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The Transmission Mechanism from Australian Mining Stock Volatility to Australian Exchange Rate Volatility

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As an integrated world economy and export-orientated mining country, the price volatility of Australian mining stocks is potentially correlated with the Australian exchange rate volatility. Hence, the investigation into the volatility co-movement between Australian exchange rate dynamics and Australian mining stock price dynamics should be conducted to shed light on financial risk management. The volatility correlation between Australian exchange rate dynamics and Australian mining stock price dynamics has rarely been discussed in the literature. This paper tests whether Australian exchange rate volatility changes significantly in response to Australian mining product price variations using a sample of 10 years data with monthly frequency. The conclusions are that during the volatility transmission from Australian mining product price dynamics to Australian exchange rate dynamics via intermediate variables, non-policy intermediate variables exaggerate the volatility while policy intermediate variables alleviate some volatility. Policy makers can formulate monetary and fiscal policies to reduce the volatility of exchange rate transmitted from mining product price volatility, thus, the negative impacts of Dutch Disease through exchange rate volatility can be alleviated.

1. Introduction

As a leading exporter of mining products, Australia potentially suffers from 'Dutch Disease' in terms of the incurrence of a mining boom at the cost of declines in the export orientated manufacturing sector. The underlying mechanism is that increases in the revenues of domestic mining sectors will lead to domestic currency appreciation, which makes domestic products less competitive, hence, export-orientated manufacturing products become less competitive and the revenues of export sectors decreases. The relationship between mining booms and domestic currency appreciation is an essential portion of the transmission mechanism. Hence, this paper's motivation is to identify the transmission mechanism from Australian mining product price volatility to Australian exchange rate volatility. The findings will shed light on prevention of the adverse effects of mining booms in the export-orientated manufacturing sectors, market risk management, exchange rate volatility hedging, portfolio diversification and volatility forecasting for international investors.

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The majority of Australian mining product firms are listed on the Australian Securities Exchange and mining product price indices are also provided by relevant consulting companies, hence, a basket of Australian Securities Exchange listed stocks is chosen to proxy the mining product price dynamics and volatility. Australian mining product price volatility impacts upon Australian exchange rate volatility through Australian trade balance variations, capital flows, production structure changes, short term and long term interest rates. Hence, this paper investigates both the direct and indirect transmission mechanism from Australian mining product price volatility to Australian exchange rate volatility.

Previous literature supports bi-directional correlation between Australian exchange rate dynamics and Australian mining stock price dynamics to relate the two financial markets in terms of foreign exchange market and mining stock exchange market. On the one hand, Australian exchange rate dynamics directs Australian mining stock price dynamics via the channels of mining exports, variations in mining corporates' assets denominated in foreign currency, profitability in the mining industry and value of mining corporate stocks. On the other hand, mining stock price changes transmit volatility to exchange rate variations through channels of the portfolio adjustments in terms of international capital flows. However, the volatility correlation between Australian exchange rate dynamics and Australian mining product price dynamics has been discussed in the literature. And this paper tests the hypothesis of whether there exist short-term and long-term volatility correlations between Australian exchange rate dynamics and Australian mining product dynamics.

The paper is organized as follows. The first section provides the literature review and main contributions from previous academics in modelling correlation between exchange rate dynamics and stock price dynamics. The second section introduces the data, the methodologies applied and model specification. The final section summarises the findings and indicates the limitations of this study which can be further researched. Decreases in short-term interest rate in terms of interbank cash rate stimulate the economy, hence, the Australian dollar appreciates; while increases in long-term interest rate in terms of ten-year government bond interest rate indicate more profits for foreign investors, hence, the Australian dollar appreciates. Increases in RBA broad money promote domestic investment and production, hence, the Australian dollar appreciates.

2. Literature Review

The bi-directional co-movement between Australian exchange rate dynamics and Australian mining stock price dynamics has been heatedly debated among scholars. Gorden (1981) evaluated policies posed by the Australian mining resources boom to conclude that mining boom with policy adjustment led to real Australian exchange rate appreciation while mining boom without policy adjustment prevented nominal exchange rate appreciation and inflation. Dwyer, Forsyth and Spurr (2004) elucidated that mining booms increased mining stock prices leading to surplus in the current account while the simultaneous exchange rate appreciation tends to cancel out the surplus in the current account. Gregory (2011) revealed that mining boom affected Australian nominal

exchange rate directly through terms of trade while the Australian nominal exchange rate influenced mining product prices indirectly through terms of trade and real GDP growth.

