as a long term relationship. A universal example of this is the Big Mac Index, which was introduced in the magazine *The Economist* in 1986. The general understanding is that if you are to compare the price of a McDonald's Big Mac burger in country i against the price of the same burger in country j, in line with PPP it should be equal to the exchange rate. If it is lower than the exchange rate the currency is undervalued, and if it is higher than the exchange rate the currency is overvalued. There are however many limitations to the Big Mac Index. For example, it does not consider the social status of fast-food restaurants, market competition and level of taxes, to name a few. Further, the Big Mac Index by itself does not illustrate the way property prices or other non-tradeable goods such as energy might behave. For this reason PPP is measured using a basket of goods to provide a fair value of the currency valuation. The study uses PPP for analytical purpose. By incorporating PPP into the foundation of the study, I evaluate the price of the commodities to be valued the same whether discussing these against the USD or the AUD. In this thesis the commodity prices which are the independent variables in this study (outlined in Section 3.4.6) are measured in USD terms to assess their impact on the AUD.

There are countless factors which have been identified that affect the movement, direction and magnitude of changes in the exchange rates. These include, but are not limited to, actions taken by the central reserve banks, geopolitical conditions of respective countries, imports and exports, and external global markets such as stock and commodity markets (Chen & Chen 2007; Immam & Tickle 2012; Katechos 2011; Phylaktis & Ravazzolo 2005). These are all important factors and posit the opportunity for research; however, the topic is too wide and extensive to be discussed in just one study, and thus outside the scope of this study. The pre-existing research is extensive and thorough, consequently I am able to create an in-depth foundation for my research questions and provide further research to extend the existing findings in this field of study.

2.3 Terms of trade theory and impacts

Measuring terms of trade can be traced back to 1927. This was when the phrase 'terms of trade' was initially coined by Frank William Taussig, the author of *Principles of Economics* (2003). Terms of trade contain a descriptive insight into a nation by illustrating the ratio of its import and export prices. OECD countries such as Canada, New Zealand and Australia particularly focus on their terms of trade in conjunction with other indicators such as trade balance and GDP, to name a few, to assess the prosperity of the economy and the direction and wellbeing of international trade in the global market.

Australia's economic wellbeing is highly reliant on its international trade, with the country's exports worth $36562 million and its imports totalling $34958 million as of December 2017 (ABS 2017). At this time, Australia's net exports comprised almost 20% of the nation's gross domestic product (GDP) (RBA 2017) [Equation 1]. This is due to Australia being a commodity exporting small, open economy which has been exposed to the development of its international trading partners over the last two decades (Kulish & Rees 2017). This is the period over which this study examines the data. The demand for resources from emerging economies in the early 2000s, particularly China and India, resulted in a spike in commodities exported domestically. The surge in mining in Australia, which resulted in further investment in this sector, caused an increase in the rate of expansion in the local iron ore, coal and gas market and related industries (Battellino 2010; Cole & Nightingale 2016; In & Menon 1996). As a consequence, the overall price of exports increased and thus terms of trade rose significantly between 2001 and 2011 in particular (Cole & Nightingale 2016) (Figure 2.5).

This notion extends to a strand of literature which has debated that shifts in the exchange rate for OECD nations are substantially influenced by movements in terms of trade (Edwards 1995; Clements & Fry 2008; Jaaskela & Smith 2013; McKenzie 2002; Mendoza 1995).

Figure 2.5 Australian terms of trade, 1997-2017

Source: ABS 2017

Terms of trade are the ratio of export prices to import prices. The relationship is summarised as per the equation below:

$$Terms\ of\ Trade = \frac{Index\ of\ Export\ Prices}{Index\ of\ Import\ Prices} \times 100 \quad (3)$$

An increase in this index suggests that Australia is receiving more for its exports, and a decrease suggests a higher volume of imports. An appreciation in terms of trade has had an observable positive impact on economic growth, since an increase in export prices relative to import prices means that a larger volume of imports can be purchased with a given volume of exports, thus increasing the real purchasing power of domestic production for Australia (RBA 2005). This increase is equivalent to a transfer of income from the rest of the world and as such largely impacts consumption, savings and investment of the domestic currency (RBNZ 2008). This flux of income, catalysed by shifts in terms of trade, has positively influenced both GDP (Equation 1) and the real effective exchange rate (Clements & Fry 2008; Gregory & Blundell-Wignall 1990; McKenzie 2002).

Strong, positive links are drawn between terms of trade ratio (Equation 3) and appreciation of the domestic currency of the nation. This includes but is not limited to the components of terms of trade, such as the composition of exports and imports relative to the ratio. The price and volume of exports and imports and the nature of goods traded is all encompassing.

In regard to exchange rate fluctuations being attributed to movements in terms of trade, The Department of Foreign Affairs and Trade (DFAT) in Australia has always noted international trade, including both imports and exports, as a critical contributor to Australia's economic prosperity (DFAT, 2014). For a country rich in natural resources and commodities, researchers have attempted to explain that the movements of commodity pricing can be observed through the volatility of the exchange rate, resulting in movements in the AUD/USD exchange rate. Alternatively, other authors claim this is simply due to changes in the country's current account (Branson et al. 1977; Driskill 1981). Of course, there are numerous factors acting simultaneously to determine the rate, however it is still unclear and unresolved as to what extent this is conclusively due to changes in commodity prices (Ali & Rahman 2012).

Past literature very clearly determines a strong link between the TOT and the real effective exchange rate for OECD nations. In fact, Mendoza's study claimed that terms of trade shocks account for between 45-60% of observed changes in the nations GDP, and 50% of the observed variability in the real effective exchange rate (Mendoza 1995). Since 1995 however, the composition of Australia's exports and imports has changed drastically and so too have the characteristics of Australia's major international trading partners. However, the underlying finding in his empirical results highlights the need for understanding the underlying variables which catalysed the shifts in terms of trade, causing shocks in the financial market and thus the exchange rate.

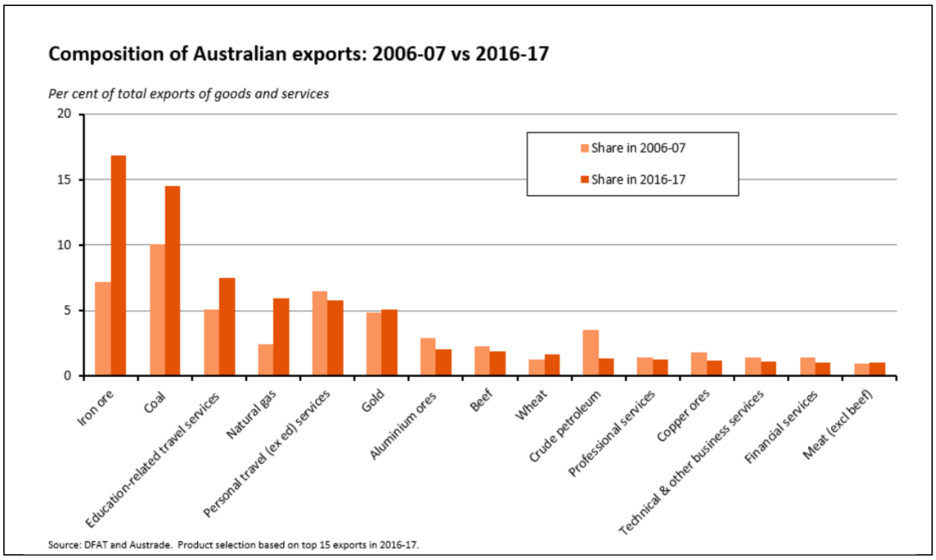


Figure 2.6 Composition of Australia's exports, 2006--07 vs. 2016--17

Source: DFAT 2017

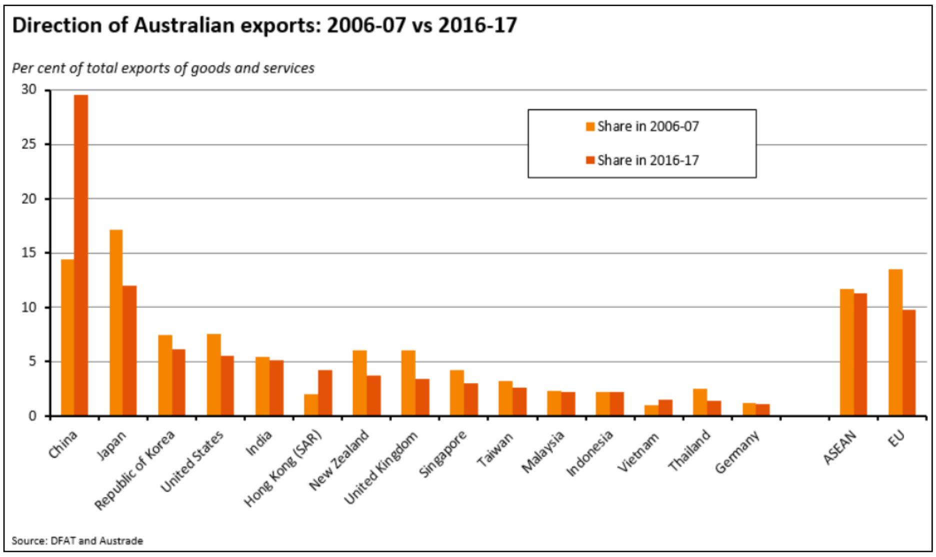


Figure 2.7 Composition of Australia's exports, 2006--07 vs. 2016--17

Source: DFAT 2017

More recent studies extend Mendoza's work by confirming this positive correlation between the real effective exchange rates in OECD nations. Terms of trade and real effective exchange rate positive correlation is apparent in many cases in contemporary literature as well (Charnavoki & Dolado 2014; Jaaskela & Smith 2013; Manalo et al. 2015; Zhang & Macdonald 2014). Terms of trade shifts were found to explain two- thirds of the variation in the real effective exchange rate over the sample, but less than one fifth of variation in the other domestic variables.

Jaaskela and Smith's (2013) study explores the macroeconomic effects of terms of trade shocks and their influence on the economy of Australia. While the authors note that previous studies have investigated this relationship (Dungey & Pagan 2009; Chen et al. 2016), they choose to depart from the usual assumption that terms of trade shocks are not responsible for changes in other macroeconomic variables. Instead, they maintain a small, open economy assumption where the global market determines the price of tradeable goods. This implies that terms of trade shocks are instigated and have consequences in the world economy. Using a benchmark VAR model in a similar fashion to Nazlioglu and Soytas (2012), Manalo et al. (2015) and Fornero et al. (2016), Jaaskela and Smith (2013) conclude that two thirds of the variation in the real effective exchange rate is due to shifts in terms of trade.

Manalo et al.'s (2015) study extends this finding by testing to investigate which sectors of the Australian economy the real and nominal exchange rates are most sensitive to. Also using a VAR model and assuming a small, open economy model, they quantify the macroeconomic impacts of changes in the mining, agricultural, construction and manufacturing industries. By using an alternative approach, they judge how the exchange rate would have been impacted in a scenario where Australia's mining boom of the early 2000s had not occurred; and in contrast to their hypothesis, they conclude only a 10% appreciation in the exchange rate isolated from changes in commodity prices. However, their results reinforce that although the exchange rate still appreciates this model, it does so less rapidly than it would in the scenario which incorporates the mining boom (Manalo et al. 2015). The limitation outlined by this study, which makes it a challenge to identify which sectors are the cause for effect in the exchange rate, is the issue of a good being tradeable versus non-tradeable. This is called the Balassa-Samuelson effect (Balassa 1964) (see section 2.4).

2.3.1 Australian international trade impacts and shocks

Most of the studies mentioned in the previous section signify two components of terms of trade which are a crucial part of what the relationship signifies. Although the calculation itself is based on the index of prices (Equation 3) and is quantifiable, the composition of exports and imports also plays an imperative role in the effects that terms of trade have. These components are highlighted by global economic activity, and commodity supply and demand of countries and nations.

2.3.2 Identification of terms of trade shocks and their effects

Jaaskela and Smith's (2013) study on the Australian economy over a twenty-six- year period finds that two thirds of the variation seen in the real effective exchange rate movements of the AUD is due to terms of trade shocks. Similar work by Kilian (2009) and Peersman and Van Robays (2009) isolates the reaction of the United States and Euro economy in response to oil price shocks, to note its effect on the real effective exchange rate. Both studies found that the economic response of the exchange rate does in fact rely on the nature of the shock (Kilian 2009, Peersman & Van Robays 2009). Using a benchmark VAR model and considering terms of trade and both export and import price inflation over the long term, three terms of trade shocks are observed and their consequences for the domestic economy are identified. These shocks are: terms of trade world demand shock, terms of trade commodity market-specific shock and globalisation shock (Jaaskela & Smith 2013).

A lift in global economic activity can induce a positive world demand shock associated with an increase in both export and import prices. Due to an overall increase in demand, prices also increase and vice versa. Global economic activity can be assessed by looking at the GDP of a country. This involves the distribution, production and consumption of goods and services around the world and is measured globally (Equation 1). World demand shocks cause a shock to incomes and increase the actual price of the goods in question. This shock is induced by import and export prices, which cause a sudden increase or decrease in demand for goods or services. Demand shocks can be caused by unexpected changes in monetary policy, natural disasters, and global increase in risk and uncertainty. It can also be as simple as a change in market dynamics. In 2004 there was a sharp global increase in the market share of electric cars, and since then the market price for lithium has increased twofold - a demand shock.

Global economic activities can be classified into four basic categories: primary, secondary, tertiary and knowledge sectors. The primary sector is raw materials, which comprises activities of transforming natural resources and raw materials into basic products, including mining, extraction of raw materials, hunting, forestry and agriculture, to name a few.

The secondary sector can be described as manufacturing and industry. This includes both light and heavy industries such as automotive, electrical, food and consumer goods. The composition of the secondary sector can vary significantly from country to country, but this sector forms a substantial part of GDP and plays an important role in stimulating economic growth. Manalo et al.'s (2015) research has a contemporary focus and understanding of this sector, and illustrates significant evidence linking the manufacturing and industry sector and its sensitivity to the real effective exchange rate (Manalo et al. 2015).

The tertiary sector includes the branches of individual human activity that provide services, and therefore provide the value of financial resources, knowledge, infrastructure and goods, to name a few. Representing a large section of the national economy in developed countries, the tertiary sector includes organisation and activities revolving around trade, transport, tourism, education and entertainment (DFAT 2017).

Finally, the knowledge sector, also known as the quaternary sector, is based on the knowledge of highly skilled workers in the economy and also includes R&D being conducted by the country. It is now seen as paramount and necessary for the growth and development of the society and overall national economy (DFAT 2017).

The second key shock identified is commodity specific. This signifies where a positive move in the commodity market can cause a lift in export prices without persuasion from changes in global economic activity (Jaaskela & Smith 2013). (This is discussed in detail in further sections.) This shock occurs as a result of commodity prices shocks, which occur when global commodity prices increase suddenly without expectation (Kilian 2009; Wadsworth & Richardson 2012). Strong growth in commodity prices in recent years has also been linked to the unusually high - and rising - intensity of use of metals in industrialising Asia, which highlighted the third shock - the globalisation shock. This shock has extreme significance in the Australian context, as it captures the integration of emerging economies such as China and India which are having an increasingly notable position in the world market (Jaaskela & Smith 2013). It is mostly attributed to the increasing growth and dominance of China, India and Eastern Europe. In 2007, GDP metal intensities in China were 7.5 times higher than in developed countries and four times higher than in other developing countries (World Bank 2009).

Charnavoki and Dolado's (2014) research in this field identifies the result of experiencing these shocks, especially those effects which are felt in small commodity-exporting economies such as Australia, and other OECD nations (Charnavoki & Dolado 2014). Most importantly, their hypothesis is designed around predictions made earlier by similar studies and aims to further the robustness of the findings. Their main hypothesis, which they prove, includes an external balance effect (Kilian 2009; Rebucci & Spatafora 2009), commodity currency effect (Cashin et al. 2004; Chen & Rogoff 2003), spending effect (Spatafora & Warner 1999) and Dutch disease effect (Cordon & Neary 1982; Spatafora & Warner 1999). Constraints to be noted regarding this empirical evidence are that fluctuations in world commodity prices are considered an exogenous factor. Next, due to not performing reverse causality testing this problem is ignored, and causes an error in findings. To combat the possibility of this error, my study tests for Granger Causal reactions between the exogenous and endogenous variables. Charnavoki and Dolado later revisit their previous study and test for reverse causality, which gives more reliable results. The limitation is due to the large sample size for which the exogenous variables are analysed separately instead of jointly, leaving the question of cointegration and co-reliance largely unanswered. For this reason, this study includes the Granger causality test in the research design and several cointegration tests so that the scope for error is limited as much as possible.

2.3.3 Terms of trade export market specific shock

A discussion from Karagedikli and Price (2012) from the Reserve Bank of New Zealand (RBNZ, 2012) focuses on the significant implications of New Zealand's terms of trade on their economy over a twenty-two-year period from 1987 to 2011. Drawing inspiration from key literature around commodity-based currencies (Chen & Rogoff 2003; Jaaskela 2011; Kilian 2009), Karagedikli & Price (2012) find that the drivers of New Zealand's commodity prices and terms of trade which are specific to New Zealand's own export prices are rare and have little significance for the New Zealand economy. The bulk of import and export price shocks are largely explicated by common shocks that drive them together such as the earlier noted world demand shock, world supply shock and globalisation shock. Globalisation shock (Jaaskela & Smith 2013) captures the entrance of large emerging economies which induce a dynamic shift in global trading partners. Along with Australia, New Zealand also experienced a surge in demand for their exports as a result of growth in demand from China and India. Because of this increase in exports, and therefore net export, the GDP for New Zealand and other OECD nations in this position shoots up (Equation 1). An increase in global GDP pushes the value of the world economy higher as a result. What Karagedikli and Price (2012) witnessed was an appreciation in export prices in New Zealand due to an excess demand for primary products from new entrants in the global marketplace. As a result, this simultaneously decreased New Zealand's import prices due to the entrance of more low-cost manufacturers in other nations (Karagedikli & Price 2012). This is the effect of a terms of trade export market-specific shock.

Table 2.1: Australia's Top 10 goods and services exports, 2018

Australia's Top 10 Goods and Services Exports, 2018 (AUD million)			
Rank	Commodity	Value ($mi)	% Share
1	Coal	6,860	15.3
2	Iron ore and concentrates	3,277	14.4
3	Natural gas	3,298	9.9
4	Education related travel services	5,234	8.0
5	Personal travel services	2,240	5.1
6	Gold	9,137	4.4
7	Aluminium ores and concentrates	1,341	2.6
8	Beef, f.c.c.	8,661	2.0
9	Crude petroleum	8,097	1.8
10	Copper ores and concentrates	5,996	1.4

Table 2.2: Australia's Top 10 goods and services imports, 2018

Australia's Top 10 Goods and Services Imports, 2018 (AUD million)			
Rank	Commodity	Value ($mi)	% Share
1	Personal travel services	4,804	10.8
2	Refined petroleum	25,266	6.1
3	Passenger motor vehicles	22,411	5.4
4	Telecom equipment and parts	14,400	3.5
5	Crude petroleum	13,790	3.3
6	Goods vehicles	10,684	2.6
7	Freight transport services	10,108	2.4
8	Computers	9,686	2.3
9	Passenger transport services	7,339	1.8
10	Medicaments	7,203	1.7

Source: DFAT, 2018

Energy and raw materials are two factors recurring in both imports and exports as variables which have had a strong and stable influence on the exchange rate (Backusab & Crucinic 2000; Chen & Rogoff 2003; Corden 2012; Kilian 2009). These primary commodities can be broken down into iron ore, coal, natural gas, gold and aluminium, and they make up a large percentage of Australia's Top 10 goods and services exports as per table 2.1. Table 2.2 highlights the Top 10 goods and services imports. As much as Australia is a commodity exporter, it is almost just as much a commodity importer as well, with refined petroleum and crude petroleum being in the Top 10 imports as they are not locally available in abundance.

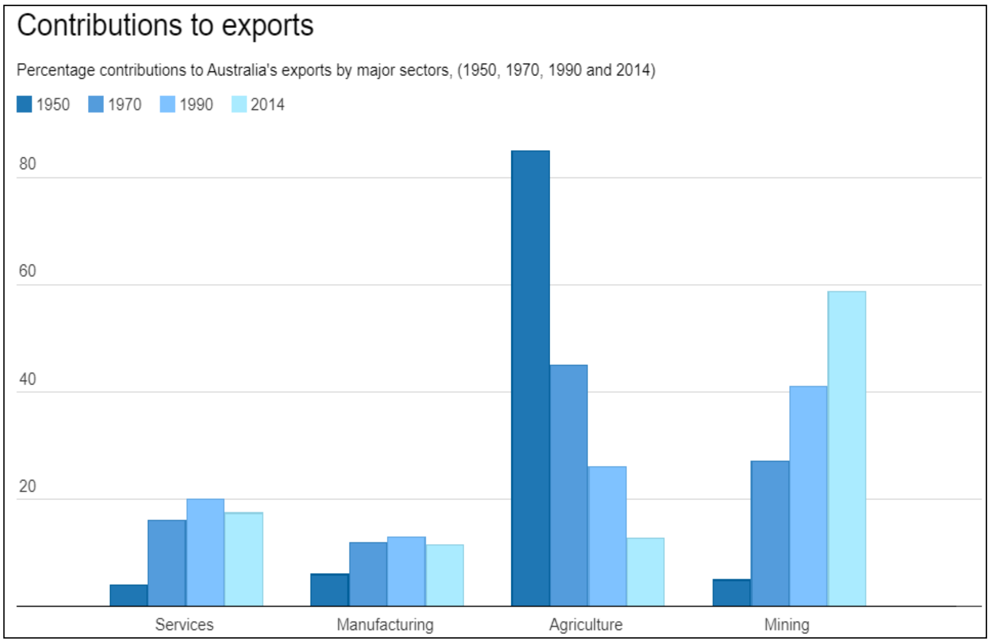


Figure 2.8 Sectorial contributions to Australian exports

Source: ABS 2018

The importance of commodity-specific shocks (Jaaskela & Smith 2013) and the relevance of this, considering Australia's export composition, takes us to the next section. Here, I review literature which focuses on commodity-specific terms of trade. It is evident based on the literature discussed in the previous section that many researchers over the last decade have established robust empirical evidence for the correlation of terms of trade, the real effective exchange rate in a small, open economy model.

2.3.4 Commodity terms of trade

The importance of trade for the prosperity of a commodity-rich economy has been well established over the last century. Many strands of contemporary literature such as in the previous section have studied international trade and globalisation and its benefits on modern economies.

Many studies in this field focus on the trade of crude oil (Chen et al. 2016; Ferraro et al. 2015; Turhan et al. 2014), and relevant oil currencies. Although not as prevalent in the Australian context as compared to other commodities, it presents a range of empirical evidence regarding the relationship of commodities and the exchange rate (Brahmasrene et al. 2014; Novotny 2012). Countries such as Canada, Saudi Arabia, Russia and Iraq are four of the top exporters of oil globally. Australia appears on this list at number twenty-nine (CIA 2016). Although oil currencies prove extended importance in the role of shifts of their relevant real effective exchange rates, their shifts involve several exogenous factors that are well and truly beyond the scope of this study. Nevertheless, this highlights the necessity to understand the relationship of highly traded commodities with floating prices.

Changes in commodity prices affect the volume of goods exported or imported. Australia's exports have been argued to be the catalyst for the majority of the shifts in the exchange rate in comparison to its imports, which can be seen in the saturation of studies discussing the former rather than the latter. The import sector is not largely skewed towards a specific industry. It is distributed almost evenly among primary commodities, travel, and transport and technology advancements, to some extent. There is robust empirical evidence that uses time series data and highlights that export prices of twenty-three similar OECD countries, including Australia, accounted for 46% and 65% of exchange rate fluctuations on average in the short and long term respectively. However, once analysed in more detail, these pass-through shifts are in the majority contributed to by the energy and raw materials sector (Barhoumi 2006; Campa & Goldberg 2008). Commodities traded are also accompanied by agricultural goods such as wheat and beef, and service exports such as travel, education and other professional services (Table 2.1). The spotlight remains on commodities though, as it is a sector which has seen the most growth over the last two decades and therefore has a larger weighting to influence terms of trade (Cole & Nightingale 2016; Tulip 2014).

This applies to both developed (Amano & Van Norden 1998; Chen & Rogoff 2003) and developing nations (Bodart et al. 2012; Cashin et al. 2004; Coudert et al. 2015). There are two key justifications that explain the interest in the relationship between commodity price and exchange rates. First, it is evident that the change in commodity price leads to a shift in exchange of the respective commodity currency (Chen et al. 2016; Chen & Rogoff 2003). Secondly, exchange rates enable market participants to predict expected changes in the commodity price market. This study focuses on the first justification, which suggests that commodity price should enable the prediction of the exchange rate, and the latter implies an opposite relationship. This study focuses on the initial relationship by incorporating reverse causality testing in the analysis section (Zhang et al. 2016).

Top 15 exports of goods and services 2016-17

		A$ bn	Share (%)
1	Iron ores & concentrates	62.8	16.8
2	Coal	54.3	14.5
3	Education-related travel services	28.0	7.5
4	Natural gas	22.3	6.0
5	Personal travel (excl education) services	21.7	5.8
6	Gold	19.0	5.1
7	Aluminium ores & conc (incl alumina)	7.5	2.0
8	Beef, f.c.f.	7.1	1.9
9	Wheat	6.1	1.6
10	Crude petroleum	5.2	1.4
11	Professional services	4.8	1.3
12	Copper ores & concentrates	4.6	1.2
13	Technical & other business services	4.2	1.1
14	Financial services	4.0	1.1
15	Meat (excl beef), f.c.f.	3.8	1.0
	Subtotal	*255.3*	*68.4*
	Total all countries	373.2	100.0
	Education	*28.6*	*7.7*
	Tourism satellite account	*37.2*	*10.0*

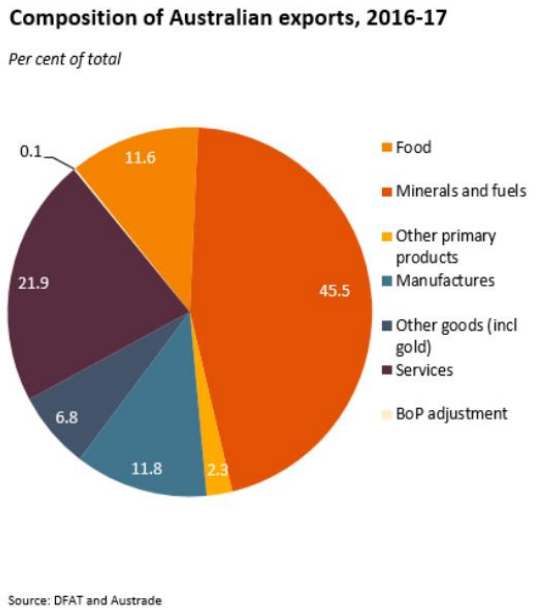


Figure 2.9 Australia's Top 15 exports, 2016--17

Source: DFAT 2017

Countries such as New Zealand and Canada are often compared alongside Australia's commodity currencies, due to their activeness in international trade and integration in global capital markets. In line with other findings, these nations have furthered the evidence that there is a positive cointegration between commodity prices and strength of local currency (Cashin et al. 2004; Chen & Rogoff 2002; Clements & Fry 2008). This frequently observed behaviour of exchange rate fluctuations and commodity prices ties back into the validity of the PPP Puzzle in long term foreign exchange market behaviour.

Chen and Rogoff's (2003) extensive study concentrated on three developed commodity-exporting nations that are a part of the OECD: Canada, New Zealand and Australia. Due to similarities in characteristics the purpose of their study was to investigate and understand the determinants of their respective exchange rates. They found that Australia and New Zealand reacted strongly to commodity prices, but the result was weaker for Canada because the diversification of its exports is structured differently. Oil is a primary commodity in many nations, and especially in Canada. A Czech study in 2012 found an inverse relationship between the price of crude oil and the USD, establishing that for every 1% the oil price rose, the exchange rate diminished by 2.1% (Novotny 2012). If we take the US, for example, oil represents a persuasive commodity currency which opens up to an entirely different and vast strand of literature debating the impacts of oil price shocks (Lizardo & Mollick 2010). Australian literature disregards the notion of oil price shocks as it is not relevant in Australia (Jaaskela & Smith 2013; Kilian, 2009; Peersman & Van Robays 2009). This is the opposite in Canada, as oil makes up most of its major primary commodity exports.

Ferraro et al.'s empirical study of the short term relationship, tested on a daily basis, between changes in the country's nominal exchange rate and the price of its major commodity exports witnesses a strong positive relationship in the short term. However, this study does not find any robust evidence of the same strong positive relationship when tested over a longer period (Ferraro et al. 2015). This study further supports empirical evidence provided by Chen (2010) that commodity prices are not able to predict the exchange rate when tested at the same frequency. Though Ferraro et al.'s (2015) results are consistent with Chen and Rogoff (2003) there are two notable differences. First, Chen and Rogoff (2003) and Chen (2010) utilise commodity indices as opposed to Ferraro et al. (2015). The latter study utilises commodity prices against the exchange rate. This has an implication for the magnitude of results, but not so much on the results of the existence of a correlation between the two variables itself. Secondly, Chen and Rogoff (2003) conduct an in-sample analysis at a quarterly frequency and conclude that commodity prices demonstrate a strong and stable influence on the real effective exchange rates of New Zealand and Australia, but not for Canada. Ferraro et al. (2015) also conduct an in-sample analysis, which confirms Chen and Rogoff's (2003) results. However, the out-of-sample results eventually depend on the frequency of testing, which is different. At the quarterly frequency, which is the same frequency considered by Chen and Rogoff (2003), there is no evidence of a relationship between commodity prices and exchanges rates in terms of out-of-sample fit. Thirdly, Chen and Rogoff (2003) found that for Canada, commodities other than oil show more evidence of in-sample predictive evidence when the energy sector is included.

After further testing, Ferraro et al. (2015) established the major difference between their study and that of Chen and Rogoff's (2003): it is not a matter of frequency of testing, but in fact the nature of the data being in-sample as opposed to out-of-sample, and the data used being the oil commodity versus non-oil commodities. In addition, Chen and Rogoff utilise the price index of exported commodities instead of price. The index is calculated based on a fixed weighting and poses further scope for the validity of data to be used for testing exchange rate determination.

Additionally, Chen and Rogoff's study was extended by Cashin et al. (2004), who conducted a similar study across not only OECD countries but 58 countries worldwide (Cashin et al. 2004). The countries examined were all commodity-exporting nations and similar cointegration testing found that a third showed a positive relationship between commodity terms of trade and the real effective exchange rate. Commodity terms of trade are calculated as the ratio of commodity export price to commodity import price, both terms of the ratio being an average weighted by the commodities specifically exported and imported by each country (Choudhri & Schembri 2014; Coudert et al. 2011; Ferraro et al. 2015).

$$Commodity\ Terms\ of\ Trade = \frac{Index\ of\ Commodity\ Export\ Prices}{Index\ of\ Commodity\ Import\ Prices} \times 100 \qquad (4)$$

Manalo et al. (2015) presented a model suggesting that without an appreciation of the terms of trade along with the growth of net foreign assets overseas, there is not a rise in the real effective exchange rate. Atkin & Connolly's (2013) examination on behalf of the RBA of economic performance of small, open commodity-exporting economies over a ten-year period supports this work. Their study found that economies such as Australia, Canada, New Zealand and South Africa, all of which fit this category, have undergone periods in which an increase in relative commodity export prices, (which result in a similar fashion) have exhibited a positive rise in both real and nominal exchange rates (Atkin & Connolly 2013; Manalo et al. 2015; RBA 2013).

Zhang and McDonald's (2014) journal article complements Manalo et al.'s by finding a means of estimating the equilibrium exchange rates for twenty-three OECD countries across the globe. They relate their significant finding (i.e. a negative relationship between the real effective exchange rates and the trade balance) to Manalo et al.'s (2014) focus on a sectoral study of the Australian economy. Their empirical evidence provides strong evidence that an appreciation of the trade balance due to an increase in net exports in turn causes the real effective exchange rate to appreciate. A major contribution to this study is the breakdown of the real effective exchange rate into two aspects: the negative long-term relationship between trade balance and net foreign assets and negative relationship.

For countries which illustrated a significant correlation in Cashin's study, based on an improvement in terms of trade of 10%, an average increase of 4-6.5% was evident in the exchange rate. The study also found an average elasticity of 0.5% between terms of trade and the exchange rate (Cashin et al. 2004; Coudert et al. 2011; Ricci et al. 2008).

2.4 PPP and the Balassa-Samuelson effect

As mentioned in the introduction, PPP (as per Equation 2) has continued to influence many open macroeconomic models and is also present in many models of exchange rate determination. The debate surrounding the validity of PPP has been a topic of interest in recent years in developed countries due to the availability of longer term series of data than was previously available, and this has assisted the development in panel data and reinterpreted PPP theory (Cayen et al. 2010; Drine 2008; Froot & Rogoff 1995; Rogoff 1996). Despite the prominence of PPP in many macroeconomic models, the fact remains that there are mixed findings regarding its validity. These macroeconomic models include the Law of One Price (LOOP), Big Mac Index, iPad Index, KFC Index, and pricing of gasoline (Big Mac Index 2017; Bloomberg 2016; Commsec 2013). There is a considerable number of findings which prove the failure of PPP for traded goods (Canzoneri et al. 1999; Devereux & Engel 1999; Macdonald & Ricci 2005; Macdonald & Ricci 2007). However, the overall belief that PPP does in fact hold is prominent for periods of more than five years. This finding is backed by research which shows that in the short term, prices are far more prone to deviations caused by shock announcements and unprecedented events (Taylor 1988; Kilian & Taylor 2004).

The recent literature which studies the relationship between PPP in a non-stationary panel data revisits three factors: the importance of reinterpreting the PPP theory, availability of the long term data series, and development in testing methods in panel data econometrics. The hypothesis of the real effective exchange rate following a random walk model is rejected when tested in the long term. On the other hand, the real effective exchange rate returns to its PPP equilibrium despite observing deviations caused by potential global shocks of nature, including (but not limited to) global growth shocks, economic activity shocks and change in commodity shocks. These studies also highlight the effect of the Balassa-Samuelson effect (Bordo et al. 2017; Chong et al. 2012; Drine 2008; Macdonald & Ricci 2005). The Balassa-Samuelson effect is in essence a productivity-biased PPP. Balassa's original study in 1964 highlights the importance of the price of tradeable and non-tradeable goods (Balassa 1964). Goods such as agriculture, mining and manufacturing are classically categorised as most tradeable, whereas goods such as construction, consumables, real estate and personal services are categorised as non-tradeable. One of the drawbacks Manalo et al.'s (2015) study faced was testing key factors which determine the tradeability or non-tradeability of goods, such as transport cost, which can cause barriers to trade and trade protectionism (Bahmani-Oskooee & Nasir 2005; Balassa 1964; Bordo et al. 2017; Gregorio & Wolf. 1994). In their process of testing sensitivities of these goods against the real effective exchange rate , the results are not adjusted for the Balassa-Samuelson effect as some goods are tradeable as opposed to others.

The Balassa-Samuelson effect fundamentally predicts that a gain in GDP due to traded goods does not lead to much of an appreciation in an equal increase of non-tradeable goods. This characteristic is attributable to the Consumer Price Index (CPI) increasing more than the other in one case (Bordo et al. 2017). The majority of empirical evidence and cross-section tests show support for the Balassa-Samuelson effect using panel data results from many countries. However, there has been ongoing controversy in the interpretation of the evidence to prove co-integration between relative productivity from tradeable and non-tradeable goods and the real effective exchange rate (Burnstein & Gopinath 2014).

Other empirical evidence and analysis of the Balassa-Samuelson effect is implemented based on three key assumptions (Drine & Rault 2006; Egert et al. 2006): it is assumed that a positive correlation exists for the differential of productivity between tradeable and non-tradeable sectors and their relative prices; the PPP assumption is strong and robust for tradeable goods; and finally, there is a positive correlation between the real effective exchange rate and relative prices of non-tradeable goods. When administering these assumptions, the empirical evidence points towards a positive correlation between productivity differentials and the real effective exchange rate in the long term (Drine & Rault 2002; Egert et al. 2006).

Bringing it back to PPP, the theory implies the exchange rate needs to be stationary. This implies that deviations from the real effective exchange rate are only temporary, and persistent frequent deviations from the real effective exchange rate equilibrium cannot exist. In this case PPP exemplifies reasonable prediction to long term exchange rate behaviour. However, the empirical evidence regarding this approximation does not have definite findings. Gil-Alana and Toro (2002), Tawadros (2002), Parikh and Walkerly (2000) and Bahmani-Oskooee and Wu (2017) found empirical evidence in favour of long term PPP theory, whereas Bahmani-Oskooee et al. (2016), Kilian and Taylor (2004) and Fleissig and Strauss (2000) rejected it. The Balassa-Samuelson effect hypothesis, which attempts to justify the persistence deviations of the real effective exchange rate, characteristically focuses on the actual tradeability of the goods in question (Bordo et al. 2017). Bordo et al.'s (2017) study extends the literature on the Balassa-Samuelson effect by investigating a channel, which does not incorporate non-tradable goods. By exploring the terms of trade channel, the Balassa-Samuelson effect is able to explain the real effective exchange rate behaving persistently. Furthermore, Sheng and Xu (2011) and Gubier and Sax (2019) test a similar TOT adjustment. These authors find empirical evidence that accounts for TOT that reverse the Balassa-Samuelson effect. This continues to assume only tradeable goods (Bordo et al. 2017; Gubier & Sax 2019; Sheng & Xu 2011).

The Balassa-Samuelson effect is reactive to two variables. First, elasticity of substitution between goods available domestically and foreign traded goods, and second, the differential in the actual share of consumption of traded goods domestically and internationally. Changes in the value of substitution elasticity and differentials in the share of goods in different nations can cause variation in calculating PPP based REER (Bordo et al. 2017; Choudri & Schembri 2010). This ultimately disrupts the extent to which terms of trade shift in response to global and domestic productivity shocks, and the calculation of the real effective exchange rate (see Chapter 4). These are important parameters for considering the underlying model of my cointegration analysis. It further reinforces using terms of trade to combat issues faced with tradeability of goods in question, when looking at the real effective exchange rate in addition to the unanswered PPP Puzzle.

2.5 Australia's commodity exports

To develop an understanding of Australia's top 5 exports (by % share) they are(in descending order: iron ore and concentrates (16%), coal (14.8%), natural gas (6.6%), gold (4.6%) and aluminium (2.2%) (DFAT 2017). Commodity currencies are named as such due to their relationship with said commodities. To develop the foundation of this research question and to understand the basis, this study focuses on commodity-specific terms of trade. After the 2008 GFC many countries apart from the US and the Eurozone fared particularly well due to commodity exports. Due to this flux of global macroeconomic change, the prices of commodities varied as well (Bahmani-Oskooee et al. 2013). As an open economy which exports a commodity in large volumes, the exchange rate should reflect commodity prices of these movements due to their direct impact on Australia's prosperity and economy.

2.5.1 Iron ore and commodity currencies

The history of the Australian iron ore trade dates from the 1950s to the initial trade partnership between Australia and Japan. Since 1957 however, the dynamic of how this commodity is produced, priced, transported and negotiated has advanced to a large extent. Furthermore, now the recipient of 80% to 85% of Australia's iron ore production is China, due to its increasing steel production. Jeffrey D. Wilson (2012) investigates shifts in the Asia-Pacific market price for iron ore which increased as a result of the expansion of China's steel industry since 2000. The determination of iron ore prices before 2010 was simply decided between purchasers and sellers as one-year fixed-term contracts. This differs from commodities such as copper, gold or crude oil which have had a floating price since the late 1990s and early 2000s. Post 2010, and due to China's heightened demand, the iron ore price is determined by the Steel Index as a result of supply and demand daily at 11:00 a.m. Greenwich Mean Time (Wilson 2012). The pricing of iron ore, both past and future, is discussed further in Sukagawa's (2010) study.

Brazil is a large player in the world export market. Second to Australia in iron ore exports, some of its other large exports include coffee, cocoa, livestock and other agricultural products. The recipient of many of these products is the US. An in-depth 2013 study, which analyses how exports and imports between Brazil and the US affect the exchange rate risk, uses cointegration analysis (Sukagawa 2010). Over a thirty-nine year study period the results are a mixed bag, with the majority of cointegration found in the agricultural sector. Other industries which also offered a robust cointegration with the real effective exchange rate movement were gold and non-ferrous metals such as aluminium, brass, lead and zinc. Contrasting with other studies (Apergis 2014; Ferraro et al. 2015), iron ore and other mining exports do not indicate levels of significance in relation to the Brazilian real/ USD real effective exchange rate and real volatility in comparison with the agricultural sector (Bahmani-Oskooee et al. 2013). A thorough research article from 2015 used extensive time series analysis to understand the relationship between the AUD/USD and iron ore prices over the span of eight years (Haque & Lilford 2015). Using different unit root tests (i.e. the ADF and DF-GLS to check for stationarity and the Johansen cointegration model to suit the multivariate autoregressive model), the results indicated a positive correlation between the two variables. They found that iron ore prices were positively responsible for 0.31% of each 1% appreciation of the exchange rate and a significant r-squared outcome of 0.32 (Haque & Lilford 2015). (This research paper is of paramount inspiration for this study.)

2.5.2 Gold and commodity currencies

Australia's history of gold mining began in the late 1800s and mining has continued to boom, making Australia the world's second largest gold producer after China. Numerous studies have analysed the prominence of gold in circulation from currency to the highly traded 'safe haven' commodity as it is now. Another study over 12 years breaks down the link between the predictability of gold and the AUD (Apergis 2014). As Australia's fourth largest commodity export, Apergis delves into the forecasting potential of gold prices in AUD for the AUD/USD REER and finds an orderly connection between the two variables. This study complements literature that employs commodity prices to predict exchange rates (Chen et al. 2010) by using a Vector Error Correction Model (VECM) in conjunction with an autoregressive OLS estimator and DF-GLS test with out-of-sample predictions. A similar methodological model used by Han et al. (2012) proposes utilising an interval testing model instead of the more popular point method, which is used in most literature. By using an interval testing model, the authors are able to implement the data in terms of intervals which result in increased robustness of the significance level (Han et al. 2012). While the data span is shorter, from 2002 to 2008, it is found that the relationship between gold and the exchange rate over the long term is positive despite the infrequency of data. Secondly, when tested over lower frequencies, the price of gold tends to have a more powerful effect on changes in the exchange rate (Han et al. 2012), although over a shorter term this may be due to exogenous factors and shocks due to the recognition of gold globally as a safe haven currency (as previously mentioned). These exogenous factors are later noted and included by Haque and Lilford (2015), including the effects of terms of trade shocks and differentials in interest rates between Australia and the US and currency pairs attribute as a 'carry trade'. In addition to studying the relationship between iron ore prices and the exchange rate, Haque and Lilford (2015) also investigate a similar integration in gold price, this time, however, using longer time data at weekly intervals. This study reinforced Apergis' findings (2014).

In the past, gold has withstood losses during high inflation, political conflict and war. This sense of risk aversion exhibited by gold in these periods saw gold boom, but its appreciation was limited with strengthening stock prices and a booming local currency (Sujit & Kumar 2011). Due to this relationship studies have found that the real effective exchange rate may Granger cause the gold price index. No Granger causality test was performed by Han et al. (2012) to study not only long term information but also short term, using interval testing so as not to omit significant moves in gold and exchange rate prices during intervals such as daily and weekly testing. They were able to confirm that whatever the timeframe the relationship remained positive; however, it is unclear due to lack of causality testing whether the nominal exchange rate affected gold prices (Han et al. 2012).

2.5.3 Coal, aluminium and natural gas

Energy and fuel commodities such as oil, coal and natural gas attract investors due to their numerous industrial applications and revenue generating characteristics. Coal generates over 40% of the world's electricity and is used by many of the developing countries such as China in order to produce steel. Natural gas is also the leading energy commodity for power generation.

The study of energy commodity prices in relation to the real effective exchange rate for commodity-exporting nations has proved their importance in the role they play in the economy. However, Dauvin's (2013) study finds that oil is the dominant endogenous variable which causes these shifts in the exchange rate. Utilising annual data, and 31 years of the panel cointegration method from 1980 to 2011, Dauvin's study found a positive relationship in the long term for energy- and commodity-exporting countries, between energy prices and currency appreciation. Overall, the pattern demonstrated that an increase of 10% in the price of energy caused a 2.5% rise in the currency price. However, the study also noted a threshold beyond which there was no reaction to the price, and this threshold was maintained by the price of oil (Dauvin 2014; Lizardo & Mollick 2010). Aside from the effect that 'oil currencies' have on the exchange rate, other energy commodities do in fact play a role in this relationship and my research question will explore this in more detail.

The final commodity is aluminium. This durable, strong metal has numerous domestic uses as well as high grade aeronautical and aircraft manufacturing application. There is a lack of research in reviewing the impact of aluminium prices, as unlike other commodities it is a consumable good rather than a commodity which generates further energy.

2.6 Literature review summary

A summary of the key literature highlighted in this chapter is summarised below. These are the key articles and research findings which contribute towards the development of my research questions and hypothesis.

Table 2.3 Summary of Key Literature Review

Citation	Key Variables Used	Limitation of the Study	Summary
Otto (2003)	Terms of Trade, Real Output and Trade Balance	This study provides us with a theoretical foundation, however, is not a current study.	Otto (2003) finds that nations which have a large primary export sector react to their shifts in terms of trade. Where the terms of trade shock is positive, there is also an increase in the countries' trade balance. This is the case for both Australia and New Zealand. This study implements an ADF Unit root test, and standard VAR model.
Cashin et al (2004)	Real exchange rate, and the Real Price of Commodity Exports	This study provides a theoretical foundation, however, is not a current study.	This study finds that the long term real commodity prices justify one third of the long term shifts in the real exchange rate for developed nations which export commodities. The author implements a VECM model and Granger test for causality. Developing nations show evidence of reverse causality as their exchange rate shows more dominance over dictating the long term price of commodities in their currency. This study employs OLS regression analysis.
Chen & Rogoff (2003)	Australian, New Zealand and Canadian commodity price index. AUD/USD, NZD/USD and CAD/USD exchange rate		For OECD countries such as Australia, New Zealand and Canada, Chen and Rogoff (2003) find evidence to suggest the overall world commodity exports influence the exchange rate significantly. They implement OLS Regression analysis and ADF Unit root test. For elasticity they use the Hodrick-Prescott test, and Durbin-Watson for Correlation.

Akram (2009)	Industrial production logs, real price of crude oil, food, metals, industrial raw materials, real interest rate and real exchange rate for OECD nations		Akram's (2009) study is a key foundation for this thesis. He establishes that when the interest rate decreases, the commodity price increases. Further, the changes in the interest rate and exchange rate are caused by fluctuations in commodity prices and changes in the commodity prices are caused by a shock to the exchange rate and real interest rate. There is reverse causality between the price of commodities and the real exchange rate. The author uses a standard VAR model and adjusts for lag.
Kumar (2011)	Stock market returns, price of gold, price of oil, real exchange rate	This study does not highlight the long-term relationship between the variables.	Kumar (2011) finds that the gold price and the exchange rate have a bidirectional relationship. A similar relationship is found between the price of oil and the exchange rate. The author concentrates on the USD and finds that the gold price has the largest impact of a 10% variance in the dollar. He implements an ADF unit root test, standard VAR model and Johansen cointegration test. Further, he tests for impulse response function as well.
Han et al. (2012)	Price of gold, AUD/USD nominal exchange rate	This study uses the nominal exchange rate and does not perform a Granger causality test.	Han et al. (2012) test this in both short- and long term frequency, finding evidence of a positive long term relationship between the AUD/USD exchange rate and gold price. This relationship is found to be stronger in the lower frequency. The direction of the relationship is not observed as this study does not perform a Granger causality test.
Jaaskela &Smith (2013)	Terms of trade, price of exports, inflation	This study does focuses on terms of trade as a whole and does not pinpoint an industry within which the structural shocks are found.	Using a benchmark VAR model, and Bayesian methodology, Jaaskela & Smith (2013) find that terms of trade explain two thirds of the shift in the exchange rate. They further note that the floating exchange rate acts as a buffer against terms of trade shocks. This is significant as an increase in the terms of trade expands the economy.

Dauvin (2014)	The real exchange rate for energy production countries, the real exchange rate for commodity currencies	Dauvin (2014) focuses on a large group of countries, and the study provides more of an overview as opposed to detailed explanation for each currency. Furthermore, it notes only the long term relationship.	Dauvin (2014) concludes that terms of trade influence change to the real exchange rate depending on whether the oil price of above or below a certain threshold. When the price of oil is below a certain threshold, the terms of trade do not have a similar impact. This is attributed to the Balassa Samuelson Effect. This study implements panel smooth transition regression and a panel cointegration test due to a large number of variables. The study implements the ADF unit root test and a VECM model.
Apergis (2014)	Price of gold, the real exchange rate of AUD/USD	Using the VECM model is preferred for long term relationships. The author does not use the VAR model which is preferred for short term relationships.	Apergis (2014) uses an out-of-sample prediction and finds the results advise that gold prices drive the AUD/USD. This is the case on a daily and quarterly timeframe. This is the case both in the short- and the long term. The author implements the ADF unit root test and a VECM model.
Zhang & MacDonald (2014)	The exchange rate for OECD and developing countries, trade balance, terms of trade		Although this study focuses on net foreign assets and trade balance, the preliminary results indicate that the long term cointegration between the exchange rate and terms of trade is insignificant. They implement the Panel cointegration test and long term regression.
Haque & Lilford (2014)	Price of gold, the Real exchange rate of AUD/USD		Consistent with other studies (Apergis 2014, Han et al, 2012) this study finds the relationship between the exchange rate and gold price is bidirectional in nature. In terms of elasticity, this study finds a 1% increase in gold price causes a positive shift of 0.5% in the exchange rate. They implement methodology consistent with this thesis, using an ADF unit root test, standard VAR model and Johansen cointegration test.