The causality between Australian exchange rate volatility and mining product price movement has been researched extensively in the literature. Clements and Manzur (2006) demonstrated that under the condition of purchasing power parity holding true for trade products only, exchange rate volatility of dominant countries induced variations in world mining product prices. Arezki, Dumitrescu, Chen, Rogoff and Rossi (2010) showed that exchange rate volatility had remarkably robust power in predicting global mining product prices both in sample and out of sample. Freytag and Quintyn (2012) discovered that currency volatility caused mining product price movement before capital liberalization while the causality ran the other way around after capital liberalization and they also inferred that mining product price movement explained both the excess exchange rate volatility and short-term disproportionate share of speculative capital inflows.

The relationship between exchange rate dynamics and mining product price volatility has long been discussed among scholars. Liang (1998) indicated that the volatility of mining commodity prices depended on both the market structure and economic agents' perception about future exchange rate movements. Taglioni (2002) indicated that exchange rate volatility reflects the mining products' price when the country under investigation traded mining products extensively with other countries. Cuddington and Liang (2003) summarized that mining product price exhibited greater volatility under a flexible exchange rate regime with greater variations in exchange rate dynamics than fixed exchange rate regime with less variations in exchange rate dynamics. Chen, Rao and Lin (2006) conceded that the exchange rate level and its volatility generated significant impacts upon the direction and magnitude of mining products' price dynamics. Cavalcanti, Mohaddes and Raissi (2011) concluded that high mining product price volatility is usually associated with instable exchange rate dynamics in mining countries

However, previous research used to simulate either the relationship between the mining product price dynamics and the exchange rate dynamics or the relationship between the mining product price dynamics and the exchange rate's volatility. The volatility correlation between Australian exchange rate dynamics and Australian mining product price dynamics has not yet been addressed specifically in the literature. Hence, this paper intends to fill in this research gap and generate new ideas from this volatility correlation investigation.

3. Data and Methodologies

3.1. Theoretical Modelling

The VARMA-GARCH model is formulated to capture the volatility correlation between Australian exchange rate dynamics and Australian mining product price dynamics. I

chose the VARMA-GARCH model because it enables the capture and characterisation of the dynamics and volatilities of the observed data. The exchange rate series and all the mining product price series are indexed by i. Each mean equation takes the form of ARMA(1,1),

$$r_{it} = \beta_0 + \beta_1 r_{it-1} + \varepsilon_{it} + \rho_1 \varepsilon_{it-1}$$
$$\varepsilon_{it} = \sigma_{i,t} \epsilon_{it}$$

Where r_{it} is the monthly return of either Australian exchange rate or Australian mining product price; the moving average term $\varepsilon_{it} + \rho_1 \varepsilon_{it-1}$ accounts for the non-linearity; the innovation term ϵ_{it} is a strong white noise process and is normally, identically, independently distributed; $\sigma_{i,t}^2$ is the conditional variance of the ith return at time t. The conditional variance ${\sigma_{i,t}}^2$ adopts the specification proposed by McAleer and Ling (2003) as follows.

$$\sigma_{i,t}^2 = \alpha_0 + \sum_{j=1}^{n} \alpha_{1,i,j} \, \varepsilon_{j,t-1}^2 + \sum_{j=1}^{n} \alpha_{2,i,j} \, \sigma_{j,t-1}^2$$

Where $\sigma_{i,t}^2$ denotes the current conditional variance of Australian exchange rate or mining product price; $\sigma_{j,t-1}^2$ denotes the past conditional variance of Australian exchange rate or mining product price; $\sum_{j=1}^{n} \alpha_{1,i,j} \, \varepsilon_{j,t-1}^2$ refers to the short-term persistence of past shocks captured by the ARCH term while $\sum_{j=1}^{n} \alpha_{2,i,j} \, \sigma_{j,t-1}^2$ refers to the long-term persistence of past variance captured by the GARCH term. This specification, in particular, highlights the inter-dependence between past shocks and past volatilities.

Previous literature rarely used the VARMA-GARCH model to simulate oil price volatility transmission mechanism. However, this theoretical specification has extended the work of previous literature. It incorporates the mining product price shocks' level effects and volatility effects into the same dynamic framework simultaneously and this will allow tracing of the transmission mechanism of price shocks to exchange rate volatility more precisely.