Haque et al. (2014)	Price of iron ore, Real exchange rate of AUD/USD		Haque et al. (2014) find a positive relationship between the price of iron ore and the real exchange rate. The causality is unidirectional, stating the iron ore Granger cause generates changes in the exchange rate. The IRF provides evidence that the iron ore price reacts to shocks to the exchange rate as well. They implement methodology consistent with this thesis, using an ADF unit root test, standard VAR model and Johansen cointegration test.
Ready et al. (2017)	Commodity price index, CPI-adjusted forward rate, CPI-adjusted real exchange rate, GDP		Ready et al. (2017) determine that raw commodity-exporting countries witness an increase in their interest rate. The interest rate differential increases due to returns from carrying trade strategies. They implement cross-sectional panel regression using a GMM method.
Demirer & Belasen (2019)	Crude oil, copper, gold, coffee commodity index, Future exchange rate against USD for AUD, CAD, NOK, NZD, BRL, CNP, ZAR, CLP, RUB		Demirer & Belasen (2019) publish a recent study which detects that the relationship of gold prices with the AUD/USD, NZD/USD and ZAR/USD is bidirectional in nature. Exogeneity is an issue, but it is addressed by the price of West Texas oil and Brent oil prices. The strength of the bidirectional causality is more prominent post-GFC. There is an indication based on this evidence that the currency market can be forecasted based on the commodity price index.
Ali & Rahman (2012)	Australia coal exports, AUD/USD exchange rate	Pearson correlation test has limitations, these are addressed in this thesis by using Johansen cointegration.	Ali & Rahman (2012) find the volume of coal exports of Australia has a positive relationship with the AUD/USD exchange rate. This relationship is strengthening with the increase in coal being exported. They use Pearson correlation and use a simple log-linear OLS regression
Ma & Wang (2019)	Price of crude oil, natural gas, steam coal, iron ore; AUD/USD exchange rate RMB/USD exchange rate	This study does not consider the impact of interest rates.	Ma & Wang (2019) find that where the price of commodity increases, the AUD strengthens and RMB price weakens. This relationship is stronger between 2010-2015, in comparison with 2015-2018

Lodha (2017)	USD/INR exchange rate, price of gold and price of crude oil	The VECM model is preferred to test a long term relationship.	This study reveals that there is no long-run interdependence between the price of gold, oil and the exchange rate in the long term. There is evidence which suggests bidirectional Granger causality is present between oil and the exchange rate, and unidirectional relationship from the price of oil to the price of gold.
Lof & Nyberg (2017)	Commodity price index, price of bitcoin and real exchange rate for developed countries	This study looks at a commodity price index as opposed to separate prices for commodities.	Lof & Nyberg (2018) find noncausality between commodity prices and exchange rates, noting that commodity prices do not have predictive capability on the exchange rate, due to the financialisaton of commodities due to speculative trading strategies.
Adam et al. (2018)	IDR/EUR exchange rate, price of rice, price of crude oil	Crude oil is a tradeable asset for speculative purposes, however rice is not. There are many other variables which have not been noted for this study.	Using a similar methodology to my study, this study finds there is no long term cointegration between crude oil prices and the exchange rate. The relationship between the exchange rate and the price of rice is only found within a short term three month period.
Chen et al. (2014)	The commodity price index for 51 commodities in nominal exchange rate terms	This study uses the nominal exchange rate as opposed to using the real exchange rate	This study finds it is the nominal standardised value of the USD which influences the commodity price.

2.7 Chapter summary

The relationship between exchange rates and commodities is not simple, but highly complex. My study of the literature review illustrates the numerous factors at play. Although many studies quantify the positive effect that commodities such as gold, iron ore and overall global commodity prices have on some OECD nations such as Australia and Canada, underlying dynamics such as the tradeability of goods and bidirectional relationships are also important aspects to note. The consistency of literature confirming the significant positive influence terms of trade have on the exchange rate for a commodity-exporting country leads me to believe that, in the following chapters, there is much to investigate in regards to individual factors which impact this relationship by exploring the dynamic of commodity terms of trade to extend this strand of literature.

Chapter 3: Research Design

3.1 Introduction

This chapter is split into three sections. Section 3.1 discusses the development of the research questions and the hypothesis. Section 3.2 discusses the source and description of independent and dependent variables, and also provides the justification and reasoning for selecting the variables. After outlining the data, the research design discusses the methodology being employed in section 3.3. This section describes the methodology and process used for quantitative analysis of the dataset and reviews the conception of these methodologies and their necessity in being chosen for implementation in this study. I build a model of this methodology and ensure there is clarity in which steps need to be taken to produce robust results. This study engages both time series and panel data research techniques to investigate the relationship between the real effective exchange rate with commodity terms of trade and prices in Australia.

3.2 Research questions and hypotheses

This chapter presents the research questions and hypotheses which are established as a result of reviewing the current literature. By studying the existing literature on commodities and terms of trade for export-heavy countries, I have developed two sets of research questions to contribute and extend current knowledge and findings in this field. Given that there are many microeconomic and macroeconomic determinants of exchange, the key aim of the research is to investigate the effect of commodity terms of trade for Australia on the AUD/USD real effective exchange rate and further this understanding regarding Australia's top five commodity exports. This constitutes the scope of the research questions and the objectives outlined in the two research questions.

3.3 Development of research questions

Chapter 2 notes a positive relationship between increasing terms of trade index and domestic currency strength. This study extends this finding in order to provide further evidence to support the relationship between not only terms of trade, but commodity terms of trade with contemporary data. RQ1 aims to understand the extent of the relationship between commodity terms of trade and the real effective exchange rate. The twenty-year period examined captures two important events: the mining boom and the Global Financial Crisis (GFC). The mining boom witnessed a spike in demand shock, and the GFC saw a deceleration in global growth. Despite these events, there has been an overall steadiness in the growth of commodity terms of trade from Australia to its trading partners.

RQ2 is founded on the basis that as a small, open commodity exporting nation, Australia is highly dependent on its exports for economic prosperity and the strength of its currency. For this reason, this study isolates Australia's five largest commodities by volume and measures them by their price/USD to capture their influence on the exchange rate. Secondly, by focusing on these commodities the study addresses and compares qualitatively which commodities have an impact on the real effective exchange rate. This research compares the largest exported commodities by volume and price for Australia.

The literature review further highlights limited contemporary literature that focuses on individual commodities (Chen et al. 2014; Lof & Nyberg 2017; Ready at al. 2017). Although the overall understanding of both the commodity index and commodity-exporting nations is essential in building the underlying foundation of these variables, it is also necessary and useful to analyse the commodities individually. The second research question addresses this gap. The research questions are outlined in the next section.

3.3.1 Research questions

RQ1: Does the Australian commodity terms of trade influence the AUD/USD real effective exchange rate over the long term?

The hypotheses for RQ1 are:

Null Hypothesis H_0: Australia's commodity terms of trade do not influence the AUD/USD real effective exchange rate.

Alternative Hypothesis H_1: Australia's commodity terms of trade do influence the AUD/USD real effective exchange rate.

The second research question initially explores the causality of the relationship. Next, it determines the relationship between Australia's exports and the exchange rate. This is followed by a comparative analysis of the price of five commodities which are iron ore, natural gas, aluminium, coal and gold.

RQ2: Does the price of Australia's five largest raw materials commodity exports influence the AUD/USD real effective exchange rate?

The hypotheses for RQ2 are:

Null Hypothesis H_0: The price of Australia's five largest raw materials commodity exports does not influence the AUD/USD real effective exchange rate.

Alternative Hypothesis H_1: The price of Australia's five largest raw materials commodity exports does influence the AUD/USD real effective exchange rate.

3.4 Data

This section discusses the variables used for this thesis and describes the source of the data, the reason for selection and the description of the data. I discuss the descriptive statistics for independent and dependent variables and conduct a trend analysis to highlight initial observations of the data.

3.4.1 Variables

To investigate the relationship between the exchange rate and commodity terms of trade (RQ1), previous studies use a basic model that includes only two variables: the real effective exchange rate and commodity terms of trade (Jaaskela & Smith 2013, Otto 2003). In order to examine the second relationship between the exchange rate and commodity prices in a similar fashion, most studies simply look at the exchange rate and the commodity price.

The two main variables used for this thesis, to examine the first relationship, are the real effective exchange rate (AUD/USD REER) and commodity terms of trade (CTOT), weighted appropriately for Australia. To investigate the second relationship, the variables employed are the AUD/USD REER and real commodity prices (RCOMP). A third variable is also accounted for: the real interest rate (RIR). The RIR is included as it has an influence on all variables: AUD/USD REER, CTOT and RCOMP. The significance of the RIR is outlined below:

Real interest rate and real effective exchange rate

The relationship between the real interest rate (RIR) and AUD/USD REER assumes a non-arbitrage environment in which a rise in the RIR results in the appreciation of the domestic currency. This is due to an increase in the demand for a currency with an increasing RIR. Having a higher interest rate makes the currency more attractive for buyers to invest their assets, as it allows them to generate a higher yield and gain a higher carrying rate. There are numerous studies that confirm the positive relationship between these variables in the long term.

Real interest rate and commodity terms of trade

Generally, studies have discovered that nations which export high volumes of raw commodities tend to exhibit higher interest rates (Akram, 2009). Due to the price of goods exported being influenced by changes in interest rates, where the value of a currency appreciates due to a rise in the real interest rate, terms of trade are also expected to increase as a result.

Real interest rate and the real commodity price

The effect the RIR has on the price of commodities in inverse to its relationship with the AUD/USD REER. A higher RIR generally has a negative effect on the real price of commodities. The reason for this is found to be the increased cost of holding and carrying inventory for nations. Typically, customers are inclined to purchase commodities when required rather than for increasing their stock inventory. Furthermore, due to commodities being traded extensively in financial markets, when RIR's are increasing there is a visible shift in investment conditions of commodities. In saying this, the observation is for global commodity prices, when looking at commodities individually the results may differ. Nevertheless, it is an important factor to consider.

3.4.2 Data

This study focuses on analysing a twenty-year period between Quarter 1 (January 1997) and Quarter 4 (December 2017) in order to capture recent and relevant long-term characteristics of the floating foreign exchange market. The extant literature finds that many studies found limitations after using time spans which are too short (Bekaert et al. 2007; Chinn & Meredith 2005). Furthermore, this time span encompasses the mining boom experienced by Australia in the early 2000s and notes the globalisation shock felt by Australia as a result of a rise in demand from its trading partners, China and India. It also adds an element of volatility, and risky dynamic market conditions during the GFC of 2007; this allows the results to witness changing market conditions.

The data being used is time series data which allows me to look at actual movements in data over time, as all variables will be of equal quarterly intervals. Over a specified period of time from Quarter 1 (January 1, 1997) to Quarter 4 (December 31, 2017), the variables are recorded at regular quarterly intervals to achieve uniformity in the time series dataset. There is one dependent variable and six independent variables. The dependent variables are the AUD and USD exchange rate, expressed in terms of the real effective exchange rate based on CPI [Equation 3]. The six independent variables are commodity terms of trade, and the price of the following commodities against the USD: iron ore, natural gas, coal, gold and aluminium.

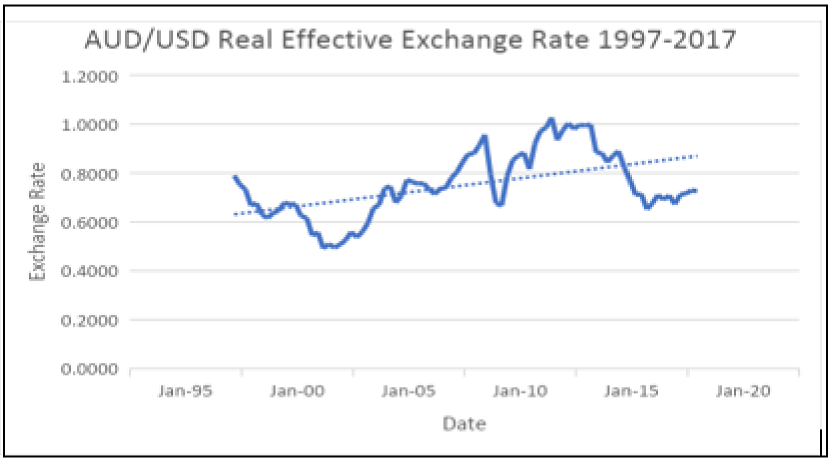
3.4.3 Data source

The data is collected on a daily basis and transformed to quarterly data. To convert the data to quarterly intervals, I use the closing price on the last trading day of each quarter: March, June, September and December. This data is nominal in nature and has been adjusted for CPI to show the real commodity price. This is collected from Quarter 1, which is the last recorded trading day (March 31, 1997) to Quarter 4 (December 31, 2017). The historical prices for these variables have been sourced from different avenues, but all via Index Mundi. The iron ore prices in USD per metric ton and Australian thermal coal prices in USD per metric ton are sourced from Bloomberg. Natural gas prices in USD per Million Metric British thermal unit (MMBtu) are sourced from the Thomson Reuters DataStream, World Bank. The prices for gold in USD per ounce and aluminium in USD per metric ton respectively are derived from the World Bank. The daily data is transformed accordingly to quarterly data, providing a sample size of 84.

3.4.4 Dependent variable – real effective exchange rate

The dependent variable is the quarterly foreign exchange rate of the Australian and USD exchange rate, which has been sourced from the RBA for exchange rates from Q1 (January 1997) to Q4 (December 2017), and from Thomson Reuters for the remainder. The exchange rate is collected at 4:00 p.m. Sydney time with the AUD denoted as the base currency. We are using this specific exchange rate as monetary data is collected in terms of USD, and this will provide uniformity across the board. Furthermore, the USD is the highest traded currency globally, and this AUD/USD pair will reflect shock movements more noticeable than other pairs. The quarterly data is at the end of March (Q1), June (Q2), September (Q3) and December (Q4).

Figure 3.1: AUD/USD real effective exchange rate 1997-2017



The CPI_t and $CPI_t^{(foreign)}$ is the weighted average of the price of a basket of goods and services in Australia and the US respectively. As a function of $CPI_t^{(foreign)} = \prod_{i=1}^{N} CPI(i)_t^{w^{(i)}}$. Here w (*i*) is the US weight. This a geometrically weighted average, as this is the method used most often in literature.

Table 3.1 Summary of statistics for real effective exchange rate

Data	Real Effective Exchange Rate
Mean	0.7500
Standard Error	0.0150
Median	0.7331
Standard Deviation	0.1370
Sample Variance	0.0188
Kurtosis	-0.6301
Skewness	0.1861
Range	0.5346
Minimum	0.4911
Maximum	1.0257
Sum	63
Count	84

To avoid any bias of an undervalued or overvalued exchange rate, I use the real effective exchange rate (AUD/USD REER). Using the AUD/USD REER rather than the nominal exchange rate (NER) allows the exchange rate to be comparable across other countries. This is in line with what is typically used for literature studying the dynamics of the exchange rate. The NER is adjusted for a difference in domestic price levels denoted by the respective CPI to give us the AUD/USD REER (Cashin et al. 2004). It is:

$$REER_t = \frac{NEER_t - CPI_t}{CPI_t^{(foreign)}} \quad (5)$$

Here,

$REER_t$ for AUD/USD is represented as a function of the NER and CPI of the home and foreign country, representing a basket of goods for Australia and the US respectively. Where the Real Effective Exchange Rate (AUD/USD REER) is calculated using the Nominal Effective Exchange Rate (NEER) multiplied by the ratio of the domestic price level (P) against the foreign price level (P*). The descriptive statistics of the real effective exchange rate follow.

$NEER_t$ represents the nominal exchange rate for the AUD/USD, where $NEER_t = \prod_{i=1}^{N} S(i)_t^{w(i)}$, where S(i) is a geometrically weighted average between Australia and the US measuring the USD value for one unit of the AUD (base 1997Q1= 100).

The Real Effective Exchange Rate (AUD/USD REER) for the AUD/USD pair has ranged between \$0.4911 and \$1.0257 in the 20 year period studied in this thesis. Reaching its peak in June 2011, it has since returned to its medium. The line of best fit, which represents the trend, shows an overall growth in the currency pair with a positive slope coefficient. This is a similar observation for five out of six independent variables discussed in the next section.

3.4.5 Independent variables - commodity terms of trade

Using commodity terms of trade as opposed to terms of trade allows the study to capture changes in the prices of imported and exported commodities for Australia. Commodity terms of trade are country-specific for Australia, and this is the independent variable for RQ1. The CTOT is a variation of the TOT function and encompasses the real weighted price of exported commodities against the real price of imported commodities as a geometrically weighted index. It is the ratio of the real effective weighted commodity export prices to weighted real effective commodity prices for Australia at time *t*, as represented below:

$$CTOT_{Australia,t} = \frac{\prod_t (P_e/MUV_t)^{X_{c,t}}}{\prod_t (P_i/MUV_t)^{M_{c,t}}} \quad (6)$$

The individual prices of the commodities exported and imported are represented by P_e and P_i (base 1997Q1= 100) respectively. A deflator MUV_t is used, which is the manufacturing unit value index. $X_{c,t}$ is the allocation of the exports of commodity, *c*, and $M_{c,t}$ is the share of imports of commodity *c* in Australia's GDP. The IMF defines the CTOT as being constant over time, by weighting the share of exports and imports on an average basis. This allows the index to capture fluctuations in the price of commodities instead of the volume traded. Furthermore, by denoting the weighting by share of GDP it reflects the significance of commodities to the Australian economy. The time series data is sourced from Thomson Reuters and transformed from daily data to quarterly data. The descriptive statistics are as follows.

The overall range of commodity terms of trade (CTOT) has remained between 94.27 and 102.48 from March 1997 to December 2017. Despite its troughs and peaks, from 1999 it grew from its low of 94.27 to its peak in 2011. After 2011 there was a considerable drop in the CTOT, with 2015 witnessing the index drop to near 20 year lows. Since then, however, the CTOT has continued to increase moderately. All in all, the trend is positive and deviates minimally from its mean.

Figure 3.2: Australian commodity terms of trade 1997--2017

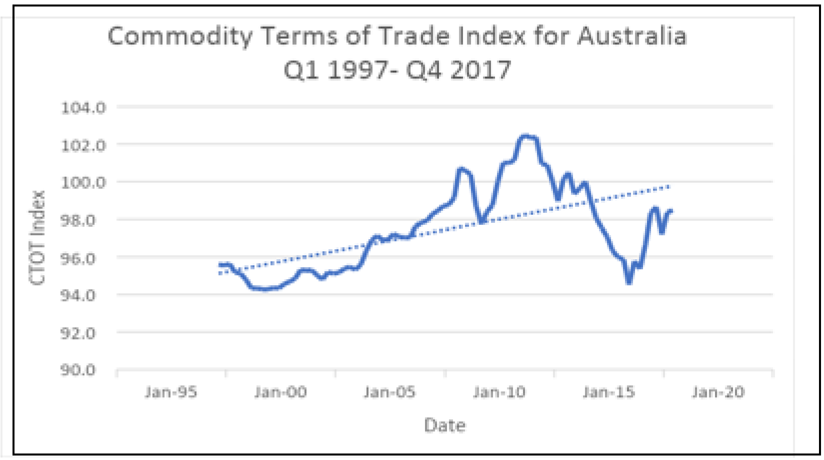


Table 3.2 Summary of statistics for commodity terms of trade

Statistic	Commodity Terms of Trade
Mean	97.4665
Standard Error	0.2553
Median	97.1414
Standard Deviation	2.3263
Sample Variance	5.4117
Kurtosis	-0.8759
Skewness	0.4166
Range	8.2080
Minimum	94.2699
Maximum	102.4779
Sum	8090
Count	84

To evaluate the second research question (RQ2), the five independent variables will focus exclusively on Australian trade and commodity markets and will be measured as per their prices in USD, similar to other literature reviewed.

3.4.6 Independent variables - commodity prices

As opposed to other goods and services which constitute the exports and imports of a country, commodities are fungible. Instead of prices being set by the sellers these commodities are a tradeable asset, with a high liquidity marketplace and significant market capitalisation. As fungible goods, commodities are treated as equivalent regardless of where they were produced or who produced them. Hence, their prices, determined by market forces of supply and demand, are set by market participants and not by exporters.

Australia however, due to its significant involvement in global trade and export of commodities, has higher market power, prominently in relation to iron and coal exports. Countries such as India have a strong impact on the price of cotton, and Brazil, on the price of coffee. Nevertheless, commodity exporting countries such as Australia, New Zealand and Canada are price-takers in the global marketplace (Chan et al. 2000).

Most of the existing literature which studies this relationship between AUD/USD REER and RCOMP uses the commodity price index as opposed to the commodity price. Using the commodity price index is reasonable to use in a panel data approach where cross-sectional data is being tested. Nevertheless, the index is a weighted average of an asset and represents the broad asset class using a basket of goods, rather than its specific value. So although it may be a suitable approach when factoring in the overall price to use the commodity price, in this situation the real commodity price allows this study to better capture the relationship by omitting the use of a 'weighted average' and instead using the exact real price.

Similar to Deaton and Miller (1995), the RCOMP is derived from the nominal commodity price (NCOMP), which is deflated using the US CPI. The NCOMP is as follows:

$$NCOMP_t = \prod_{i=1}^{n} P_{Commodity,,t}^{W_i} \qquad (7)$$

Where n *is* the number of commodities being used, which is 1, as this study looks at one commodity at a time. These commodities are chosen, based on the share of Australia's exports in 2018. Notably, this study oversees data from 1997 to 2017 (base 1997Q1= 100), and the composition of Australia's five largest exports has shifted over twenty years.

Table 3.3 Australia's Top 5 commodities exported in 2018

Australia's Top 5 Commodities Exports, 2018 (AUD million)			
Rank	Commodity	Value ($mi)	% Share
1	Coal	66,860	15.3
2	Iron ore and concentrates	63,277	14.4
3	Natural gas	43,298	9.9
4	Gold	19,137	4.4
5	Aluminium ores and concentrates (including alumina)	11,341	2.6

The selection has been based on data from 2018 so it can capture the growth of these commodities. The composition of Australia's largest exports is obtained from the DFAT database (Figure 1). Of this list, the exported services, such as education related services and travel are omitted, as the study focuses on exported goods. The final list, % share of export and value in AUD million follows as presented in Table 3.3.

Next, in equation 8, P is the price of the commodity against the USD at time t, and W_i is the weighting of the exported commodity i. In order to be consistent with past literature (Cashin, Sespedes, & Sahay 2004) commodity price needs to be reflected in real terms. This is done using a similar method to obtain the real effective exchange rate and deflated using the quarterly US CPI (base 1997Q1= 100). This gives the following relationship:

$$RCOMP_t = \frac{NCOMP_t - CPI_t}{CPI_t^{(foreign)}} \tag{8}$$

3.4.6.1 Iron ore trend analysis

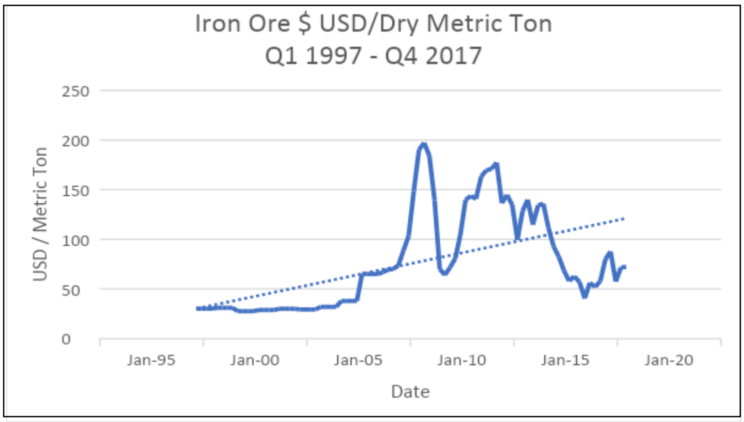


Figure 3.3: Iron ore price USD/dry metric ton 1997-2017

Initially iron ore shows little fluctuation in price. It plateaus for the first six years of the study. However, once the mining boom picked up in 2004 there was a sharp increase in the price of iron ore which climbed from its low of USD 27.90/dry metric ton in 2003 to its peak of USD 197.12 in 2008. Subsequently however, due to slower global growth felt during the GFC, the price plummeted to USD 64.70 within a year. The price has since recovered to USD 170.88 and steadily dropped to just below its mean of USD 72.25. The iron ore price deviated highly from its mean, with a significant standard deviation of 48.93, and the average price has increased overall.

3.4.6.2 Australian thermal coal trend analysis

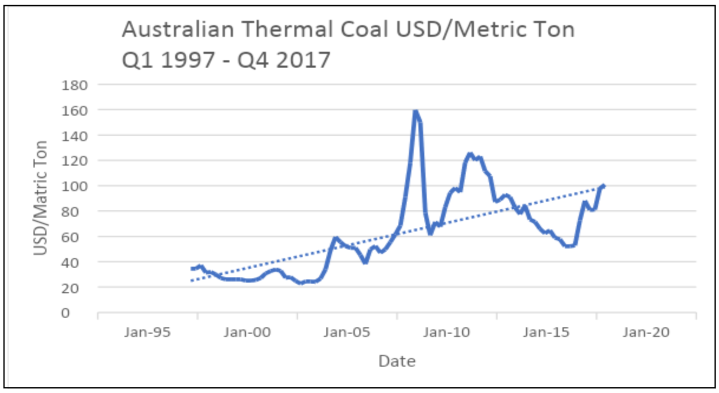


Figure 3.4: Australian thermal coal/USD per metric ton 1997-2017

Like iron ore, coal was impacted by the mining boom in the early 2000s and experienced its highest price of USD 159.75 after a sudden increase in global demand in 2008. Before this sharp increase in price, the trend was already positively steady. Also impacted by the GFC in the years 2008 and 2009, the price plunged to less than half its value to USD 60.25. Coal regained its value steadily in the following years after Australia's secondary mining boom in early 2010 but decreased from those levels in the following years. More recently, in 2016 and 2017 the price of Australian thermal coal has moderately increased, sitting well above its mean of USD 62 at USD 100.81/metric ton.

3.4.6.3 Natural gas trend analysis

Natural gas is the only variable in this study without an overall increase in price from 1997 to 2017. There were three peaks in the price of natural gas in December 2000, December 2005 and June 2008 of USD 8.95, 12.83 and 12.68 respectively. Each plummeted immediately with the price returning close to the mean of USD 4.47 /MMBtu. By observing the graph below, other than short-term increases in price as a result of external factors of supply and demand, the price shows some stationarity by returning to its mean.

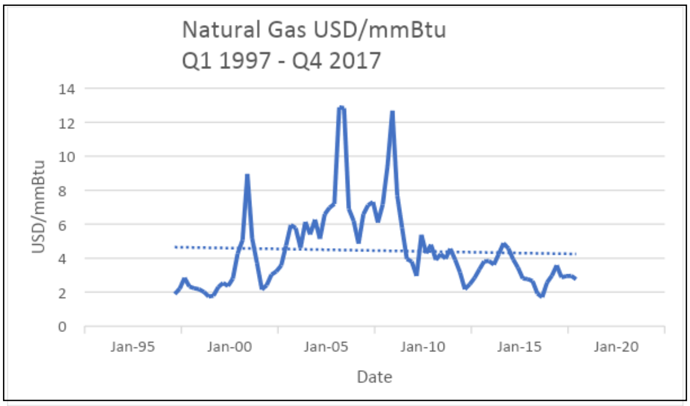


Figure 3.5: Natural gas price USD/mmBTu 1997--2017

This is confirmed in Chapter 5 with the unit root test.

3.4.6.4 Gold trend analysis

The gold price rose over the course of the study, with an overall range of USD 1,510 and a high standard deviation of 483, with the price rarely returning to its mean. From a minimum price of USD 261/troy ounce in June 1999, the price of gold has substantially increased and peaked at USD 1,772 in September 2011. As summarised in the review of past literature, gold is considered a safe haven, and the reason for this strong positive increase in the price can be attributed to many external factors. The trend line has a strong positive coefficient and the gold price sample has the second most fluctuation in price, after aluminium, in terms of range.

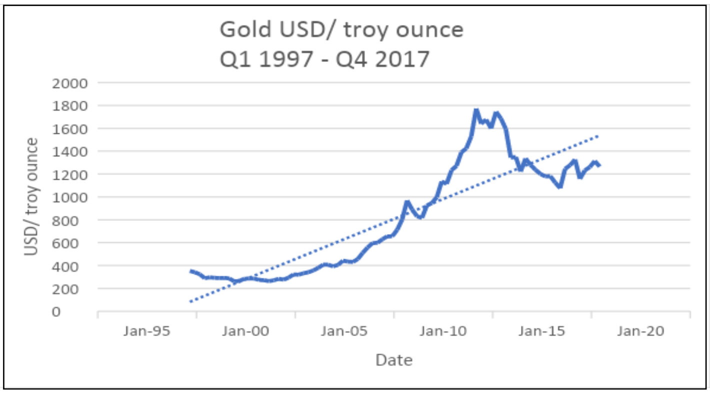


Figure 3.6: Gold price in USD/troy ounce 1997--2017

3.4.6.5 Aluminium trend analysis

The overall trend for the price of aluminium over the twenty-year period is positive. During this period, it reached a low of USD 1,181.59 in December 1999 and a high of US 2957.86 in June 2008. Significant movements can be seen in the early to mid-2000s as it reached its peak, and then plummeted in the second half of 2008 due to the oncoming GFC. Since then, it has recovered from its 2009 low of USD 1,335 and rose to USD 2,080.47 in the last recorded period of this study. The aluminium price has had the highest range in price movement of USD 1,823.70.

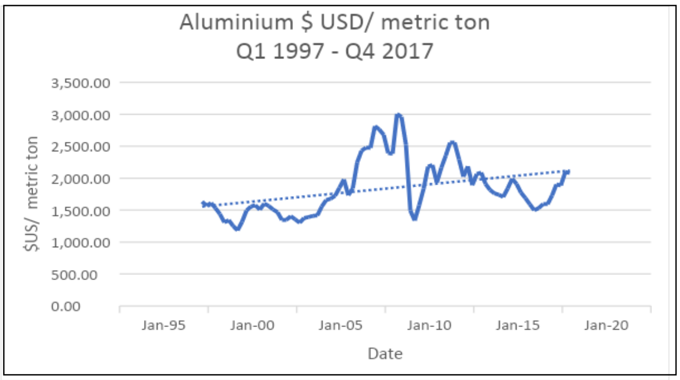


Figure 3.7: Aluminium price USD/metric ton 1997--2017

The descriptive statistics for independent variables follow.

Table 3.4 Summary of statistics for independent variables

	Coal	Natural Gas	Aluminium	Gold	Iron Ore
Mean	62.2253	4.4764	1839.1722	814.90	76.1469
Standard Error	3.5696	0.2627	47.8933	53.07	5.3713
Median	55.3800	3.9000	1731.3000	712.65	65.0000
Standard Deviation	32.5203	2.3936	436.3285	483.52	48.9349
Sample Variance	1057.5718	5.7295	190382.5545	233793.87	2394.6202
Kurtosis	0.0818	3.4704	-0.0913	-1.3465	-0.4348
Skewness	0.7720	1.6837	0.8067	0.3255	0.8554
Range	137.0500	11.1800	1823.7000	1510.8300	169.5300
Minimum	22.7000	1.7000	1181.5900	261.3100	27.5900
Maximum	159.7500	12.8800	3005.2900	1772.1400	197.1200
Sum	5165	372	152651	67637	6320
Count	84	84	84	84	84

3.4.7 Summary of variables analysis

Overall, the AUD/USD REER, CTOT, iron ore, coal, aluminium and gold price all have a positive trend. Natural gas is the sole independent variable which remains very close to its mean through the extended time period, other than three short-lived spikes in price. It does not illustrate a similar trend. The five commodities show little fluctuation and a rise occurred in the price between 1997 and 2004. After this period, when Australia had its mining boom, prices for most commodities increased rapidly and peaked. For all variables, levels remain higher for one to two years before price lowering. The next key observation is the increase in variation of price after the onset of the GFC. After 2008, the levels of all the variables drop, some more significantly than others. The gold price and commodity terms of trade suffer the least depreciation, recovering their losses in the following years quite steadily. The other variables vary in price over the following decade, however they show a positive trend after 2015. Overall, the price trend of the AUD/USD REER and CTOT is similar. There is also a notable resemblance for independent variables, therefore testing and considering the correlation of the independent variables is a key step in the methodology process. In relation to the second research question (RQ2), apart from natural gas the independent variables show similarities in trend with the AUD/USD REER. These relationships will be tested further in the following chapter.

3.5 Research Method

In line with similar studies, this research uses a quantitative approach to test the hypotheses. Three types of analysis are employed: panel data correlation and elasticity testing, time series analysis, and regression analysis. This measures the relationship between AUD/USD REER and RCOMP, and AUD/USD REER and CTOT. The combination of both techniques allows my study to investigate differences in the relationship of my variables in greater depth. These relationships are investigated by employing time series analysis and panel-data technique using eViews econometrics software.

Time series analysis is used to derive statistical results from the dataset and other characteristics, which are interpreted in the analysis chapter. For the time series analysis, the data is tested for a unit root using the Augmented Dickey-Fuller (ADF) and Philips-Perron (PP) for stationarity. Cointegration between the variables is tested next, using the Johansen cointegration model. The third step of the time series analysis employs the Granger causality model to test for a causal relationship both in the short- and long term using a Vector Auto Regressive (VAR) or Vector Error Correction model (VECM).

A panel cointegration test is employed to verify and confirm whether there is a correlation between AUD/USD REER and CTOT, and AUD/USD REER and RCOMP for the five commodities. To test the elasticity of the relationship, a log-linear elasticity method is employed.

3.5.1 Time series analysis

The time series analysis technique is a three-step process, as mentioned above, and this technique is used to test the relationship between AUD/USD REER and CTOT and AUD/USD REER and RCOMP. The procedure is outlined below.

3.5.1.1 Unit root test

The characteristic of time series data is decided by the way it is collected. The data must be collected over uniform intervals of time. To conduct time series analysis, it is important to test the data for stationarity. If the data is not stationary, time series analysis cannot be used. Furthermore, using non-stationary data can manipulate regression analysis if a non-stationary variable is tested against other non-stationary variables. Next, in order to use either the VAR or VEC model to investigate the hypotheses, all variables need to be stationary to identify the optimum lag lengths. Lastly, for non-stationary data, if the variables are cointegrated the OLS estimation would output unreliable results.

Conventionally speaking, in a time series the variable is stationary when its mean and variance are steady and constant over different time periods. The second rule it must fulfil to be stationary is that covariance between two values depends on the tenor or length of time, and not on the actual time when observed. To test for stationarity the ADF and PP unit root test is used. All variables are tested for stationarity.

a. Augmented Dickey-Fuller method (ADF)

The ADF test is the augmented version of the DF test (Dicky & Fuller 1979). The Dickey-Fuller test on its own is adopted when the variables are correlated at the level. The ADF model is given by the following equation, and is only valid when the series is in an AR (1) process (eViews 2019), which is the basic unit root formula as follows:

$$\Delta y_t = \alpha y_{t-1} + \chi_t' \delta + \varepsilon_t \quad (9)$$

In this equation, y_t are the dependent and independent variables where y_t represents the non-stationary series of all variables selected for this study and y approaches infinity with an increase of variance with time if $|p| \geq 1$. When $|p| < 1$, this indicates the variable is stationary. These are the AUD/USD REER, CTOT and RCOMP for the select commodities. These will all be tested for a unit root. α represents 'p-1' where the p value is an estimation parameter, and will justify whether or not I reject the null hypothesis, and $\chi_t'\delta$ is the regressor for when I test for constant, trend, or both. Finally $\varepsilon_{t,}$ assumes the white noise and t is the time Q1 1997 to Q4 2017.

For RQ1 the ADF test is:

$$\Delta REER_{(Q1,1997-Q4,2017)-1} = \alpha y_{(Q1,1997-Q4,2017)-1} + \chi'_{(Q1,1997-Q4,2017)-1}\delta + \varepsilon_{(Q1,1997-Q4,2017)-1} \tag{10}$$

$$\Delta CTOT_{(Q1,1997-Q4,2017)-1} = \alpha y_{(Q1,1997-Q4,2017)-1} + \chi'_{(Q1,1997-Q4,2017)-1}\delta + \varepsilon_{(Q1,1997-Q4,2017)-1} \tag{11}$$

For RQ2 the ADF test remains the same as above for the AUD/USD REER as per Equation 3.6. For the RCOMP all individual prices are tested as per the model below:

$$\Delta RCOMP_{(Iron\ ore,coal,gold,natural\ gas,aluminium)_{(t)-1}} = \alpha y_{(t)-1} + \chi'_{(t)-1}\delta + \varepsilon_{(t)-1} \tag{12}$$

Development of the DF test by MacKinnon (1991, 1996) estimates a larger simulation than the original DF test. The ADF allows for a higher-order lag, whereas the DF test is invalid as it does not assume for the disturbance caused by white noise (eViews 2019). The ADF is a parametric method of controlling serial correlation.

Using Akaike's Information Criteria (AIC), I specify a number of lag lengths to eliminate the chance for serial correlation. The test is carried out using the following regression:

$$\Delta y_t = \alpha y_{t-1} + \chi_t'\delta + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + \cdots + \beta_4 \Delta y_{t-4} + \varepsilon_t \tag{13}$$

In this regression, to test the appropriate lag length y_t denotes the variables being tested. As in the AFD model, α represents 'p-1' where the p value is an estimation parameter and $\chi_t'\delta$ is the regressor for when I test for constant, trend, or both. β_1, β_2…β_4 represent my lag length estimates. I begin with one and test up to the value of four, as I use quarterly data.

For this model the null and alternative hypotheses are:

$$H_o: \alpha = 0$$

$$H_1: \alpha < 0$$

The hypotheses are tested using a t-ratio for α as per below. This is the test statistic for the ADF test:

$$t_\alpha = \frac{\hat{\alpha}}{\left(se(\hat{\alpha})\right)}$$

Here, $\hat{\alpha}$ represents the estimate for α, and the coefficient standard error is written as se.

To confirm stationarity of a variable, the null hypothesis is rejected when t_α is less than the critical value of the ADF test. When t_α is more than the critical value the null hypothesis is accepted, confirming the presence of a unit root. We use the ADF unit root test in line with key studies which implement time series analysis (Apergis 2014, Dauvin 2014, Kumar 2011, Ma & Wang 2019). In order to obtain valid results, I also need appropriate lag selection as a criterion for this test. This is discussed in the following sections.

b. Philips Perron (PP) test

The PP test is a nonparametric method for testing the stationarity of a variable. Here, it is different from the ADF test where the model addresses the unit root by differencing the variables to the first difference for regression suitability.

Based on the ADF test, for this model the null and alternative hypotheses are the same:

$$H_o: \alpha = 0$$

$$H_1: \alpha < 0$$

The guideline to either accept or reject the null hypothesis is similar to that outlined in the previous section. Once the variables are confirmed to be stationary, I test the variables for cointegration. This is discussed next.

3.5.1.2 Johansen cointegration test

The study uses the Johansen cointegration test in order to examine the short term or long term cointegration of the sample date, following Jaaskela and Smith (2013), Kumar (2011) and Haque and Lilford (2014). As a basic rule, when applying a regression model the variables should be stationary. When they are non-stationary there is a possibility of the series having spurious regression. If the variables (such as the AUD/USD REER and RCOMP) are non-stationary at level, their difference is expected to be non-stationary as well, unless only one of these is stationary at level. In a situation such as this, the variables AUD/USD REER and RCOMP are considered to be cointegrated when there is a long term or equilibrium relationship between them (Gujarati 2009).

Based on output from the unit root tests, the Johansen cointegration test is employed between:

a. The AUD/USD REER and the CTOT (Relationship 1)
b. The AUD/USD REER and the RCOMP (iron ore, coal, gold, natural gas and aluminium) (Relationship 2)

These are tested in the same integration order and find the number of independent linear combinations are present for the time series variables with a stationary process. There are two forms of the Johansen cointegration tests: Trace and Maximum Eigenvalue. Both tests are performed in order to produce the robust results outlined below:

a. Trace test

The Trace test t-statistic reports the number of cointegrating relationships between independent variables. This is tested to understand whether there is a notable relationship between the variables themselves. Here the following hypotheses are tested:

$$H_o: k = k_o$$

$$H_1: k > k_o$$

The null hypothesis tests for the number of linear combinations k to be equal to the input value of k_o. This is the null hypothesis and states no cointegration. The alternative hypothesis states cointegration where the quantity of linear combinations is greater than k_o. If the null hypothesis is rejected, there is evidence suggesting at least one cointegrating relationship.

b. Maximum Eigenvalue test

When employing the Johansen cointegration test, the results include a Maximum Eigenvalue result. The Eigenvalue advises if there is any variance in the direction of values. It is similar to the Trace test, but the difference is in the alternative hypothesis:

$$H_o: k = k_o$$

$$H_1: k > k_o + 1$$

The null hypothesis $H_o: k = k_o$ implies there is no cointegration between variables. In this case, the alternative hypothesis $k > k_o + 1$ states there is only one linear combination of the variables in their non-stationary form to be stationary. The result from this test, as noted in eViews (2019), may conflict with the trace statistic. If there is more than one linear combination where there is cointegration, the test may be less powerful than the trace test.

3.5.1.3 Cointegration equation

The second step of my time series analysis is estimating the long term equilibrium of the relationship between the variables using the OLS method. If there is evidence of cointegration in the Johansen cointegration test using the trace or Maximum Eigenvalue test, the following model will measure:

$$REER_{\frac{AUD}{USDt}} = \alpha + \beta CTOT_{Australia,t} + \beta RIR_{Australia,t} + \varepsilon_{it} \tag{14}$$

β, the coefficient, measures the elasticity of the AUD/USD REER relating to the CTOT in the long term. This relationship states that a 1% increase in the CTOT can be linked to a β% change in the AUD/USD REER.

$$REER_{\frac{AUD}{USDt}} = \alpha + \beta RCOMP_{Australia,t} + \beta RIR_{Australia,t} + \varepsilon_{it} \tag{15}$$

As above, the coefficient measures the elasticity of the AUD/USD REER relating to the RCOMP instead. This too is the long term elasticity. This relationship states that a 1% increase in the CTOT is linked to a β% change in the AUD/USD REER over time, *t.* The OLS will advise the elasticity of the relationship; the next step is to determine the causality of the relationship. This is discussed in the next section.

3.5.1.4 Granger causality

At this stage, I establish whether the variables are stationary and whether there is cointegration between them. The Granger causality test is a model based on prediction, which identifies and addresses any endogeneity issues. Developed by Granger in 1969, this test is a method to find causality between two variables in a time series. This will allow me to test whether one variable comes before another in the time series by testing the null hypothesis against an alternative hypothesis. The null hypothesis states that the changes in one variable do not affect changes in the second variable. The foundation of the Granger causality test states that the present cannot be the result of what happens in the future, whereas what happens in the future can be a result of what happens in the present. Hence, if I reject the null hypothesis stating that the changes in AUD/USD REER do not cause changes in the CTOT variable, this suggests the past values of AUD/USD REER have had an impact and provide data to help predict the future level of CTOT.

This thesis explores Granger causality for Relationship 1, between AUD/USD REER and RCTOT, and for Relationship 2, between AUD/USD REER and RCOMP, for the five commodities. This allows me to determine the direction of the relationship.

Testing for Granger causality includes three steps: (1) to adopt a suitable model for Granger causality testing, (2) to determine the parameters for estimation of the model, and (3) to test the hypotheses to validate the existence, and if so the direction of Granger causality for Relationships 1 & 2. These steps are outlined below:

a. A suitable model to test Granger causality

In order to build a robust model for this test, the control variable RIR is included, as mentioned in the earlier section, when conducting the test between AUD/USD REER and CTOT, and AUD/USD REER and RCOMP of iron ore, coal, natural gas, gold and aluminium.

Based on Equations 3.10 and 3.11, where there is evidence of a cointegrating equation between the dependent and independent variables a VEC model is adopted (Equation 3.12). Where there is no cointegration, a VAR model is employed (Equation 3.13).

If AUD/USD REER and RCOMP are not cointegrated, a vector auto-regression (VAR) model is estimated to test for Granger causality between AUD/USD REER and RCOMP. In my thesis, I employ the Toda and Yamamoto (1995) augmented VAR model instead of the traditional VAR model. The reason is that in the Toda and Yamamoto augmented model, all variables are used, regardless of their order of integration. We must not take the difference of the variables even when variables are not stationary. Meanwhile, in a traditional VAR model, all variables are required to be stationary. If any variable is not stationary (i.e. I(1) or I(2)), I must differentiate that variable to make sure it is stationary in the VAR model. The stationary test is employed as per Equations 3.6, 3.7 and 3.8 to establish a level of differentiation where the value of variables is stationary.

Apart from AUD/USD REER and RCOMP, I also include a control variable RIR in the Toda and Yamamoto (1995) augmented VAR model when investigating Granger causality between AUD/USD REER and RCOMP. The VAR models are as follows:

1. To address RQ1

$$REER_t = \alpha_1 + \sum_1^k \ \beta_k RCOMP_{(t-k)} + \sum_1^m \ \beta_{(k+m)} RCOMP_{t-(k+m)} + \sum_1^k \ \beta_k REER_{(t-k)} + \sum_1^m \ \beta_{(k+m)} REER_{t-(k+m)} + \sum_1^k \ \beta RIR_{t-k} + u_{it} \quad (16)$$

2. To address RQ2

$$REER_t = \alpha_1 + \sum_1^k \ \beta_{11k} CTOT_{(t-k)} + \sum_1^m \ \beta_{11(k+m)} CTOT_{t-(k+m)} + \sum_1^k \ \beta_{12k} REER_{(t-k)} + \sum_1^m \ \beta_{12(k+m)} REER_{t-(k+m)} + \sum_1^k \ \beta_{13} RIR_{t-k} + u_{it} \quad (17)$$

Here, α is the intercepts, β is the parameter coefficient of the independent variable and k is the lag length selected by the (AIC) criterion. m is the maximum order of integration of AUD/USD REER, CTOT and the RCOMP for IOP, CP, NGP, GP and ALP, and u denotes white-noise error terms (eViews 2019). Studies generally find econometric variables such as the exchange rate commodity prices to be stationary in their first difference I (1).

Lag length (k) is the number of lagged values of the series included in the model. It is important to select a suitable lag length for VAR testing, otherwise the results are inaccurate. If the lag length selected is too short, then it omits variables and reflects the dynamic of the systems differently, and if it is too long then degrees of freedom are lost (Gujarati 2009).

Using the Akaike Information Criterion (AIC), rather than selecting a random lag length allows me to produce more robust time series results by having a suitable number of lag lengths included in the model (k). This selection is based on Equation 3.9.

Based on the result of ADF and PP unit root tests, I determine the order of integration of each variable – AUD/USD REER and CTOT and AUD/USD REER and IOP, CP, GP, ALP, NGP. From the integration results, the maximum order of integration for the two variables (m) is selected. For example, if one is differenced in the second order and the other in its first order, then the maximum level of integration is selected.

Another important test to run is a test for serial correlation. There should not be any serial correlation. If there is, then the lag length is increased until there is none.. Engle and Granger (1987) specify that if there is evidence of cointegration between two variables, there will be at least one direction of Granger causality between the variables. Once I determine that the explanatory and dependent variables are cointegrated, I perform a VEC model to clarify the direction of the causal relationship to see which variable is responsible for a shift in the other.

Where there is cointegration between variables, although the Toda and Yamamoto (1995) augmented VAR model can be used to specify Granger causality, a VEC model is believed to be more robust than the VAR model. Typically, the VAR model is only able to determine short-run

Granger causality. Meanwhile, the VEC model is capable of identifying both short- and long term relationships among variables as well as determining why the causation is caused.

The control variable RIR is also included in the VEC model when investigating Granger causality between AUD/USD REER and RCOMP, and the AUD/USD REER and CTOT. The VEC model follows:

$$\Delta REER_t = \alpha_1 + \beta ECT_{1,t-1} + \sum_1^k \beta_k RCOMP_{(t-k)} + \sum_1^k \beta_k REER_{(t-k)} + \sum_1^k \beta_k RIR_{(t-k)} + u_{it} \quad (18)$$

$$\Delta REER_t = \alpha_1 + \beta ECT_{1,t-1} + \sum_1^k \beta_k CTOT_{(t-k)} + \sum_1^k \beta_k REER_{(t-k)} + \sum_1^k \beta_k RIR_{(t-k)} + u_{it} \quad (19)$$

In this VEC model, the ECT represents the error correction term. ECTt-1 measures the extent of the deviation from time t-1 in the long term.

ECT t-1 is the first lagged value of the residuals derived from the cointegration regression of the two variables AUD/USD REER and CTOT for which AUD/USD REER is a dependent variable. ECT2 t-1 is the first lagged value of the residuals from the cointegration regression of the two variables RCOMP and AUD/USD REER, for which RCOMP represents the five individual explanatory variables which are the commodities.

b. Testing for Granger causality

The direction of causality for Relationships 1 and 2 is determined by the significance of the coefficient of the dependent variables in the augmented VAR or VEC model. The long term causality for the model is then verified by the coefficients of the error term for the VEC model. If the coefficients are positive and significant, I can confirm evidence of long term causality as a result of the independent variable to the dependent variable. If the sign on the significant result is negative, then I confirm evidence of reverse causality.