Under the assumption of normally distributed innovations ε_{it}, the method of Maximum Likelihood Estimation is applied to estimate the parameters in the VARMA-GARCH models

3.2. Data Description, Justification and Empirical Model Selection

3.2.1. Data Description and Justification

The variables involved are Australia-U.S. nominal exchange rate, S&P/ASX 200 Energy, S&P/ASX All Ordinaries Gold, S&P/ASX Mid Cap 50 Resources, Australian trade balance value, Australian Coal mining export value, oil and gas extract export value, aggregate monthly hours worked per person, RBA interbank cash rate, RBA

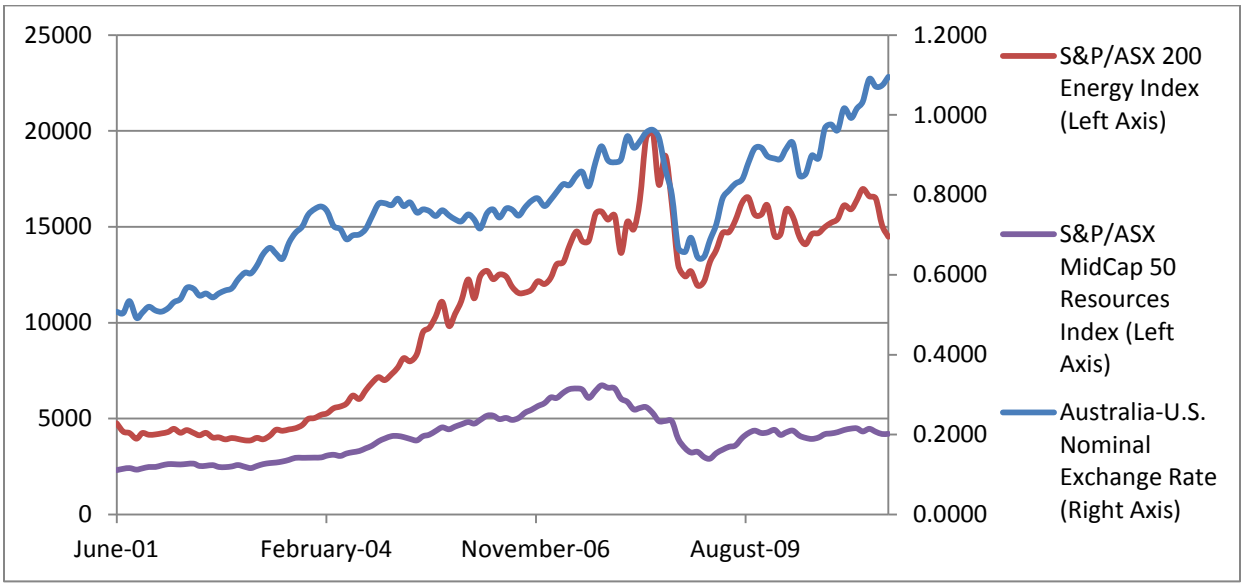
Broad Money Growth Rate. Two geopolitical dummy variables are chosen to simulate structural environmental changes. Australia-U.S. nominal exchange rate is chosen because the United States of America is the major destination for Australia's mineral exports and the U.S. dollar is the primary international settlement currency. The Australian mining product prices are proxied by the adjusted prices of S&P/ASX 200 Energy, S&P/ASX All Ordinaries Gold and S&P/ASX Mid Cap 50 Resources because they represent Australia's main mineral exports in terms of oil, natural gas, gold and iron ore respectively, the adjusted prices are selected because they account for dividends. The sampling period is from June 2001 to July 2011 with monthly frequency due to the availability of data, consistency of financial years and coverage of business cycles. The first dummy variable represents the structural changes of the 2003 Iraq war in terms of taking the value of 0 before 2003 and the value of 1 since the 2003. The second dummy variable represents the structural changes of 2008 financial crisis in terms of taking the value of 0 before 2008 and the value of 1 since 2008. This sampling size was chosen due to the availability of data and the possibility of covering all the periods of structural changes. All the variables are seasonally adjusted. The effects of monetary policies are simulated by RBA interbank cash rate and RBA financial aggregates.

Table 1. Data Set's Statistics Summary

Statistics	Australia-U.S. Nominal Exchange Rate	S&P/ASX 200 Energy Index	S&P/ASX All Ordinaries Gold Index	S&P/ASX MidCap 50 Resources Index	Australian Coal Mining Export Value ($ Million)	Australian Oil and Gas Extract Export Value ($ Million)	Australian Metal Ore Mining Export Value ($ Million)	Australian Aggregate Monthly Hours Worked per Person (Hours)	RBA Interbank Cash Rate (%)	Ten Year Government Bond Interest Rate (%)	RBA Broad Money ($ Billion)
Mean	0.77	10558.10	16.07	4039.20	2164.66	1149.42	2383.93	1464794.40	5.12	5.55	914.76
Median	0.76	11977.35	16.84	4087.42	1815.00	1022.50	2071.50	1472447.75	5.00	5.55	839.80
Standard Deviation	0.15	4840.01	4.95	1220.94	1274.01	447.78	1682.56	92415.38	1.02	0.44	268.19
Kurtosis	-0.51	-1.47	-1.18	-0.69	0.96	-0.65	0.10	-1.28	-0.05	1.51	-1.45
Skewness	0.03	-0.14	0.12	0.44	1.21	0.67	1.01	-0.09	0.08	-0.64	0.32
Minimum	0.49	3870.30	7.41	2316.58	748.00	508.00	669.00	1306622.30	3.00	4.09	583.20
Maximum	1.10	19926.40	26.15	6736.26	6500.00	2244.00	6839.00	1621039.70	7.25	6.59	1376.00
Count	122	122	122	122	122	122	122	122	122	122	122