3.5.2 Long term elasticity

To test for long term elasticity this thesis implements a log-linear model function where only my dependent variables, the real effective exchange rate, will be transformed using the logarithm. I can implement this model as the real effective exchange rate in all cases is larger than zero. This model is presented below:

$$ln\,(y) = \beta_1 + \beta_{2^x} \quad (20)$$

Where y is the dependent variable, the real effective exchange rate and x represents the independent variable which will be as per RQ1 and RQ2, commodity terms of trade, and real commodity price, respectively.

Using this model, I am able to identify the elasticity of the model. Here, a one-unit appreciation of x leads to a $\beta_2 \; X \; 100$ increase in y.

3.5.3 Regression Analysis (OLS)

The third analysis conducted is regression analysis. This thesis adopts the regression analysis method of ordinary least squares (OLS). The OLS panel analysis method is employed to determine the relationship between dependent and independent variables. OLS is a simple method of linear regression that allows minimisation of the sum of squared errors. The regression equation to address RQ1 is:

$$REER = \alpha + \beta_1 CTOT + \varepsilon \quad (21)$$

In this model, the real effective exchange rate (AUD/USD REER) is the dependent variable, and commodity terms of trade (CTOT) is the independent variable and ε is the Error term. Here, α represents the y-intercept of the regression. Due to the large sample of data for CTOT, I use transform CTOT values to its natural log. This allows the distribution of the sample to be normalised. A similar approach is used in Akram (2009) and Alit and Rahman (2012).

The next set of OLS regression equations investigates RQ2. There are five regression equations. Here, each equation examines an individual commodity. For all equations, the dependent variable remains the same as the AUD/USD REER. The explanatory variables are the real price of iron ore, coal, gold, natural gas and aluminium. Similar to Equation 3.20, ε represents the Error term. Hence, the regression equations that address RQ2, the relationship between the REER and Real Commodity Price for Australia are:

$$REER = \alpha + \beta\, CoalPrice + \varepsilon \quad (22)$$

$$REER = \alpha + \beta\, IronOrePrice + \varepsilon \quad (23)$$

$$REER = \alpha + \beta\, GoldPrice + \varepsilon \quad (24)$$

$$REER = \alpha + \beta\, NaturalGasPrice + \varepsilon \quad (25)$$

$$REER = \alpha + \beta\, AluminiumPrice + \varepsilon \quad (26)$$

In addition to time series analysis to test the two research questions, a panel data correlation analysis is also adopted to investigate these relationships. Generally, a panel dataset is longitudinal data containing observations over several time periods for the same individual. It differs from time series in the sense that time series measures the change over time, whereas with panel data the overall change is not measured, but the time is. A key reason for adopting the panel data technique is that this method of analysis can be used constructively to measure the interdependent relationships between the independent variables as well. Furthermore, in adopting the panel-data technique, this thesis uses a log-linear model to test elasticity. The results from these tests are presented and analysed in the following chapter.

3.6 Chapter summary

This chapter discussed the quality and source of the data and various forms of econometric analysis adopted. The data has been sourced from reliable databases such as Bloomberg, Thomson Reuters and the central bank. The methodology discussed here is implemented in the next chapter in order to thoroughly understand the relationship between dependent and independent variables. The methodology adopted includes three sections of analysis. The first section of the analysis discusses the correlation and elasticity of the variables. The second section adopts a time series approach, and the final section presents regression analysis using an OLS method. The results from these analyses are presented in the next chapter.

Chapter 4: Results and Analysis

This section presents the results produced by following the time series and panel data techniques outlined in the previous section. There are three subsections. The first subsection is the time series data analysis. I test for a unit root using the methods outlined in Chapter 3, followed by the Johansen cointegration test. On finding cointegrating equations between my variables I run a Granger causality test using a VEC model. The next subsection performs a correlation and log-linear elasticity test. The final subsection for results performs two forms of regression analysis. For this, I use OLS panel regression. The results are discussed thoroughly.

4.1 Time series analysis

This section presents the time series test results. The order of time series analysis is the unit root test using ADF and PP method, followed by the Johansen cointegration test, optimal lag selections, and finally the Granger causality test.

4.1.1 Unit root test

The estimates for the unit root test are presented in Table 4.1. The table presents the unit root test performed using the ADF and PP methods. Each variable is tested to check for a unit root, which is a necessary test prior to performing regression analysis. Further, the ADF test also advises the lag length at which the variable is stationary. The critical value I am using to deduce whether to reject the null hypothesis is 5%. Based on my trend analysis (see Figures 3.1 to 3.7) my initial observations suggest that variables are not stationary. The charts do not return to a mean. This is the case for all of the variables apart from natural gas, where I suspect the variable may already be stationary at level. I will now look at the unit root test estimates, by variable.

The independent variable, the AUD/USD REER, is non-stationary in level when tested with intercept, and both intercept and trend. Using both methods, ADF and PP, I find that it is necessary to test the variable in its first difference. Here, I found significant statistical results in that the REER is stationary in its first difference. The p-value is ≤ 0.0001 for all t-statistics. The lag length suggests a maximum lag of 0. I opt to use the lag length suggested by the AFD as opposed to the PP model, as I am opting for a maximum lag length of four.

I find similar results for commodity terms of trade (CTOT). We and conclude that the CTOT time series has a unit root at level. Although when tested with the PP method, the CTOT is found to be stationary to a 5% significance level with trend and intercept. Figure 3.2 does not look to be stationary. I compare this with the graph of CTOT in its first difference in Figure 4.1.

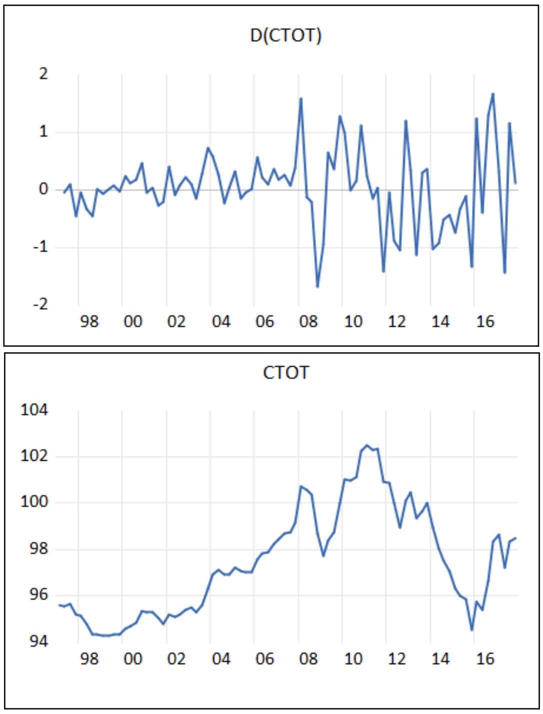


Figure 4.1: Commodity terms of trade in first difference (above) and level (below)

The result may show stationary at level due to the size of the sample. Typically for the unit root test, a long term span is suggested (over 12 years). Although the sample size is twenty years, the quarterly data only provides 84 samples. For this reason, I look to the ADF test results to confirm the CTOT is stationary in first difference. When tested at first difference, both the ADF and PP test statistics suggest the CTOT to be stationary in its first difference to a significance level of ≤ 0.0001. The lag length is suggested as 0.

The estimates for coal are as per my expectation and are stationary at first level. There is no unit root present in the time series for its level. The estimates are not statistically significant and with p-values ≥ 0.05 in all cases when tested in its level form. The lag length suggests a lag of three intervals. The test statistics for ADF with intercept, PP with intercept, and intercept and trend are statistically significant at a level of ≤ 0.0001. The ADF test statistic for trend and intercept is also significant, but to a level of 1%. I reject the null hypothesis that the real price of coal has a unit root, and conclude it is stationary in its first difference with a lag of 3 to avoid serial correlation.

Similarly, the estimate for iron ore price is in line with my expectation based on trend analysis in Figure 3.3. I reject the null hypothesis that there is a unit root at level. My ADF estimates indicate a lag of 3, and a statistical significance of ≤ 0.0001 when differenced to its first order. The results are uniform across both the ADF and PP test for statistical significance indicating first difference stationarity.

Natural gas estimates are intriguing. Based on my trend analysis, I suspect the real price of natural gas may be naturally non-stationary in nature. The ADF intercept and PP intercept test statistic estimates suggest that at level, natural gas does not have a unit root. This is significant to a level of 5%. Figure 4.2 (below) allows visualisation of the pattern of real natural gas prices at both levels, and first difference. I suspect that if the sample size is larger, the results may be of higher significance. It appears in level the chart is returning to its mean. These results are in line with similar studies (Apergis 2014; Demirer & Belasen 2019) and find the data to be stationary in the first difference. This provides me with confidence that the data is suitable for further time series analysis.

Table 4.1 Time series unit root testing using ADF and PP

Variable	Level/ First Difference	ADF t-Statistic		Philips-Perron t-statistic		Conclusion
		With intercept	With trend and intercept	With intercept	With trend and intercept	
Real Effective Exchange Rate	Level First Difference	-0.43 (0) -7.97 (0) ***	-2.04 (1) -7.92 (0) ***	-1.72 (2) -7.91 (5) ***	-2.01 (1) -7.85 (6) ***	The Variable is Stationary in First Difference
Commodity Terms of Trade	Level First Difference	-1.37 (0) -7.82 (0) ***	-1.51 (0) -7.78 (0) ***	-1.53 (3) -7.84 (3) ***	-1.77 (4) * -7.79 (3) ***	The Variable is Stationary in First Difference
Real Interest Rate	Level First Difference	-1.53 (2) -6.33 (1) *	-3.38 (1) -6.33 (1) *	-1.81 (1) -4.60 (10) *	-2.28 (1) -4.56 (10) *	The Variable is Stationary in First Difference
Coal Price /USD	Level First Difference	-1.80 (2) -5.58 (3) ***	-2.52 (2) -5.54 (3) **	-1.98 (3) -6.10 (10) ***	-2.74 (2) -6.03 (10) ***	The Variable is Stationary in First Difference
Iron Ore/USD	Level First Difference	-1.54 (4) -6.613 (3) ***	-1.35 (4) -6.64 (3) ***	-2.06 (4) -6.47 (4) ***	-2.06 (4) -6.45 (4)***	The Variable is Stationary in First Difference
Natural Gas /USD	Level First Difference	-3.04 (0) * -7.20 (2) ***	-3.08 (0) -7.22 (2) ***	-2.90 (6) * -10.96 (22) **	-2.88 (7) -12.26 (24) ***	The Variable is Stationary at Level and First Difference
Gold Price/USD	Level First Difference	-1.06 (4) -2.53 (4)	-1.79 (4) -2.53 (4)	-0.73 (1) -9.03 (1) ***	-1.38 (0) -8.97 (1) ***	The Variable is Stationary in First Difference
Aluminium Price/USD	Level First Difference	-1.85 (3) -6.98 (2) ***	-1.86 (3) -6.94 (3) ***	-2.15 (9) -8.42 (44) ***	-2.44 (8) -8.56 (44) ***	The Variable is Stationary in First Difference

Note:

- () represents the lag length selected using the Akaike Information Criterion (AIC)
- The maximum lad length for ADF is set as 4, due to the nature of the data being quarterly
- * denotes the P-value ≤ 0.05
- ** denotes the P-value ≤ 0.01
- *** denotes the P-value ≤ 0.001
- The null hypothesis is rejected at a significance level of 5%

Nevertheless, I still estimate the significance at first difference, and confirm that the test statistics for natural gas prices are statistically significant at a level of ≤ 0.0001 in all ADF and PP scenarios. The optimal lag to avoid serial correlation is selected as two quarters of data.

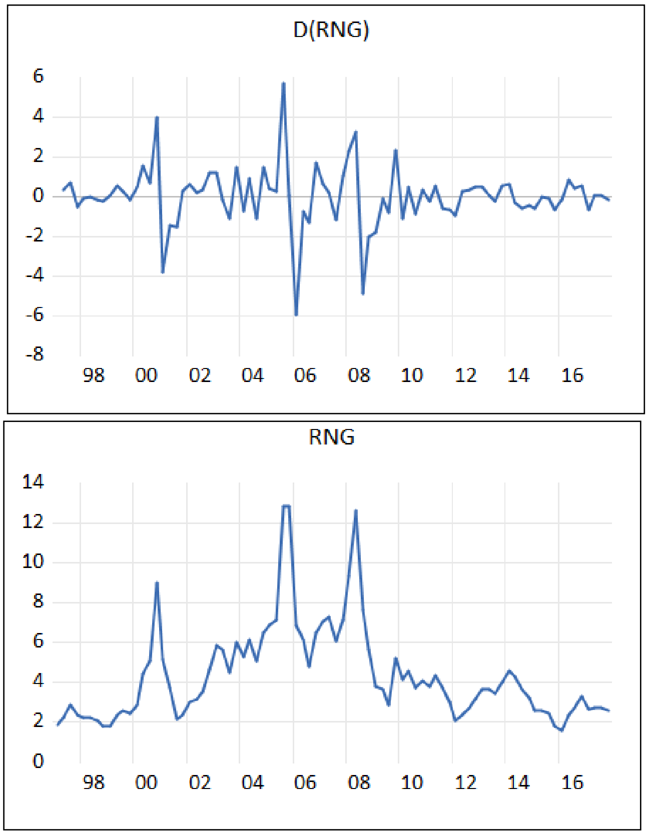


Figure 4.2: Real price of natural gas in first difference (above) and level (below)

Next, I test for stationarity in the real price for gold. The ADF test finds that gold has a unit root in both its level and first difference form. This is a surprising result as when I observe the graph in Figure 4.3 for gold price it would seem to be stationary. It is interesting to see that the graph in first difference (Figure 4.3) remains fairly steady for the first half of the sample. This suggests the RP of gold has grown in a stable manner from 1997 to 2008. Around this time, financial markets experienced the GFC that witnessed an increase in the price of gold and further variation in its vales at first difference. We observe that after 2008 there is apparent stationarity in the gold price. We conduct a second unit root test, now only testing the RP of gold between Q1 2008 and Q4 2017. This considered the second half of my sample data.

A drawback here is that the ADF unit root test is typically not suitable for short term data. However, I test to see if there is any statistical significance of stationarity. The estimates (see Table

4.4) suggest the variables are stationary for the period Q1 2008 to Q4 2017, with a suggested lag length of 2 to avoid serial correlation when using the ADF test statistic with trend and intercept.

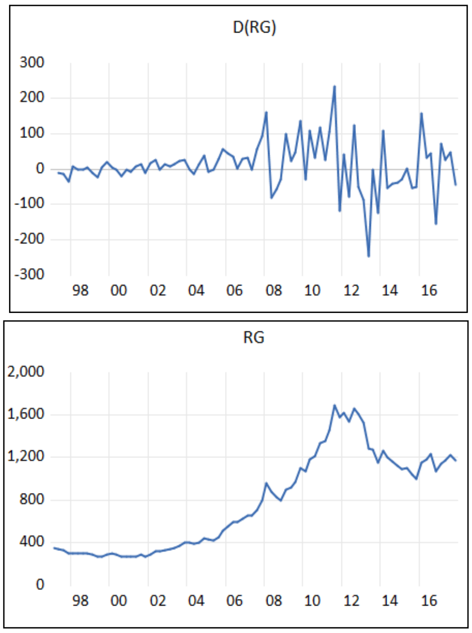


Figure 4.3: Real price of cold in first difference (above) and level (below)

Therefore, for gold, I utilise the time series in its first difference, as the PP test statistic suggests this to be significant at a level of ≤ 0.0001. Although the ADF suggests otherwise, I find that in the second half of the time series the RP of gold are stationary in their first difference at a significance level of 5%. Lastly, I observe the unit root estimates for the RP of aluminium. The estimates are in line with my expected result based on the trend analysis in Figure 3.7. I reject the null hypothesis that there is a unit root at level. My ADF estimates indicate a lag of 2, to avoid any autocorrelation. The significance of the stationarity in first difference is at a level of ≤ 0.0001.

Table 4.2: Unit root test for the real price of gold

Variable	Level/ First Difference	ADF t-Statistic		Phillips Perron t-statistic		Conclusion
		With intercept	With trend and intercept	With intercept	With trend and intercept	
Gold Price/USD	First difference	-3.46 (3) *	-4.00 (2) *	-6.45 (1) ***	-6.61 (2) ***	Stationary in first difference

Note:

- () represents the lag length selected using the AIC
- The maximum lag length for ADF is set at 4, due to the nature of the data being quarterly
- * denotes the P-value ≤ 0.05
- ** denotes the P-value ≤ 0.01
- *** denotes the P-value ≤ 0.001
- The null hypothesis is rejected at a significance level of 5%

This is the same across all scenarios under the ADF and PP models. Now that I conclude my time series to be stationary in its first difference, next I confidently perform the Johansen cointegration test.

4.1.2 Johansen cointegration test and equations

The estimates for the Johansen cointegration test are presented in Table 4.4. This test relies on both the trace test and the Maximum Eigen value test. The basis of these tests is the unit root estimates from Table 4.2. As I concluded that the time series is stationary in its first difference, I can confidently test for long term cointegration using this method. For each independent variable I test the null hypothesis, which states there is no cointegrating relationship. The model is explained thoroughly in subsection 3.2.1.2. I test my hypothesis against a significance level of 5%. I reject the null hypothesis where the p-value is >0.05. The lag length is based on the selection from the AIC. The lag lengths are indicated in Table 4.2.

The cointegration results indicate cointegration between the AUD/USD REER and all six explanatory variables in the long term. Specifically, for the CTOT, RP of iron ore and RP of natural gas I reject the null hypothesis which states there is no cointegration (H0: r = 0). In all three cases, both the trace test and Maximum Eigenvalue statistic are greater than the critical value at a significance level of 1%. For these explanatory variables, I also reject the alternative hypothesis (H0: r < 1) of more than or equal to one cointegrating equation. This indicates the existence of two cointegrating equations between: REER and CTOT, REER and RP of iron ore and REER and RP of natural gas at a 5% level of significance. This is significant result as it suggests there is a long term relationship for RQ1 between the CTOT and the REER, however, I do not yet know whether it is the independent variable which is the cause for cointegration or the dependent. This is the same for RQ2, and the next step will allow me to analyse which variable is the root for the cointegration.

For the remaining three independent variables, the RP of coal, gold and aluminium, I find one cointegrating equation. I reject the null hypothesis stating no cointegration between the REER and RP of coal at a 5% level of significance based on the trace statistic. However, the Maximum Eigenvalue estimate is inconsistent with this finding. I do not reject the null hypothesis for the Maximum Eigenvalue result. This test typically provides the number of vectors which are cointegrated. For this reason I conclude that, based on the trace statistic, there is one cointegrating equation between the REER and RP of coal. Coal represents a large section of Australia’s export, so this is consistent with my expectations (Table 3.3). It is unclear for now whether it is the coal price which impacts the REER, or the REER which influences cointegration with the price of coal. The causality test in section 4.1.3 will provide an indication of the direction of the relationship.

In line with my expectations thus far, the Johansen cointegration trace and Maximum Eigenvalue tests are consistent in proving one cointegrating equation between the REER and RP of gold, and REER and RP of aluminium. The null hypothesis is rejected at a 1% significance level. Now that I have established there is long term cointegration within the six relationships being tested, I employ a vector error correction model (VECM) to test for long term Granger causality within the variables. This allows me to understand the direction of the relationship and is presented in the following subsection.

4.1.3 Granger causality test

Based on the existence of the Johansen cointegration test (Table 4.3), the REER is found to be cointegrated in the long term with the CTOT and the RP of coal, iron ore, natural gas and aluminium. Hence, I implement Granger causality for these relationships using a VECM (Eq. 3.14). To test for Granger causality between the REER and the RP of gold I implement the VAR model. As the VAR model advises the short run causality, I run this test for all explanatory variables in order to understand any short run cointegration. Although the short term relationship is not a key focus of this study, this allows me to critically understand the relationship of the variables.

Table 4.3: Johansen cointegration test using trace and Maximum Eigenvalue tests

The dependent variable used here is the AUD/USD Real Effective Exchange Rate

		Trace test				Maximum Eigenvalue test				Conclusion	
Explanatory Variable	Hypothesized Number of CE(s)	Trace statistic	0.05 Critical Value	Probability	No. of CE (s)	Maximum Eigenvalue	0.05 Critical Value	Probability	No. of CE (s)	Cointegration	No. of CE(s)
Commodity terms of trade	H0: r = 0	19.1339	15.4947	0.0135	2	15.9483	14.2646	0.0268	2	Yes	1
	H0: r ≤ 1	3.1856	3.8415	0.0743		3.1855	3.8415	0.0743			
Real price of coal	H0: r = 0	15.1583	15.4947	0.0561	1	12.5172	14.2646	0.0927	1	Yes	0
	H0: r ≤ 1	2.6411	3.8415	0.1041		2.6411	3.8414	0.1041			
Real price of iron ore	H0: r = 0	22.2504	15.4947	0.0041	1	19.8737	14.2646	0.0058	1	Yes	1
	H0: r ≤ 1	2.3768	3.8415	0.1231		2.3768	3.8415	0.1231			
Real price of gold	H0: r = 0	4.3465	15.4947	0.8737	0	3.4172	14.2646	0.9151	0	No	0
	H0: r ≤ 1	0.9293	3.8414	0.3350		0.9296	3.8414	0.3350			
Real price of natural gas	H0: r = 0	11.4500	14.4947	0.1853	1	8.3795	14.2646	0.3414	1	Yes	1
	H0: r ≤ 1	3.0706	3.8414	0.0797		3.0706	3.8414	0.0797			
Real price of aluminium	H0: r = 0	11.0625	15.4947	0.2077	1	7.6746	14.2646	0.4127	1	Yes	1
	H0: r ≤ 1	3.3879	3.8414	0.0657		3.3849	3.8414	0.0657			

Note:
- * denotes the P-value ≤ 0.05
- ** denotes the P-value ≤ 0.01
- *** denotes the P-value ≤ 0.001
- CE is cointegrating equation
- Lag lengths are selected as per the AIC from Table 4.4
- Johansen cointegration test specification allows for linear deterministic trend in data and intercept and trend in CE
- I test the null hypothesis against a significance level of 10%
- Where the significance level is less than 10%, I reject the null hypothesis

Table 4.4: Long term Granger causality using VECM

Granger causality VEC model					Conclusion
Variables	**Lag**	**Null Hypothesis**	**F-Statistic**	**P-Values**	**Null Hypothesis**
Commodity terms of trade	0	REER does not Granger Cause CTOT	3.8915*	0.0245	Reject
		CTOT does not Granger Cause REER	6.5393**	0.0024	Reject
Real price of coal	3	REER does not Granger Cause RP of coal	3.1376*	0.0304	Reject
		RP of coal does not Granger Cause REER	5.41373**	0.0014	Reject
Real price of iron ore	3	REER does not Granger Cause RP of iron ore	0.5316	0.6620	Do Not Reject
		RP of iron ore does not Granger Cause REER	5.6633**	0.0015	Reject
Real price of natural gas	2	REER does not Granger Cause RP of natural gas	1.2213	0.3005	Do Not Reject
		RP of natural gas does not Granger Cause REER	0.2694	0.7645	Do Not Reject
Real price of aluminium	2	REER does not Granger Cause RP of aluminium	0.2444	0.7838	Do Not Reject
		RP of aluminium does not Granger Cause REER	4.0510*	0.0212	Reject

Note:
- * denotes the P-value ≤ 0.05
- ** denotes the P-value ≤ 0.01
- *** denotes the P-value ≤ 0.001
- We test the null hypothesis against a significance level of 5%. Where the significance level is less than 5%, I reject the null hypothesis

Table 4.5: Long term cointegrating equation using VECM

Variables		**Constant β_0**
Commodity terms of trade	0.0575	4.8520
Real price of coal	0.0052	-0.4361
Real price of iron ore	0.0035	-0.4861
Real price of natural gas	-3.3533	-15.6290
Real price of aluminium	0.0005	0.2171

4.1.4 Granger causality (VEC) model

The results for the explanatory variables tested for Granger causality using the VECM are presented in Table 4.6. The relationships tested are:

a. AUD/USD Real Effective Exchange Rate and commodity terms of trade
b. AUD/USD Real Effective Exchange Rate and the Real Price of Coal
c. AUD/USD Real Effective Exchange Rate and the Real Price of Iron ore
d. AUD/USD Real Effective Exchange Rate and the Real Price of Natural Gas
e. AUD/USD Real Effective Exchange Rate and the Real Price of Aluminium

For relationship a, the null hypothesis states that the CTOT does not Granger Cause the AUD/USD REER. I reject this null hypothesis, with a significance level of 0.24%. I also reject the null hypothesis which states that the AUD/USD REER does not Granger Cause the CTOT to a significance level of 2.4%. This suggests there is bidirectional causality between the CTOT and AUD/USD REER. Furthermore, I then input my estimates for the VECM cointegrating equation (Table 4.5) into Eq. 3.14 in order to examine the relationship for change in the REER, $\Delta REER_t$ to understand RQ1. This is relationship a and is defined as below:

$$\Delta REER_t = 1.000\text{REER} + 0.0575\text{CTOT}_1 + 4.8520$$

Similar to relationship a, there is evidence of bidirectional causality for relationship b. The estimates indicate the REER Granger Causes the RP of coal to a 5% level of significance, and the RP of Coal Granger Causes the REER to a 1% level of significance. In both cases, I reject the null hypothesis. I use a lag of 3, as established by AIC. The relationship is defined as below:

$$\Delta REER_t = 1.000\text{REER} + 0.0052(\text{RP of Coal})_2 - 0.4361$$

The observed relationship is positive. Next, I observe the Granger causality estimates between the RP of iron ore (relationship c) and RP of aluminium (relationship e) suggests unidirectional Granger causality. I reject the null hypothesis stating that the RP of iron ore does not Granger Cause the AUD/USD to a 0.15% significance level, and reject the null hypothesis stating that the RP of aluminium does not Granger Cause the

AUD/USD to a 2.12% significance level. The VECM cointegrating relationships of c and f are defined below:

$$\Delta REER_t = 1.000\text{REER} + 0.0035(\text{RP of iron ore})_2 - 0.4861$$

$$\Delta REER_t = 1.000\text{REER} + 0.0005(\text{RP of aluminium})_2 + 0.2171$$

Finally, I observe the long term Granger causality between REER and the RP of natural gas. Here (relationship d), I observe there is no causality between the two variables, and therefore I do not reject the null hypotheses. The t-statistic is 76.45% significant, and there I can confidently confirm a causal relationship does not exist between the variables according to the long term VECM. Nevertheless, the Johansen cointegration model was tested at a 10% significance level, where the significance is for a cointegrating equation for relationship d for 7.9%. If I were to utilise a significance of 5%, this hypothesis would be rejected. In order to capture the short run causality of these relationships (a-e) I include them in the VAR model as well. This is presented in the following subsection.

The level of significance highlights the robustness of the relationship in the long term. Although the initial cointegration test finds that the cointegration relationship exists the VEC test reveals that the cointegration may not be linked, and there may be other factors which are causing the cointegration. The strongest relationships in order of most significant (in brackets) to least are the RP of iron ore (0.15%), the CTOT (0.24%), the RP of coal (1%), the RP of aluminium (2.12%), the RP of natural gas (7.9%), Granger causaslity and the AUD/USD REER in the long term positively. The RP of natural gas is an outlier in this scenario, as the significant level is lower than the other independent variables.

4.1.5 Granger causality (VAR) model

In Table 4.6 I present the results for the explanatory variables tested using the Granger causality VAR model. Based on the Johansen cointegration test, indicating there is no long term cointegration between the AUD/USD REER (Table 4.3) and the RP of gold, I use the VAR model so I can observe whether there is any causation in the short term. In addition to gold I also perform this test for relationships a-e, so I can observe whether there is a short- and long term relationship present. In subsection 4.2.3.1 I observe that in the long term, although there is evidence of cointegration, the AUD/USD REER and RP of natural gas do not in fact have a causal relationship. My VAR test may be able to indicate evidence of causation in the short term instead. I use a significance level of 5% to test the null hypothesis.

First, I observe the relationship of AUD/USD REER with commodity terms of trade, and the real price of iron ore. In both cases we do not observe causation in the short run, and hence do not reject the null hypotheses. Evidence suggesting that the AUD/USD REER does not Granger cause the CTOT and RP of iron ore is significant to a 41.4% and 81.10% level. For results suggesting that the CTOT Granger causes the AUD/USD REER, the significance is quite low at 5.7%. Although we reject the null hypothesis, this p-value suggests there is a moderate causal relationship present.

On the other hand, the p-values for REER and the RP of natural gas suggest a significant causation between them. The p-values estimate the RP of natural gas does Granger cause the AUD/USD REER to a .3% level of significance. The reverse relationship is also significant to a 4.2% level of significance. For these variables, there is strong evidence suggesting bi-directional causality. The Johansen cointegration test established a long term cointegrating relationship for these variables (Table 4.3), yet the VEC model provided no strong results suggesting the possibility of causation (Table 4.4). Here, we can determine that, long term cointegration is weak, yet there is evidence suggesting strong causation in the short term (Table 4.6).

Next, we observe the relationship of AUD/USD REER with the RP of gold, and the real price of aluminium. In both instances, the estimates suggest evidence of reverse causality. The explanatory variable does not Granger cause shifts in the AUD/USD REER to a significance level of 85.60% and 51.90% for gold and aluminium, respectively. However, the exchange rate is responsible for causing shifts in gold and aluminium prices, to a significance level of 2.7% and 0.00% respectively.

Finally, we observe the causation relationship between the AUD/USD REER and RP of coal. Similar to the long term VEC model (Table 4.4) the evidence suggests that in the short term, the RP does Granger cause shifts in the AUD/USD REER. This p-value is significant at 3.7%. We do not reject the null hypothesis suggesting that the REER does not Granger cause the RP of coal. The reverse relationship is not significant ≤ 5%.

In summary, for the observation of a short term relationship, we observe one instance of bi-directional causality for the exchange rate and natural gas. There is also one instance of causality, suggesting that coal prices Granger cause the exchange rate. The VAR model suggests no short-term relationship for RQ1 between the exchange rate and commodity terms of trade. Finally, there are two cases of reverse causality, for gold and aluminium.

Table 4.6: Granger causality with VAR model

Granger causality VAR model relationship (short-run relationship)					Conclusion
Variable	**Lag**	**Null Hypothesis**	**F-Statistic**	**P-Values**	**Null Hypothesis**
Commodity terms of trade	0	AUD/USD REER does not Granger Cause CTOT	0.668	0.414	Do not reject
		CTOT does not Granger Cause AUD/USD REER	3.637	0.057	Do not reject
Real price of coal	3	AUD/USD REER does not Granger Cause RP of Coal	3.208	0.073	Do not reject
		RP of Coal does not Granger Cause AUD/USD REER	4.332	0.037*	**Reject**
Real price of iron ore	3	AUD/USD REER does not Granger Cause RP of Iron Ore	0.96	0.811	Do not reject
		RP of Iron Ore does not Granger Cause AUD/USD REER	5.327	0.149	Do not reject
Real price of natural gas	2	AUD/USD REER does not Granger Cause RP of Natural Gas	6.347	0.042*	**Reject**
		RP of Natural Gas does not Granger Cause AUD/USD REER	9.167	0.003*	**Reject**
Real price of gold	4	AUD/USD REER does not Granger Cause RP of Gold	11.01	0.027*	**Reject**
		RP of Gold does not Granger Cause AUD/USD REER	1.33	0.856	Do not reject
Real price of aluminium	2	AUD/USD REER does not Granger Cause RP of Aluminium	18.988	0.000**	**Reject**
		RP of Aluminium does not Granger Cause AUD/USD REER	1.313	0.519	Do not reject

Note:

- * denotes the P-value ≤ 0.05
- ** denotes the P-value ≤ 0.01
- *** denotes the P-value ≤ 0.001
- We test the null hypothesis against a significance level of 5%. Where the significance level is less than 5%, I reject the null hypothesis

- VAR model implemented where there is no cointegrating equation in the long term

4.2 Panel data correlation and elasticity

This section presents the panel cross-correlation and log-linear elasticity results. In addition to performing the time series analysis, correlation analysis provides further insight regarding the relationship between the variables.

The cross-correlation results are presented in Table 4.5. These findings are not entirely in line with the expected results. The real exchange rate shows a correlation with the values of all independent variables to at least a 1% level of significance. This is a strong result and indicates the results are highly significant. All correlations, whether weak or strong, are positive in nature. However, the correlation between these variables is lower than my expectation. In decreasing order, the AUD/USD REER has a correlation of 50.52 % with the RP of aluminium, which is a moderate correlation. For the remainder of variables the relationship is weak, between 0.20 and 0.39. The correlation between the AUD and USD REER is 35.03%; with the RP of iron ore, 33.25%; with the RP of coal, 30.43%; with the RP of gold; 29.23% with the RP of natural gas, and 28.39% commodity terms of trade.

I observe positive correlations between commodity terms of trade index and RP of coal (63.50%) to a significance level of ≤ 0.001, and commodity terms of trade index and RP of iron ore (72.82%), also to a significance level of ≤ 0.001. This result is understandable, as iron ore and coal are large components of Australia's commodities traded internationally. Aluminium is also moderately correlated with the CTOT and shows a correlation of 52.61%. Apart from the aforementioned relationships, there are only two other relationships which show strong correlation. These are significant to a value of 1%. The first is the RP of coal and iron (59.05% correlated) and second, the RP of coal and aluminium (60.18% correlated).

Overall, the strongest correlations are between the CTOT and RP of iron ore (72.82%) and coal (63.50%), the RP of coal and iron ore (59.05%) and the RP of coal and aluminium (60.18%) (Table 4.5). For visual analysis, Figure 4.4 represents the correlations estimated in Table 4.5 between the AUD/USD REER and independent variables listed below. This is consistent with their dominance in Australia's exports. Iron ore and coal comprise a large part of the exported commodities, a total of 29.9% (Table 3.3). The correlation between the metals itself is also explanatory as they are both used heavily within the industrial production, infrastructure and manufacturing industry in

China and other trade partners. These commodities are impacted in similar ways by international demand.

Next, I test the long term elasticity. For this I employ a log-linear elasticity model. The results indicate that a one-unit appreciation of the real commodity price will lead to an increase of '$\beta_2 X 100$' % in the real effective exchange rate. These results are presented in Table 4.6. The strongest elasticity is between commodity terms of trade and the AUD/USD REER, where for every 1% increase in the CTOT, the AUD/USD REER shifts by 5.63% (Table 4.8).

This is surprisingly large elasticity, as in the previous section I noted that the two variables are only correlated by 28.39%. Both results are significant at a level of 0.1%. This is highly significant, and based on these results I am able to reject the null hypothesis for RQ1.

Table 4.7: Pearson cross-correlation between independent variables

Variable	Exchange Rate	Commodity Terms of Trade	Real Price of Coal	Real Price of Iron Ore	Real Price of Gold	Real Price of Natural Gas	Real Price of Aluminium
Commodity terms of trade	0.2839**	1.0000	-	-	-	-	-
Real price of coal	0.3325**	0.6350***	1.0000	-	-	-	-
Real price of iron ore	0.3503**	0.7283***	0.5905***	1.0000	-	-	-
Real price of gold	0.3043**	0.2626*	0.1685	0.2711**	1.0000	-	-
Real price of natural gas	0.2923**	0.1976	0.2842**	0.1963	0.0621	1.0000	-
Real price of aluminium	0.5052***	0.5261***	0.6018***	0.4472***	0.2767**	0.2984**	1.0000

Note:

- * denotes the P-value ≤ 0.05
- ** denotes the P-value ≤ 0.01
- *** denotes the P-value ≤ 0.001

Table 4.8: Long term log-linear elasticity of independent variables

The dependent variable here is the AUD/USD REER

	Log-Linear Elasticity Model	
	B2 Coefficient	**Elasticity (B2 Coefficient x 100)**
Commodity terms of trade	0.0563	5.63 %
Real price of coal	0.0033	0.30 %
Real price of iron ore	0.0027	0.27 %
Real price of gold	0.0004	0.04 %
Real price of natural gas	0.0193	1.93 %
Real price of aluminium	0.0002	0.02 %

Note:

- * denotes the P-value ≤ 0.05
- ** denotes the P-value ≤ 0.01
- *** denotes the P-value ≤ 0.001

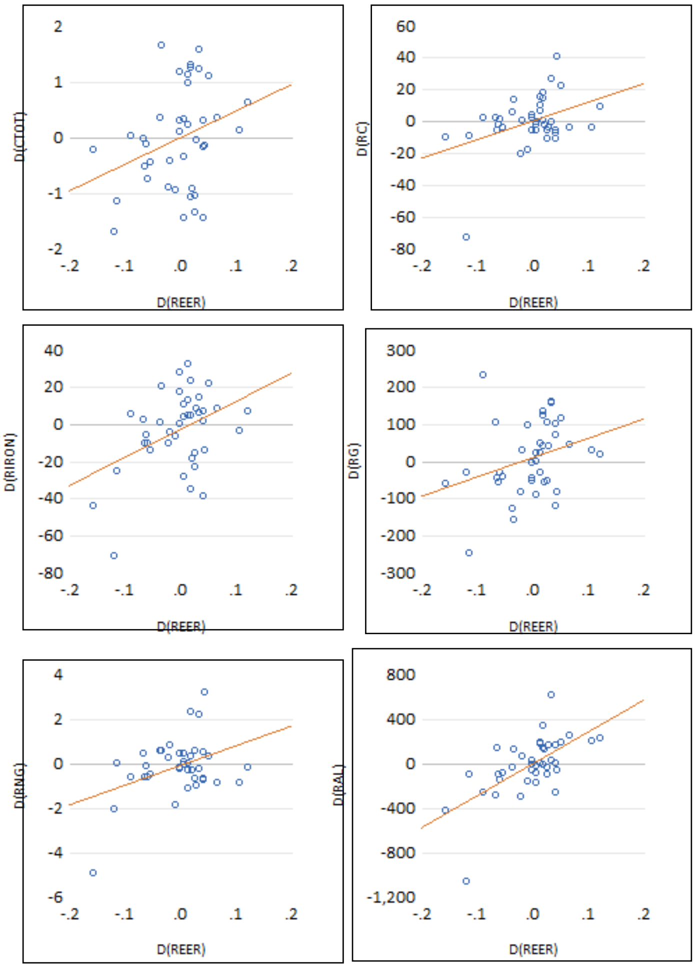


Figure 4.4: Scatter plot of correlation between REER and independent variables

Next, a one unit increase in gold estimates an increase of 0.3% in the AUD/USD REER. This elasticity, too, is significant at a level of 0.1%. The RP of iron ore estimates a similar result, suggesting an elasticity of 0.27% with the dependent variable. The RP of gold and aluminium, although statistically significant, have extremely weak elasticities of 0.04% and 0.02% respectively. Natural gas indicates an elasticity of 1.93%, however it is statistically insignificant. Therefore, I do not accept this result. Overall, the long term elasticity indicates that the elasticity between the AUD/USD REER and natural gas, coal and iron ore is strong. The long term elasticity is of key importance as it confirms a significant relationship between variables. Furthermore, the estimates from Table 4.6, in conjunction with correlation analysis (Table 4.5 and Figure 4.4), indicate a positive relationship between the AUD/USD and all explanatory variables.

Aluminium demonstrates the least amount of elasticity. Similar to the previous tests (Johansen cointegration and VECM Granger causality) the evidence suggesting a strong relationship between the price of aluminium and AUD/USD REER is insignificant. Aluminium constitutes only 2.6% of Australia's exports (Table 3.3), therefore does not appear to have a large impact on the AUD exchange rate over the long term. As opposed to the other commodities, most of the aluminium produced in Australia is used domestically (DFAT, 2011).

The time series analysis in the next section confirms the direction of the relationship and robustness of the data. Based on these preliminary results I began to understand that for RQ 1 there is some data to suggest I reject the null hypothesis. There is significant elasticity between the CTOT and the AUD/USD REER. Similarly, for RQ2 I began to comprehend significant elasticity between some of the commodity prices and the real exchange rate. In the following section I perform regression analysis using the OLS model.

4.3 Regression analysis by OLS

Table 4.7 consists of individual OLS estimations for the initial regression analysis based on Equations 3.20 and 3.21, as explained in section 3.3.3. This analysis finds that shifts in the AUD/USD REER are positively correlated with commodity terms of trade with a coefficient β of 1.9960. This is in line with my expectations, as previous studies found a similar positive correlation between the AUD/USD REER and terms of trade. This result is significant at a level of 0.95%. The R-squared value suggests that 8.02% of the variation in the AUD/USD REER is explained by variation in commodity terms of trade index, positively.

The second section of my OLS estimate observes the relationship between the AUD/USD REER and individual commodities. In line with expected results, the evidence suggests a positive correlation between the dependent variable with all independent variables. For iron ore, the positive β coefficient of 0.0869 is significant at a level of 1.00%. The R-squared value explains that 10.25% of the variation in the AUD/USD REER can be explained by the real iron ore price. Similarly, the coal price and natural gas price explain 8.5% and 3.5% of changes in the dependent variable, respectively. Although the regression coefficients for all independent variables are positive, some show signs of a weak relationship. The coefficient for iron ore price at 0.0869 is followed by real coal price coefficient, at 0.0943. Although the regression coefficients for all independent variables are positive, some show signs of a weak relationship. The coefficient for iron ore price at 0.0869 is followed by real coal price coefficient, at 0.0943.

The coefficient for iron ore price at 0.0869 is followed by real coal price coefficient, at 0.0943. The results meet the significance level of 1% but they are not strong. This finding is not consistent with my expectations. As two of the largest exports from Australia I expect iron ore and coal to have a stronger relationship with the AUD/USD REER. This may be due to spikes in price during the GFC period (2008-09). Next, the natural gas price also has a weak coefficient of 0.0374, and the result is only significant at a level of 7.5%. Along with R-squared 3.5%, regression analysis suggests the relationship between the AUD/USD REER and natural gas is insignificant.

On the other hand, the gold and aluminium prices have strong positive correlations with the dependent variable. The estimates suggest a strong β of 0.2772 and 0.2351 for gold and aluminium respectively. The results are significant at a level of 1% as well. For gold this result is expected, as found in previous studies (Apergis 2014; Haque and Lilford 2015). R-squared further estimates that 15.62% of variation in the AUD/USD REER is attributed to the gold price. For aluminium, this level of positive correlation is unexpected.

As a smaller share of Australia's exports, aluminium is a commodity with fewer uses and lesser demand than for other commodities mentioned in this thesis. Although considering the trend analysis (Figure 3.7 (aluminium) and Figure 3.1 (REER)), there were many similarities.

Both graphs show evidence of an overall increase in price, as well as similarities in time where they experienced rapid appreciation and depreciation in their value also. Overall, the OLS presents strong evidence that commodity terms of trade, gold and aluminium have a strong positive relationship with the dependent variable. The OLS regression indicates that a positive correlation between iron ore and coal prices exist but is relatively weaker than the other commodities, gold and aluminium. Natural gas does not appear to have a significant relationship with the AUD/USD REER. The results found in this chapter are presented in the results summary.

Table 4.9: Ordinary Least Squares (OLS) panel analysis

Here, the real effective exchange rate is the dependent variable. The relationship that the AUD/USD REER has with explanatory variables: commodity terms of trade, real iron ore price, and real coal price, real gold price, real natural gas price and real aluminium price is displayed.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.0015	0.0050	-0.2960	0.7680
Commodity Terms of Trade	1.9960	0.7508	2.6584	0.0095
R-squared			*0.0802*	
Adjusted R-squared			*0.0689*	
F-Statistic			*7.0672*	
C	-0.0016	0.0049	-0.3251	0.7460
Real Iron Ore Price	0.0869	0.0285	3.0425	0.0032
R-squared			*0.1025*	
Adjusted R-squared			*0.0914*	
F-Statistic			*9.2571*	
C	-0.0019	0.0050	-0.3809	0.7043
Real Coal Price	0.0943	0.0343	2.7523	0.0073
R-squared			*0.0855*	
Adjusted R-squared			*0.0742*	
F-Statistic			*7.5752*	
C	-0.0048	0.0049	-0.9803	0.3298
Real Gold Price	0.2772	0.0072	3.8726	0.0002
R-squared			*0.1562*	
Adjusted R-squared			*0.1458*	
F-Statistic			*14.9996*	
C	-0.0009	0.0051	-0.1771	0.8599
Real Natural Gas Price	0.0374	0.0207	1.8017	0.0753
R-squared			*0.0353*	
Adjusted R-squared			*0.0267*	
F-Statistic			*3.2461*	
C	-0.0012	0.0045	-0.2775	0.7821
Real Aluminium Price	0.2351	0.0441	5.3370	0.0000
R-squared			*0.2602*	
Adjusted R-squared			*0.2510*	
F-Statistic			*28.4841*	

4.4 Chapter summary

In this chapter I successfully tested my hypothesis for RQ1 and RQ2. For RQ1, rejected the null hypothesis, and found that the Australian commodity terms of trade do influence the AUD/USD real effective exchange rate in the long term. I also ran multiple tests to understand this relationship. The Johansen cointegration test provided evidence of long term cointegration between the variables, and my VECM Granger causality test confirmed that commodity terms of trade have a causal impact on the AUD/USD REER. As causation is not a strong indication of a relationship, I further analysed correlation, elasticity and regression for this relationship. Even though my correlation analysis suggests a weak, yet positive correlation of 28.3%, the log-linear test for elasticity suggests that for every 1% increase in commodity terms of trade the REER shifts by 5.6%. Lastly, the regression analysis supports these results by examining that 8.02% of variation in the REER is caused by shifts in the CTOT (as per Table 4.7).

I conclude that the Australian commodity terms of trade do influence the AUD/USD real effective exchange rate over the long term. Previously, this thesis establishes that terms of trade influence the exchange rate in OECD nations, including Australia. There is also robust empirical evidence to suggest that an increase in terms of trade results in an appreciation of the wealth for countries rich in natural resources (Brahmbhatt et al. 2010; Spatafora & Warner 1995). This is the case in both the short and long term. The results provide evidence to suggest this is the same for commodity terms of trade in Australia in the long term. I did find a robust relationship in the short term between the REER and commodity terms of trade. In the long term however, advances in technology, productivity shifts, expected global growth, and supply and demand from close trading partners play a vital role in dictating prices of exports and imports, and hence commodity terms of trade. In the long term, the REER dictates commodity terms of trade. In Australia's past, the mining boom has played the biggest role.

For RQ2, I ran the same tests individually for the five explanatory variables (Table 3.1). These were summarised in order of largest to smallest shares of commodities exported. First, I discussed the results for coal. Johansen cointegration estimates test statistically significant for long term cointegration. The VEC model Granger causality finds that in the long term the causality in bidirectional. In the short run there is evidence of unidirectional causality. The significance of the coal price causing movement in the exchange rate is stronger than that suggesting the reverse relationship. In addition to the time series analysis, the correlation analysis suggests that for every 1% increase in the price of coal the real exchange rate is positively affected by 0.3%. Finally, the OLS regression satisfies that 8.5% of variation in the dependent variables can be explained by the price of coal. I reject the null hypothesis for RQ2 and establish that the price of coal does influence shifts in the real effective exchange rate in the long term. In addition, my VAR model also supports this relationship in the short term.

Next, I summarised the results for iron ore. Here, I also reject the null hypothesis. The evidence suggests the existence of long term cointegration, and like coal, there is bidirectional causality present. There is no evidence of causation in the short term. A weak cross correlation of 35.03% is present, supported with an elasticity that suggests that for every 1% increase in the price of iron ore the exchange rate appreciates by 0.27%. OLS regression analysis is significant to a level of 1% and suggests that 10.25% of variation in the exchange rate can be positively explained by changes in the price of iron ore.

For natural gas, I do not reject the null hypothesis. I do not find strong evidence suggesting the price of natural gas influences the exchange in the long term. Although I find there is a cointegrating relationship in the long term, there is evidence to suggest causation in the short term. The regression coefficient is in line with these results and suggests a weak relationship. Even though the correlation of 29.23% and elasticity of 1.93% results indicate the possibility of a notable relationship, the time series results suggest otherwise. Overall, the results were unsatisfactory and therefore I do not reject the null hypothesis.

For gold, there were mixed results. I find this to be the only commodity which has no long term cointegration with the exchange rate. In the short term, the VAR model suggests strong evidence supporting reverse causality. This is in line with the long term elasticity, which is not substantial at 0.04%. My regression results on the other hand are statistically significant at a p-value of < 0.001, and an f-square suggesting 15.62% of variations in the exchange rate is attributed to shifts in the price of gold. Nevertheless, I do not reject my null hypothesis. My evidence does not support that the RP of gold influences the real exchange rate in the long term.

Finally, I observed the results for aluminium, which amounts to 2.5% of Australia's commodity exports. Due to its small role as a commodity export, the results are not as expected. There was strong evidence to support long term cointegration between the RP of aluminium and the exchange rate, suggesting the former causes the latter. Further, aluminium revealed the highest cross-correlation of all commodities of 50.52%, although elasticity was minimal at 0.02%. The regression results are also highly significant at <0.0001 with an r-squared value suggesting 26.02% of the variation in the exchange rate can be explained by shifts in the price of aluminium. I do however also uncover reverse causality (as in gold) where the exchange rate causes shifts in the price of aluminium. Overall, however, I do not reject the null hypothesis and conclude for RQ2 that the RP of coal, iron ore and aluminium do influence the AUD/USD real effective exchange rate in the long term.

Chapter 5: Discussion

5.1 Introduction

In chapter 5, I discuss my results from Chapter 4, and how these relate to key literature reviewed in Chapter 2 (and highlighted in Table 2.3). I analyse the importance of these results and discuss the consequences for policymakers and market participants who are affected both directly and indirectly by these findings.

The discussion highlights the implications on the current monetary outlook for the Australian economy and allows me to thoroughly answer the research questions. Based on my results summary in the previous chapter (section 4.4), I strongly establish that the Australian commodity terms of trade CTOT and prices have a significant relationship in the Australian financial market with the AUD and USDREER. Specifically, I reject the null hypothesis for research questions 1 and 2. In section 5.1.2 I establish the implications my results may have on the Australian economy. In section 5.1.3 I discuss the relationship between the AUD/USD real effective exchange rate and the five commodities against which I have measured this relationship. Finally, I also consider the potential environmental effects of my findings.

5.2 Commodity terms of trade and the AUD/USD exchange rate

The next section discusses how my findings for RQ1 confirm a strong positive correlation between commodity terms of trade and the AUD/USD exchange rate which affect the Australian economy.

The primary reason I select commodity terms of trade as the independent variable rather than the terms of trade stems from the reason that much pre-existing literature focuses on the latter. Due to Australia's richness in raw materials commodity exports, the commodity terms of trade allow me to accept that in line with the terms of trade. The commodity sector is a large contributor to the strong positive relationship I observe between the commodity terms of trade the real effective exchange rate of AUD/USD.

My results expand on previous studies that concentrate on terms of trade, and I find that results for commodity terms of trade are in line with these results (as highlighted in Table 2.3). Previous studies note that nations with a large primary commodity export sector tend to react to shifts in terms of trade more strongly than those that do not have one (Otto 2003). Key studies such as Jaaskela and Smith's (2013), which is a large inspiration for this thesis, note that two thirds of exchange rate shifts can be explained by terms of trade. Otto's (2003) evaluation is consistent with mine, however I do not find evidence as significant as that found by Jaaskela and Smith. The key difference between their 2013 study and this thesis is the incorporation of a Bayesian VAR model as opposed to standard VAR. The Bayesian method is suitable for very large samples as it avoids the issue of over parameterisation.

My model had a sample size of 84 and would be unsuitable for the Bayesian VAR model. If I were to use a Bayesian model, the results would not be robust due to the size of the sample for this study being limited in nature. A benefit in using the standard VAR model, as I have in this thesis and as have Otto (2003) and Haque and Lilford (2015), is that there is less room for error. A Bayesian approach requires in-depth understanding of the uncertainty framework and external variables need to fit prior distribution of parameters and sign restrictions.

In this study, I choose to observe CTOT as the independent variable for RQ1, which is uncommon in contemporary literature as it omits the prices of non-commodity goods and services that are imported and exported. I note that although many past studies have observed 'commodity currencies' and commodity-exporting nations, these studies still choose to use terms of trade as opposed to commodity terms of trade (Chen & Rogoff 2003; Cole & Nightingale 2016; Kulish & Rees 2015). Measuring terms of trade allows these studies to capture the overall influence trade prices have on the Australian economy. The exclusion of non-commodity goods and services may be a drawback; however, in this study this is a point of difference as it allows me to better measure the importance of commodity prices in relation to the Australian economy. The evidence suggests that positive long term cointegration exists between commodity terms of trade and the real exchange rate (as per Table 4.3). In line with relevant literature (Haque & Lilford 2015; Sujith & Rajesh 2011) a similar time series analysis technique is implemented to understand the relationship between econometric variables. The evidence of correlation is supported by causation as well; indicating the commodity terms of trade causes the change in the real effective exchange rate.

Next, I discuss the current monetary outlook and how my results from Chapter 4 are impactful on the exchange rate and the market participants and policymakers who play a role in the currency market (as discussed in section 1.3).

5.2.1 Australian economy and the exchange rate

First, I discuss the implications of my findings on the Australian economy. This section discusses the direct and indirect effects the results have on Australia's monetary policy, and the macroeconomic and microeconomic outlook.

Current Australian monetary outlook

In the RBA's recent monetary forecast (October 2019), members note they expect significant risks related to a downturn in global growth and a reduction in Australia's cash rate to 0.75%. This negative outlook is attributed to geopolitical factors such as trade disputes between the US and China. Globally, the interest rates for large economies such as the US and Canada are declining, and further monetary easing is expected in Australia's future to meet its inflation target of between 2 and 3%. The RBA, however, expects it will not be able to meet its goals to meet forecast levels of unemployment and inflation.

The real interest rate is a key exogenous consideration in this study. Ready et al. (2017) found that interest rates often rise for nations which export raw commodities in large volumes. This is due to gains received from carry trade strategies, and interest rate arbitrage (Ready et al. 2017). For the duration of the study the AUD/USD is a carry trade, since the 2018 Australian interest rate has decreased below that of the US. The carry trade is no longer the case for the AUD/USD exchange rate. Ready et al.'s (2017) findings mention that the positive relationship between the interest rate and raw commodities export are partially attributed to the carry trade. In the case that there is no longer a carry trade in the future for Australia, the dynamic of interest rates and commodity exports may be reversed. On the other hand, Akram's study (2009) highlights that shifts in interest rates are inversely correlated to the price of commodities. He also notes the presence of reverse causality between the exchange rate and commodity prices due to shocks on the exchange rate caused by the real interest rate (Akram 2009). Their seventeen-year study also takes place during the pre-GFC period from 1990 to2007. Nevertheless, in relation to the relationship between commodity prices and the USD their findings are similar between the two studies (Akram2009; Ready et al. 2017). This finding is in line with the results of this thesis. Commodity prices are negatively correlated to the USD. In my case the USD is the base currency, therefore this relationship holds.

Based on this comparison, I interpret that the GFC does not have an impact on the direction of the relationship and long term cointegration of commodity prices and the exchange rate. A major difference between this study and Akram's (2009) is that the latter study also incorporates the RP of oil. Although oil is not a large export for Australia, it has a deep integration in the production, logistics and deliverance of raw materials. The oil price responds positively to interest rate shocks over the long term. Although noteworthy, oil price shocks are outside the scope of this study.

Next, I discuss how my findings directly affect the price of raw material commodity exports and imports.

Direct effects on the price of exports and imports

A direct impact of the change in exchange rates is the price of internationally traded goods due to fluctuations in cost of buying and selling. My evidence suggests that when a commodity comprises over 10% of Australia's net exports, there is a clear, positive effect on the exchange rate when the price of that commodity increases. However, in the short term the causality is reverse in nature. The macroeconomic fundamentals behind this are as follows.

When there is a rise in the AUD, as it gains value against the USD an increased amount of foreign currency is needed in order to buy the given amount of AUD. Relative to the price of the same goods overseas, this makes the goods produced in Australia more expensive for exporters. A depreciation in the exchange rate has the opposite effect. Due to the raw commodities having a direct positive impact on the exchange rate in the long term, the relationship between commodity terms of trade and the real effective exchange rate is similarly positive.

Cashin et al. (2004) noted that even before the mining boom, the real price of commodity exports witnessed a similar positive relationship with the strength of the domestic currency, especially in export heavy nations. Their extension of Chen and Rogoff's (2002) 'commodity currency' discussion resonates with the importance of this relationship in making decisions regarding monetary policy and controlling inflation (Cashin et al. 2004; Chen & Rogoff 2002).

A major difference between Chen and Rogoff's key study and this thesis is that their study employs the commodity price index as the independent variable, as opposed to the commodity price. The CPI-adjusted real price of commodity is still suitable for the time series model rather than the commodity price index. In addition to using a different time frame from the study, the difference in the independent variable for Chan and Rogoff allows them to capture a large array of commodities. I extend this finding by remarking that the commodities which comprise a large percentage in Australian exports are those responsible for these shifts in the long term. In this case this is the real price of coal and iron ore.

Next, I discuss the contribution this information makes to the role big banks play in the Australian economy, and more specifically, management of the floating exchange rate.

Direct effect on the big banks

Large banks have teams dedicated to managing their foreign currency exposure and use long-term hedging and derivative strategies to manage risk. Making an informed decision is critical. Given the long-term nature of the relationship (see RQ1), a shift in commodity terms of trade can be used to confidently measure long-term forecasts for the real effective exchange rate. Amongst other factors such as potential interest rate changes, foreign direct investment and employment, commodity terms of trade can indicate the health of export prices. Similarly, the confirmation of direction and strength of Australia's individual commodities is a factor banks can measure.

This measurement of the β coefficient as per Table 4.5 indicates the slope coefficient relative to commodity for the Beta currency.

Direct effect of importers and exporters

Importers and exporters of commodities will benefit from these findings. Small and large businesses carry the risk of uncertainty and cannot forecast the exchange rate. Therefore, companies cannot confidently predict the cost of buying or selling a commodity at any time. Furthermore, even those who do not buy or sell commodities are affected by the exchange rate.

To guard against exchange rate risks, products such as options and futures are used in order to guarantee an underlying budgeting level, often set at a specific exchange rate. Problems arise when the corporation misinterprets the risk and enters exchange rate contracts which become ‘out-of-the-money’. An iron ore company would be arranging contract with its buyers at fixed rates, variable to any dynamic change. An increase in the iron ore price by 1%, according to my results, would appreciate the real effective exchange rate up to 0.3%. This minimal shift of only 1% in commodity prices results in the exchange rate with a difference of $190,000 on USD 63 million worth of exports (DFAT 2018). Shifts much larger than this have occurred in the last twenty years with the price of iron ore ranging between USD27 and USD197.

Direct effect on retail traders

Speculative financial market traders and brokers increase market liquidity. The foreign exchange market in Australia is a leveraged product, providing traders with more purchasing power with a limited margin (ASIC, 2016). Traders hedge their risk in diversifying their exposure to the market by understanding correlations between products and fundamental changes, such as a rise or fall in the terms of trade index, which indicates the direction of the exchange rate. Similarly, some traders may use a technique to short the aluminium price and long the AUD. If this is due to external effects in the short term, the AUD depreciates and the aluminium price appreciates over the long term, thus benefiting the trader.

5.2.2 Indirect effect

Indirectly, commodity terms of trade that influence the exchange rate positively, create shifts in Australian economic activity and the domestic labour market. Where commodity terms of trade depreciate, resulting in a downward shift in the real effective exchange rate, this trend decreases the competitiveness of Australian exports. In this instance, the price of Australian commodities must increase in order to remain competitive, which results in a slowdown in demand and a reduction in the quantity of exports. Similarly, imports become relatively cheaper for consumers and businesses; with regards to this shift consumer behaviour reflects an increase in foreign spending, resulting in an increase in the volume of imports. Here I consider the Balassa-Samuelson effect and the PPP model. Changes to the cost of exports and imports are influenced by tradability of goods.

Implications of the Balassa-Samuelson effect

Australia is highly dependent on the export of primary commodities (DFAT 2017). A change in commodity terms of trade for that reason has a dramatic effect on the standard of living in Australia. Although this thesis primarily focuses on exports, it is important to note that commodity terms of trade is a weighted index of both export and import prices (Eq. 3.2). This is a major implication in relation to understanding this relationship. As seen in Figure 3.2, commodity terms of trade increase gradually until the GFC period around 2008, followed by a sharp drop and rapid increase to reach its peak in 2010. More recently the index dropped to lows experienced in 2002 and regained its losses, finding its way back up to near its mean of 98. With these shifts being responsible for 8.02% of variation in the exchange rate, the implications for policymakers and market participants has been heightened.

A deterioration of export prices and thus commodity terms of trade means exports are cheaper, and imports become more expensive and vice versa. Here, although exports are cheaper, an increase in the exchange rate in turn becomes more expensive for large-scale commodity exporters. Similarly, with cheaper imports I would expect the effect on net exports to be almost neutral. However this may not be the case, as imports are not skewed towards a specific industry as exports are. The composition of imports is outlined in Table 2.3 and the largest three imports are spread across travel, petrol and motor vehicles. There is no floating market for these products, so they are not considered as part of the scope of this study.

In 2018, $66,860 million worth of coal was exported. An increase of that volume resulted in a 1% increase in commodity terms of trade at that time, causing an appreciation of 5.63% in the exchange rate. For instance, the real effective exchange rate in January 2015 was 0.7097 AUD for every USD 1.00. Here, if there is an increase of 1% in commodity terms of trade, as observed, the exchange rate rises to 0.7144, which occurs in 2017. For the same amount of exports, coal exporting companies would receive $632 million less. On average, 54% of coal mined in Australia is exported (Gladstone Centre of Clean Coal, 2007). The remainder constitutes 85% of the electricity generated in Australia. World leading companies, such as BHP and Rio Tinto, collectively mined over

90 million tonnes of coal in 2015 (Ibisworld 2017). By applying this knowledge, where commodity terms of trade increase by 1%, a large multinational company (e.g. a coal exporter) needs to consider how a 5.63% appreciation in the exchange rate will affect its budget. For the same amount of exported goods, the income from coal exports increases by $632 million. This amount then reduces the GDP (Equation 1). Further, such a large shift not only affects the inflow of funds but also impacts employment opportunities, wages, and company investments.

Based on this, coal exporting companies are heavily affected by an overall decrease of $632 million in the influx of AUD funds. Further, the coal mining sector comprises 8.5% of Australia's GDP and contributes to 2% of the entire workforce of Australia. A decrease in GDP indicates a slowdown in economic growth as it essentially represents a function of purchasing and selling on a macroeconomic scale. I now discuss the impacts of the results on the employment sector.

Implications for Australia's labour market

One of the roles of a central bank is to achieve its highest possible level of employment. As a world leader in the mining of coal, iron ore and aluminium, the mining sector in Australia is responsible for a large percentage of total employment. In 2018, the Australian mining industry employed over 249,800 people (ABS, 2019). An increase in employment allows companies to grow and their employees to contribute to consumer spending. Overall, the mining sector is the backbone of Australian employment in Western Australia and Queensland, where coal, iron ore and bauxite mines are located.

As a result of lower employment in the mining sector, the downturn in the economy has witnessed a decrease in consumer spending. Consumer spending is inversely related to the GDP (Equation 1). Secondly, net exports decrease as Australia's net exports are skewed heavily towards exports rather than imports. Australia's trade balance is positive, meaning there are more exports than imports. Hence, having a weaker AUD creates wealth for exports. On the other hand, this is problematic for importers who suffer in low exchange rate conditions when funds are not managed accurately. Struggling companies have to reduce staff and increase the price of goods to maintain profit margins. Overall, a reduction in the exchange rate is beneficial for the Australian export industry but in turn damages the import sector. Fortunately, the effects of commodity prices are more relevant in the long term. Importers may need to consider long term exchange rate movements to create a buffer in order to maintain competitiveness in the marketplace.

5.3 Real commodity price and the real effective exchange rate

In this section I discuss Research question 2. Here I discuss the influence the five commodities have on the real effective exchange rate. Based on the evidence from the results section, I reject the null hypothesis and do not reject the alternative hypothesis. Most commodity prices of Australia's natural resource commodity exports have a strong relationship with the real effective exchange rate. As they comprise a large percentage of Australia's exports, this is in line with my expectations and predictions from my literature review. Manalo et al. (2015) reinforce that the exchange rate would appreciate without the mining boom, but it would do so at a slower pace. Furthermore, Akram's (2009) pre-GFC study advises similar results to this thesis, noting that the GFC has little effect on the existence of the relationship.

5.3.1 Coal price and the real effective exchange rate

As the world's largest coal exporter (IEA 2017), Australia is subject to high demand from global coal importers such as China, India and Japan. As one of the lowest priced power generating fuels, coal is Australia's largest exported commodity. Coal's elasticity with the real exchange rate illustrates that the real exchange rate experienced a shift of 0.30% in response to every 1% change in the price of coal. These price fluctuations, especially for an energy intensive nation, have compounded consequences. According to the RBA (2017), Australia's coal demand is expected to continue to increase due to global expansion and the favourable quality of Australian thermal coal. Ali and Rahman (2012) discuss the phenomena that the strength of the relationship between the AUD and USD exchange rate is increasing with the volume of coal being exported. Furthermore, the substitution of coal with other power generating fuels is complex due to the higher cost of other fuels, in addition to the cost of substitution itself. However, Ali & Rahman (2012) do not use a time series analysis approach. I adopt their approach in addition to the time series analysis. Their evidence is based purely on a Pearson correlation and simple OLS regression test.

In early 2019, Australia approved plans for the Carmichael Coal Mine to open in the Galilee Basin in Queensland. This will be one of six new mines. The introduction of this coal mine is expected to export up to 15 million tonnes of coal at peak production per annum. It is claimed that this coal mine will become one of the largest in the world, and certainly the largest in Australia. Based on the mean price for coal at USD 62.22 /metric ton (Table 2.3), the introduction of 15 million tonnes of coal has a value of USD 933.33 million added to Australia's economy. This will drive up net exports and increase Australia's GDP. The forecast to produce coal is almost 10 times that produced in 2018.

Furthermore, it is expected to create between 800 and 1500 jobs based on a June estimate. This is a positive factor to meet the RBA's goals to increase employment. It will also attract more people to rural areas in rural mining towns of Australia, and increase spending for local economies. From the rapid increase of supply, the law of macroeconomics states that the price of coal is expected to drop. According to my results, a downturn shift in the price of coal causes a reduction in the exchange rate. As an exporting nation, this means more AUDs will be received for each USD. Due to its bidirectional causality, coal prices will adjust directly to find their long term equilibrium. Coal exporters must monitor their long term exposure to meet demand and find an equilibrium exchange rate to set their contracts. They must consider the reverse causal relationship in order to incorporate the cyclical nature between the coal price and the real effective exchange rate.

5.3.2 Iron ore price and the real effective exchange rate

Australia is also the world's largest global exporter of iron ore. The results section indicates a significant relationship between the iron ore commodity price and the real effective exchange rate. This is a commodity which is highly reliant on demand from China because most Australian iron ore is exported to China. In 2018 not only did iron ore comprise 15% of Australia's total exports, it also comprised 3.3% of the nominal GDP. As the demand from China remains high for Australian iron ore, an increase in price means a boost in Australian GDP. The household sector in Australia benefits highly from the strengthened profits received from the mining sector.

The effects this has on the Australian economy are vast. With over 150 iron ore mine sites, the economic contribution impacts employment, exploration, development and project expansion in Australia. Further to Haque and Lilford's study (2015), which was a key inspiration for my research question, I prove that there is unidirectional causality between the price of iron ore and the real exchange rate in the long term. This is robust evidence tested at a 5% level of significance. The relationship does not exist the other way. The Johansen cointegration results further provide data supporting a long term relationship between the two variables. Although there was cointegration in the long term, the test for short term causality was run as well as using the VECM. The VECM suggests no causality in the short run, only in the long term. Given the nature of the mining industry, the business cycle is lengthy due to mining, testing, delivering and receiving payment for this raw material. For this reason, it is also evident that the effects of changes in iron price are not felt immediately, but over time. As per my cointegration test, out of all the commodities coal and iron ore presented evidence suggesting long term cointegration.

5.3.3 Gold price and the real effective exchange rate

Out of all the commodities examined in this thesis, gold is the one with the most interest from researchers. As a highly traded commodity on the floating market, gold is popular as a safe haven trade selection. The long term elasticity test indicates very little elasticity: a 0.03% change in the real exchange rate for every 1 % shift in the gold price. In the time series analysis, I determine that the gold price is stationary in its first difference, in the short run. The results indicate that gold price does not generate a change in the real exchange rate for Australia. However, there is evidence which suggests reverse causality.

This is different from the results provided by KS and Sajit (2011), who find that there is bidirectional causality. Their study focuses on gold price against the USD as well. This is a key point as the gold price relies heavily on the USD. The difference is that my test incorporates the real interest rate differential as a control variable. Incorporating the real interest rate supports evidence provided by Akram (2009), who considers that changes in commodity prices are produced as a result of shocks to the real interest rate. Measuring the changes felt by the AUD would need to eradicate exogenous effects felt by changes in the USD. Furthermore, now that I am looking at a commodity which comprises a small part of Australia’s export market, the results suggest there is no long term effect felt as gold mining is not a big industry in Australia. In comparison with coal and iron ore, gold does not have any further uses in manufacturing or energy production. Although its price per ounce may be high, this affects the way its value is perceived by the industry. It is important, however, to note that shifts in the AUD/USD real exchange rate via Granger Cause changes in the gold price. There is scope for future research to understand this relationship further. For this commodity I do not reject the null hypothesis. The gold price does not influence the real effective exchange rate of the AUD/USD.

5.3.4 Natural gas price and the real effective exchange rate

Similar to gold, there is no observed strong relationship between natural gas prices and the real exchange rate in Australia in the long term. The long term elasticity initially indicates significant elasticity between the natural gas price and the real exchange rate. For example, for every 1% shift in the natural gas price the test indicates the real exchange rate will shift by 1.27%. This is the highest out of all commodities. Time series analysis, however, sends a different message. Regarding the level in first difference, both stationary variables do not show any long term cointegration based on the Johansen cointegration equation. LNG production plants in Australia are growing, as it has taken over from Qatar as the world largest exporter of natural gas. There is also no significant evidence suggesting that changes in the natural gas price generate shifts in the real effective exchange rate. This may be due to various factors.

One factor is that natural gas does not play a large enough role in exports composition to have a dramatic effect on the exchange rate. Also, the effect natural gas has on local spending is reversed. As gas is an important part of electricity generation in Australia, due to high exports, gas prices are causing electricity prices to soar, and this affects household spending. Not only are Australian residents having to pay more for their electricity usage, but due to the increased price of power and contracts for shipping a certain requirement of gas to trading partners, it is becoming costly for Australian companies to retain staff. In 2016, the Australian Workers Union reported a decrease in employment in this sector due to the increased price of gas. Overall, playing a small role in exports but offering high revenue in return with a negative effect on the Australian employment market, the evidence suggests a net neutral effect on the real exchange rate. On one hand it is increasing export revenue, on the other hand it is decreasing consumer spending for Australians on a microeconomic scale. Following Ali and Rahman's (2012) discussion, I note that due to the natural gas component not comprising a large portion of Australia's exports, there is no strong connection between the variables.

5.3.5 Aluminium and the real effective exchange rate

Aluminium, like gold and natural gas, plays a small role in Australia's exports. However, the results for aluminium were most unexpected. Although a world leader in the production of aluminium, Australia only makes up 4% of the world's aluminium exports. Further, this thesis focuses exclusively on exports. Aluminium is also used locally for domestic goods such kitchen utensils and household objects due to its non-toxic and low-density characteristics, along with its high conductivity. On a larger scale it is important for the transport construction such as railways and airplanes due to its alloy component.

In summary, in the long term the price of aluminium influences the real exchange rate, and vice versa in the short term. After reaching a certain threshold the effect of the aluminium price is reversed. I attribute this effect to aluminium imports. In 2018, Australia exported 1,629,759 tonnes of aluminium and imported 300,355 tonnes (ABS 2019). This is a net export of 1,329,404 tonnes. An increase in the exchange rate would make it beneficial for aluminium importers to partake in short term contracts to benefit from higher exchange rates. This in turn would increase the demand for aluminium purchased from international trading partners. An increase in demand and higher amounts of imported aluminium result in a reduction of the aluminium price in the long term. Based on my long term VECM results the exchange rate drops in this scenario, making it beneficial for aluminium exporters. I do not pay much attention to the results of the OLS regression here. As a univariate model it measures the fluctuations between variables; however, it does not allow me to account for external factors which may be responsible for shifts in the price of aluminium.

5.3.6 Implication of the Global Financial Crisis (GFC)

The findings from this study suggest that the GFC does not have a significant impact on the long-term relationship between a. The real exchange rate and the CTOT, and b. the exchange rate and commodity prices. Due to the increase in mining within Australia witnessed from 2002 onwards, the economic activity within Australia remains strong during the GFC. My data is also of a long term quarterly nature. I have outlined further scope to discuss the implications of the GFC in section 6.4.

5.4 Summary

This chapter discusses the results in line with the literature review highlighted in Chapter 2. I establish how the results contribute to market participants and impact Australian economic policy. The positive impact commodity terms of trade and the real commodity price have on the exchange rate results in both direct and indirect effects on the economy. There are significant impacts on the inflow and outflow of funds in Australia and how multinational corporations, and the central bank, maintain their activities that allow them to reach their economic goals.

Chapter 6: Conclusion

6.1 Introduction

This chapter concludes the thesis. I discuss the key findings from my results and discussion in section 6.2 where I answer research questions. Section 6.3 notes limitations of this study regarding methodology and scope. Section 6.4 discusses the scope for future research.

6.2 Key findings

This thesis established that commodity terms of trade and prices of Australia's largest exports have a strong, complex relationship. Commodity terms of trade portray positive cointegration and a high degree of elasticity with the exchange rate. Coal, iron ore and aluminium prices portray similar positive evidence suggesting that the price of these commodities influences the exchange rate in the long term. In the case of iron ore and coal I attribute the relationship to their dominance in the export share in Australia in recent years, and their input to industrialisation through steel production (iron ore) and energy production (coal). My findings support earlier key studies (Akram 2009; Haque & Lilford 2014; Jaaskela & Smith 2013) and add value to individual commodities in addition to industry studies conducted. Natural gas and gold variations in the exchange rate are significant in the short term.

For RQ 1, I rejected the null hypothesis. There is a strong relationship between Australian commodity terms of trade and the real exchange rate. It is also evident that commodity terms of trade positively Granger Cause shifts in the exchange rate. To answer RQ 2, I also rejected the null hypothesis. The findings suggest that the real commodity price of coal and iron influence the real exchange rate. I did not reject the null hypothesis in the case of other commodities. This is attributed to factors such as the volume of exports not being large enough to cause a change to the Australian economy, and the characteristic of the commodity not being involved in the energy production category, as compared to iron ore and coal.

This thesis investigated two key relationships for long term correlation using time series analysis. Considering quarterly data from Q1 (March) 1997 to Q4 (December)

2017, this study found significant results for both relationships. First, the relationship between commodity terms of trade and the real effective exchange rate. In line with studies confirming a relationship between terms of trade and the exchange rate, I have presented further evidence which supports this finding, found to be stationary in its first difference, and long term elasticity which demonstrates a strong positive correlation. Further time series analysis also provided support for this direct relationship. Commodity terms of trade data was used extensively by the central bank, large corporations and retail traders to make informed decisions. The information uncovered in this thesis will allow these market participants to create policy and strategy in the best interests of Australia's economic prosperity.

The second key relationship investigated by this study was the relationship between Australia's five largest commodity exports and the real effective exchange rate. Following similar correlation and time series analysis, there is evidence to suggest that commodity terms of trade, iron ore and coal prices are elastic with the real exchange rate. This is also the case for natural gas. However, for gold and aluminium prices there was no significant elasticity. This further confirms the significance of commodity terms of trade and thus exports, specifically in the commodities sector. These findings add significant value for participants in the foreign exchange and export market, especially for those who export these major commodities worldwide. Even small changes in commodity prices have significant impacts on cash flow for large Australian mining corporations.

Conclusively, there was a significant integration of commodity terms of trade with the real effective exchange rate, rejecting the null hypothesis for RQ1. The relationship between aluminium, iron ore and coal prices in the long term was significant; however, only in the short term is there evidence to indicate that the price of gold and natural gas influences the real exchange rate.

6.3 Limitations of thesis

The limitations of this thesis affect the research methodology and scope.

Augmented Dick-Fuller test limitations

The limitations regarding methodology apply to the power of the ADF test and Johansen cointegration test. The unit root test I implemented was better suited to sample sizes of over 100. My sample size was 84, and this may affect the robustness of the unit root test.

Regression Analysis

The regression analysis employed for this thesis is univariate OLS regression. Major attention was given to time series analysis, as performing the Johansen cointegration test and OLS regression analysis can lead to inconsistencies in results. The regression analysis uses non-stationary data, therefore the strength of the relationship between the variables is not robust; however, it is further proof that the relationship is positive or negative in the long term. For future research, I recommend using a multivariate regression model.

Global Financial Crisis

This thesis does not divide the data into pre- and post-GFC. The GFC is a prominent financial event in history which, as noted in previous sections, has had a big impact on financial markets. However, although the data was not divided I studied literature published pre-GFC (Akram 2009), which conducted similar research with similar results.

6.4 Scope for Future Research

There is large scope for further research to understand factors which impact the exchange rate. Whilst this thesis has focused on the importance of the export sector and the commodity terms of trade, further researchers can investigate the role imports play on the exchange rate as well. Import sectors such as education and tourism play a large role in the Australian economy.

Also, a further study comparison study can be performed on the impacts of the independent variables and its impact on the exchange rate over the short term, and the contrast of results we have uncovered in the long run. Lastly, the mining of coal and iron ore have detrimental effects on the environment and climate. We recommend future researchers to discuss the environmental impacts of mining raw commodities as well. Lastly to better capture the implications of the GFC we recommend future research to split the data sample to pre and post GFC period.

For improvements to the methodology, we recommend multiple linear regression instead of a simple linear regression for the OLS testing.

6.5 Summary

This chapter is a recap of the key findings of the thesis. In addition to highlighting the takeaways from our research questions, this chapter notes the limitations of this thesis, and the significant scope for future research. Those who may be interested in conducting future research in this field may find this information useful.

Chapter 7 References

Adam et al. (2018). "The causal relationship between crude oil price, exchange rate and rice price. " International Journal of Energy Economics and Policy 8 (1): 90-94.

Akram, F. (2009). "Commodity prices interest rates and the dollar." *Energy Economics* 31(6): 838-851.

Ali, L. & S. Rahman (2012). "Influence of Australian coal export on A$/US$ exchange Rate: A longitudinal study." *International Business & Economics Research Journal* 11(4): 397-406.

Amano, R. & S. Norden (1998). "Oil Prices and the rise and fall of the US real exchange rate." *Journal of International Money and Finance* 17(2): 299-316.

Anderson, O., et al. (2003). "Micro effects of macro announcements: real -time price discovery in foreign exchange." *American Economic Review* 93(1): 38-62.

Andries, A. M., et al. (2017). "The relationship between exchange rates and interest rates in a small open emerging economy: The case of Romania." *Economic Modelling* 67: 261-274.

Apergis, N. (2014). "Can gold prices forecast the Australian dollar movements?" *International Review of Economics & Finance* 29(1): 75-82.

Bahmani-Oskooee, M., et al. (2013). "The effects of exchange-rate volatility on commodity trade between the U.S. and Brazil." The North American Journal of Economics and Finance 25(August): 70-93.

Bahmani-Oskooee, M. et al. (2016). "Revisiting purchasing power parity in Eastern European countries: quantile unit root tests." *Empirical Economics* 52(2): 463-483.

Bahmani-Oskooee, M. & A. Nasir (2005). "Productivity bias hypothesis and the purchasing power parity: A review article." *Journal of Economic Surveys* 19(4): 617-696.

Balassa, B. (1964). "The Purchasing-Power Parity doctrine: A reappraisal." *Journal of Political Economy* 72(6): 584-596.

Barhoumi, K. (2006). "Differences in long run exchange rate pass-through into import prices in developing countries: An empirical investigation." *Economic Modelling* 23(6): 926-951.

Battellino, R. (2010). "Mining booms and the Australian economy. " R. B. A. Australia. Sydney, *The Sydney Institute*. March quarter 2010: 63-70.

Bekart, G., et al. (2007). "Uncovered interest rate parity and the term structure." *Journal of International Money and Finance* 26(6): 1038-1069.

Belke. A. et al. (2010). "Global liquidity and commodity prices - a cointegrated VAR approach for OECD countries." *Applied Financial Economics* 20(3): 227-242.

Bishop, J., et al. (2013). "The resources boom and the Australian Economy: A sectoral analysis." *Reserve Bank of Australia* (Bulletin March Quarter 2013).

Bordo, M. D., et al. (2017). "The real exchange rate in the long run: Balassa-Samuelson effects reconsidered." *Journal of International Money and Finance* 75: 69-92.

Brahmasrene, T., et al. (2014). "Crude oil prices and exchange rates: Causality, variance decomposition and impulse response." *Energy Economics* 44: 407-412.

Branson, W., et al. (1977). "Exchange rates in the short run: The dollar-deutschemark rate." *European Economic Review* 10(3): 303-324.

Byrne, J. & J. Nagayasu (2010). "Structural breaks in the real exchange rate and real interest rate relationship." *Global Finance Journal* 21(2): 138-151.

Carpantier, V., et al. (2012). "Real exchange rates in commodity producing countries: A reappraisal." *Journal of International Money and Finance* 31(6): 1482-1502.

Carron, K. (2015). "Calibration of Bubble Indicators for Foreign Exchange Markets" University of St. Gallen. Master's Thesis: 103.

Cashin, P., et al. (2004). "Commodity currencies and the real exchange rate." *Journal of Development Economics* 75(1): 239-268.

Cayen, J-P., et al. (2010). "What drives exchange rates? New evidence from a panel of U.S. Dollar bilateral exchange rates." *Bank of Canada Working Papers* 5: 2-33.

Chaboud, A., et al. (2010). "Trading activity and macroeconomic announcements in high frequency exchange rate data." Journal of the European Economic Association 6(2): 589-596.

Charnavoki, V. & J. J. Dolado (2014). "The effects of global shocks on small commodity-exporting economies: lessons from Canada." American Economic Journal: Macroeconomics 6(2): 207-237.

Chen et al. (2014). "What drives commodity prices? " American Journal of Agricultural Economics 96 (5): 1455-1468.

Chen, H., et al. (2016). "Oil price shocks and US dollar exchange rates." *Energy Economics* 112(2): 1036-1047.

Chen, S. & H. Chen (2007). "Oil prices and real exchange rates." *Energy Economics* 29(3): 394-404.

Chen, Y-C. & K. Rogoff (2003). "Commodity currencies." *Journal of International Economics* 60(1): 133-160.

Cheng, S. & J. Chi (2016). "Do exchange rate volatility and income affect Australia's maritime export flows to Asia?" *Transport Policy* 47(April): 13-21.

Chinn, M. & G. Meredith (2005) "Testing uncovered interest parity at short and long horizons during the post-Bretton Woods Era. " *National Bureau of Economic Research* DOI: 10.3386/w11077.

Chong, Y., et al. (2012). "The Harrod-Balassa-Samuelson hypothesis: Real exchange rates and their long-run equilibrium." *International Economic Review* 53(2): 609-634.

Choudri, E. & L. Schembri (2014). "Productivity, commodity prices and the real exchange rate: The long-run behaviour of the Canada-US exchange rate." *International Review of Economics & Finance* 29: 537-551.

Ciner, C. (2017). "Predicting white metal prices by a commodity sensitive exchange rates." International Review of Financial Analysis (52): 309-315.

Clements, K. & R. Fry (2008). "Commodity currencies and currency commodities." *Resources Policy* 33(2): 55-73.

Cole, D. & S. Nightingale (2016). "Sensitivity of Australian trade to the exchange rate." *Reserve Bank of Australia* (Bulletin September Quarter 2016) 13-20.

Conolly, E., & T. Atkins (2013). "Australian exports: Global demand and the high exchange rate. " *Reserve Bank of Australia*. (Bulletin June Quarter 2013).

Corden, W. (2012). "Dutch disease in Australia: policy options for a three-speed economy." *Australian Economic Review* 45(3): 290-304.

Cordon, M. & P. Neary (1982). "Booming sector and de-industrialisation in a small open economy." *The Economic Journal* 92(368): 825-848.

Coudert, V., et al. (2015). "On the impact of volatility on the real exchange rate - terms of trade nexus: revisiting commodity currencies." *Journal of International Money and Finance* 58: 110-127.

Crucini, M., & D. Backusab (2000). "Oil prices and the terms of trade." *Journal of International Economics* 50(1): 185-213.

Dauvin, M. (2014). "Energy prices and the real exchange rate of commodity exporting countries." *International Economics* 137: 52-72.

De Gregorio, J. & H. Wolf (1994). "Terms of trade, productivity and the real exchange rate." *International Finance and Macroeconomics Program Working Paper* no. 4807.

Demirer, R., & A. Belasen (2019). "Commodity-currencies or currency-commodities: Evidence from causality tests." *Resources Policy* 60: 165-168.

Devereux, M. B. & C. Engel (2003). "Monetary policy in the open economy revisited: Price setting and exchange-rate variability." *The Review of Economic Studies* 70(4): 765-783.

Diba, M. et al. (1999). "Relative labor productivity and the real exchange rate in the long run: evidence for a panel of OECD countries." *Journal of International Economics* 47(2): 245-266.

Dornbusch, R. (1987). "Exchange rates and prices." *American Economic Review* 77(1): 99-112.

Drine, I. (2008). "Purchasing power parity for developing and developed countries, what can we learn from non-stationary panel data models?" *Journal of Economic Surveys* 22(4): 752-773.

Drine, I. & C. Rault (2006). "Can the Balassa-Samuelson theory explain long-run real exchange rate movements in OECD countries?" *Applied Financial Economics* 15(8): 519-530.

Driskill, A. (1981). "Exchange-rate dynamics: An empirical investigation." *Journal of Political Economy* 89(2): 357-371.

Du, W., et al. (2018). "Deviations from covered interest rate parity." *The Journal of Finance* 73(3): 915-957.

Dungey, M. & A. Pagan (2009). "Extending the SVAR model of the Australian economy." *The Economic Record* 85(268): 1-20.

Dwyer, A., et al. (2011). "Global commodity markets - price volatility and financialisation." *Reserve Bank of Australia* (Bulletin June Quarter 2011)

Egert, B., et al. (2006). "Equilibrium exchange rates in transition economies: Taking stock of the issues." *Journal of Economic Surveys* 20(2): 257-324.

Fama, F. (1984). "Forward and spot exchange rates." *Journal of Monetary Economics* 14(3): 319-338.

Faust, J., et al. (2003). "Exchange rate forecasting: the errors we've really made." *Journal of International Economics* 60(1): 35-39.

Faust, J., et al. (2007). "The high-frequency response of exchange rates and interest rates to macroeconomic announcements." *Journal of Monetary Economics* 54(4): 1051-1068.

Ferraro, D., et al. (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(2): 116-141.

Flessig, A. & J. Strauss (2000). "Panel unit root tests of purchasing power parity for price indices." *Journal of International Money and Finance* 19(4): 489-506.

Fornero, J., et al. (2016). "Terms of trade shocks and investment in commodity exporting economies. " *Central Bank of Chile*: 1-48.

Frenkel, A. (1978). "Purchasing power parity: Doctrinal perspective and evidence from the 1920s." *Journal of International Economics* 8(2): 169-191.

Gali, J. & T. Monacelli (2005). "Monetary Policy and Exchange Rate Volatility in a Small open Economy." *The Review of Economic Studies* 72(3): 707-734.

Gil-Alana, L & J. Toro (2002). "Estimation and testing of ARFIMA models in the real exchange rate." *International Journal of Finance & Economics* 7(4): 279-292.

Gilbert, L. (1989). "The impact of exchange rates and developing country debt on commodity prices." *The Economic Journal* 99(397): 779-784.

Goldberg, L. & J. Campa (2008). "Pass-through of exchange rates to consumption prices: What has changed and why?" *National Bureau of Economic Research* 17: 139-179.

Goodhart, C. A. E. (2011). "The changing role of central banks." *Financial History Review* 18(2): 135-154.

Gopinath, G. & A. Burstein (2014). "International Prices and exchange rates." Handbook of *International Economics* 4: 391-451.

Gregory, R. & A. Blundell-Wignall (1990). "Choosing an exchange rate regime: The challenge for smaller industrial countries. " *International Monetary Fund*.

Gruen, R. & J. Wilkinson (1994). "Australia's real exchange rate - Is it explained by the terms of trade or by real interest differentials?" *Economic Record* 70(209): 204-209.

Gubler, M. & C. Sax (2019). "The Balassa-Samuelson effect reversed: new evidence from OECD countries." *Swiss Journal of Economics and Statistics* 155(3): 1-21.

Hacker, S. et al. (2012). "The relationship between exchange rates and interest rate differentials: A wavelet approach." *The World Econom*y 35(9): 1162-1182.

Han, A. et al. (2012). "An interval method for studying the relationship between the Australian dollar exchange rate and the gold price." *Journal of Systems Science and Complexity* 25(1): 121-132.

Haque, A., et al (2015). "Iron ore prices and the value of the Australian Dollar. " *Mining Technology* 124 (2) :107-120.

Haque, A., et al (2015). "Relationship between the gold price and the Australian dollar-US Dollar exchange rate. " *Mineral Economics* 28:65-78.

Hnatkovska, V., et al. (2013). "Interest rate and the exchange rate: A non monotic tale." *European Economic Review* 63: 68-93.

Hoffmann, M. & R. Macdonald (2009). "Real exchange rates and real interest rate differentials: A present value interpretation." *European Economic Review* 53(8): 952-970.

Immam, T., et al. (2012). "Linear relationship between the AUD/USD exchange rate and the respective stock market indices: A computational finance perspective." *Intelligent Systems in Accounting, Finance and Management* 19(1): 19-42.

In, F. & J. Menon (1996). "The long-run relationship between the real exchange rate and terms of trade in OECD countries." *Applied Economics* 28(9): 1075-1080.

Jaaskela, J. & P. Smith (2013). "Terms of trade shocks, what are they and what do they do?" *Journal of Economic Record* 89(285): 145-159.

Karagedikli, O. & G. Price (2012). "Identifying terms of trade shocks and their transmission to the New Zealand economy. " *Reserve Bank of Zealand*. 2012: 1-25.

Kasman, S., et al. (2011). "The impact of interest rate and exchange rate volatility on banks' stock returns and volatility: evidence from Turkey." *Economic Modelling* 28(3): 1328-1334.

Katechos, G. (2011). "On the relationship between exchange rates an equity returns: A new approach." *Journal of International Financial Markets, Institutions and Money* 21(4): 550-559.

Kenneth, F. & K. Rogoff (1995). "Perspectives on PPP and long-run real exchange rates." Handbook of *International Economics* 3: 1647-1688.

Kilian, L. & C. Park (2009). "The impact of oil price shocks on the U.S. stock market." *International Economic Review* 50(4): 1267-1287.

Kilian, L. & C. Vega (2011). "Do energy prices respond to U.S. macroeconomic news? A test of the hypothesis of predetermined energy prices." *The Review of Economics and Statistics* 93(2): 660-671.

Kilian, L. & M. P. Taylor (2003). "Why is it so difficult to beat the random walk forecast of exchange rates?" *Journal of International Economics* 60(1): 85-107.

Kilian, L., et al (2009). "Oil shocks and external balances." *Journal of International Economics* 77(2): 181-197.

King, M., et al (2011). "Foreign exchange market structure, players and evolution." *Research Department, Norges Bank*.

Knop, J. & J. Vespignani (2014). "The sectorial impact of commodity price shocks in Australia." *Economic Modelling* 42: 257-271.

Kohlscheen, E., et al. (2016). "When the walk is not random: commodity prices and exchange rates. " *Bank of International Settlements*. March.

Krugman, R. (1978). "Purchasing Power Parity and exchange rates: Another look at the evidence." *Journal of International Economics* 8(3): 397-407.

Kulish, M. & D. M. Rees (2017). "Unprecedented changes in the terms of trade." *Journal of International Economics* 108: 351-367.

Kumar, R. (2011). "Study on dynamic relationship among gold price, oil price, exchange rate and stock market returns." *International Journal of Applied Business and Economic Research* 9(2): 145-165.

Lizardo, R. & A. Mollick (2010). "Oil price fluctuations and U.S. dollar exchange rates." *Energy Economics* 32(2): 399-408.

Lodha, S. (2017). "A cointegration and causation study of gold prices, crude oil prices and exchange rates. " IUP Journal of Financial Risk Management 14 (1): 55-66.

Lof, M. & H. Nyberg. (2017). "Noncausality and the commodity currency hypothesis." Energy Economics 65 (1): 424-433.

Ma, Y. & J. Wang (2019). "Co-movement between oil, gas, coal, and iron ore prices, the Australian dollar, and the Chinese RMB exchange rates: A copula approach." *Resources Policy* 63: 121-139.

Macdonald, R. & L. Ricci (2005). "The real exchange rate and the Balassa-Samuelson effect: The role of the distribution sector." *Pacific Economic Review* 10(1): 29-48.

Macdonald, R. & L. Ricci (2007). "Real exchange rates, imperfect substitutability, and imperfect competition." *Journal of Macroeconomics* 29(4): 639-664.

Maeso-Fernandez, F., et al. (2006). "Towards The estimation of equilibrium exchange rates for transition economies: methodological issues and a panel co-integration perspective." *Journal of Comparative Economics* 34(3): 499-517.

Manalo, J., et al. (2015). "Exchange rate movements and the Australian economy." *Economic Modelling* 47(1): 53-62.

McKenzie, D. (2002). "The impact of exchange rate volatility on international trade flows." *Journal of Economic Surveys* 13(1): 145-181.

Mendoza, G. (1995). "The terms of trade, the real exchange rate, and the economic fluctuations." *International Economic Review* 36(1): 101-137.

Mussa, M. (1982). "A Model of exchange rate dynamics." *Journal of Political Economy* 90(1): 74-104.

Nazlioglu, S. & U. Soytas (2012). "Oil price, agricultural commodity prices, and the dollar: A panel cointegration and causality analysis." *Energy Economics* 34: 1098-1104.

Nissanke, M. (2012). "Commodity market linkages in the Global Financial Crisis: excess volatility and development impacts." *The Journal of Development Studies* 48(6): 732-750.

Novotny, F. (2012). "The link between the Brent crude oil price and the US dollar exchange rate." E. e. r. division, Czech National Bank. Prague Economic Papers.

Otto, G. (2003). "Terms of trade shocks and the balance of trade: there is a Harbenger-Laursen-Metzler effect." *Journal of International Money and Finance* 22(2): 155-184.

Parikh, A. & E, Walkerly (2000). "Real exchange rates and unit root tests." *Weltwirtchaftliches Archiv* 136(3): 478-490.

Peersman, G. & I. Robays (2009). "Oil and the Euro area economy." *Economic Policy* 24(60): 603-651.

Phylatkis, K. & F. Ravazzolo (2005). "Stock prices and exchange rate dynamics." *Journal of International Money and Finance* 24(7): 1031-1053.

Rapetti, M., et al. (2012). "The Real exchange rate and economic growth: are developing countries different?" *International Review of Applied Economics* 26(6): 735-753.

Ready, R., et al. (2017). "Commodity trade and the carry trade: A tale of two countries." *The Journal of Finance* 72(6): 2629-2684.

Reinhart, C. (2000). "Mirage of Floating Exchange Rates." *American Economic Review* 90(2): 65-70.

Ricci, L., et al. (2013). "Real exchange rates and fundamentals: A cross-country perspective." *Journal of Money, Credit and Banking* 45(5): 845-865.

Rogoff, K. (1996). "The purchasing power parity puzzle." *Journal of Economic Literature* 34(2): 647-668.

Sarno, L. & M. Taylor (2002). "Purchasing power parity and the real exchange rate." *International Monetary Fund Staff Papers* 49: 62-105.

Sensoy, A. & C. Sobaci (2014). "Effects of volatility shocks on the dynamic linkages between exchange rate, interest rate and the stock market: The case of Turkey." *Economic Modelling* 43: 448-457.

Sheng, Y. & X. Xu (2011). "Real exchange rate, productivity and labor market frictions." *Journal of International Money and Finance* 30(3): 587-603.

Shiller, R. J. (1985). "Testing the random walk hypothesis: power versus frequency of observation." *National Bureau of Economic Research Technical Paper Series* 45.

Smith, J. & C. Murphy (1994). "Macroeconomic fluctuations in the Australian economy." *Economic Record* 70(209): 133-148.

Spatafora, N. & A. Warner (1999) "Macroeconomic effects of terms of trade shocks: The case of oil exporting countries. " *Policy Research Working Papers eLibrary,*

Sukagawa, P. (2010). "Is iron ore priced as a commodity? Past and current practice." *Resources Policy* 35(1): 54-63.

Sweeney, R. J. (1986). "Beating the foreign exchange market." *The Journal of Finance* 41(1): 163-182.

Tawadros, G. B. (2010). "Purchasing power parity in the long-run: evidence from Australia's recent float." *Applied Financial Economics* 12(9): 625-631.

Taylor, M. P. (1988). "An empirical examination of long-run purchasing power parity using cointegration techniques." *Applied Economics* 20(10): 1369-1381.

Taylor, M. P. (2001). "Official intervention in the foreign exchange market: Is it effective and, if so, how does it work?" *Journal of Economic Literature* 39(3): 839-868.

Taylor, M. & P. McMahon (1988). "Long-run purchasing power parity in the 1920s." *European Economic Review* 32(1): 18.

Tulip, P. (2014). "The effect of the mining boom on the Australian economy." Reserve Bank of Australia (Bulletin December Quarter 2014).

Turhan, I., et al. (2014). "A comparative analysis of the dynamic relationship between oil prices and exchange rates." *Journal of International Financial Markets, Institutions and Money* 32(1): 397-414.

Wadsworth, A. & A. Richardson (2017). "A factor model of commodity price co-movements: An application to New Zealand export prices." *Reserve Bank of New Zealand Analytical Note Series*. Reserve Bank of Zealand. 2017.

Warell, L. (2014). "The effect of a change in pricing regime on iron ore prices." *Resources Policy* 41: 16-22.

Wilson, J. D. (2012). "Chinese resource security policies and the restructuring of the Asia-Pacific iron ore market." *Resources Policy* 37(3): 331-339.

Ye, Q. (2008). "Commodity booms and their impacts on the Western Australian economy: The iron ore case." *Resources Policy* 33(2): 83-101.

Zettelmeyer, J. (2004). "The impact of monetary policy on the exchange rate: evidence from three small open economies." *Journal of Monetary Economics* 51(3): 635-652.

Zhang, G. & R. MacDonald (2014). "Real exchange rates, the trade balance and net foreign assets: long run relationships and measures of misalignment." *Open Economies Review* 25(4): 635-653.

Zhang, H. J., et al. (2016). "Exchange rates and commodity prices: measuring causality at multiple horizons." *Journal of Empirical Finance* 36: 100-120.

Zhang, Y. & C. Zheng (2010). "The implications of china's rapid growth on demand for energy and mining products imported from Australia." *A Journal of Applied Economies and Policy* 27(1): 95-106.