Note: data sources are Reserve Bank of Australia, Australian Bureau of Statistics, Australian Securities Exchange, Yahoo Finance.

Graph 1 The Graph of Australia-U.S. Normal Exchange Rate, S&P/ASX 200 Energy Index and S&P/ASX Mid Cap 50 Resources Index



3.3. Empirical Estimation

Three versions of VARMA-GARCH models are established with varying parameters and degrees of freedom to capture non-linearity and transitional dynamics.

3.3.1. Model of Transmission Mechanism from S&P/ASX 200 Energy Volatility to Australian Exchange Rate

Mean Equation of Australian exchange rate:

$$r_{\text{Exchane Rate},1,t} = \beta_{1,0} + \beta_{1,1} r_{\text{Exchange Rate},t-1} + \beta_{1,2} r_{S\&P/ASX\ 200\ Energy,t} + \beta_{1,3} r_{\text{Trade Balance},t} + \beta_{1,4} r_{\text{Coal Mining Export},t} + \beta_{1,5} r_{\text{Oil and Gas Export},t} + \beta_{1,6} r_{\text{Work Hours},t} + \beta_{1,7} r_{\text{RBA Interbank Cash Rate},t} + \beta_{1,8} r_{\text{Government Bond Rate},t} + \beta_{1,9} r_{\text{RBA Broad Money Growth Rat},t} + \beta_{1,10} D_{\text{Iraq War}} + \beta_{1,11} D_{\text{Financial Crisis}} + \varepsilon_{\text{Exchane Rate},1,t} + \rho_1 \varepsilon_{\text{Exchane Rate},1,t-1}$$

$$\varepsilon_{\text{Exchane Rate},1,t} = \sigma_{\text{Exchane Rate},1,t} \epsilon_{\text{Exchane Rate},1,t}$$

Where $r_{\text{Exchane Rate},t}$ is the Australian exchange rate; $r_{S\&P/ASX\ 200\ Energy,t}$ is the S&P/ASX 200 Energy price index; $r_{\text{Trade Balnce},t}$is Australian trade balance value; $r_{\text{Coal Mining Export},t}$ is the Australian coal mining export value; $r_{\text{Oil and Gas Export},t}$ is the Australian oil and gas export value; $r_{\text{Work Hours},t}$ is the aggregate monthly hours worked per person; $r_{\text{RBA Interbank Cash Rate},t}$ is the RBA interbank cash rate; $r_{\text{Government Bond Rate},t}$ is the ten year government bond interest rate; $r_{\text{RBA Broad Money Growth Rat},t}$ is RBA broad money growth rate, $D_{\text{Iraq War}}$ is the dummy variable representing the 2003 Iraq War; $D_{\text{Financial Crisis}}$ is the dummy variable representing the 2008 financial crisis.

Conditional Variance Equation of Australian exchange rate:

$$\sigma^2_{\text{Exchane Rate},1,t} = \alpha_{1,0} + \alpha_{1,1}\varepsilon^2_{\text{Exchane Rate},1,t-1} + \alpha_{1,2}\sigma^2_{\text{Exchane Rate},1,t-1} + \alpha_{1,3}\sigma^2_{\text{S\&P/ASX 200 Energy},t-1} + \alpha_{1,4}\sigma^2_{\text{Trade Balance},t-1} + \alpha_{1,5}\sigma^2_{\text{Coal Mining Export},t-1} + \alpha_{1,6}\sigma^2_{\text{Oil and Gas Export},t-1} + \alpha_{1,7}\sigma^2_{\text{Work Hours},t-1} + \alpha_{1,8}\sigma^2_{\text{RBA Interbank Cash Rate},t-1} + \alpha_{1,99}\sigma^2_{\text{Government Bond Rate},t-1} + \alpha_{1,10}\sigma^2_{\text{RBA Broad Money Growth ate},t-1}$$

Where $\sigma^2_{\text{Exchane Rate},1,t}$ is the current variance of Australian exchange rate; $\varepsilon^2_{\text{Exchane Rate},1,t-1}$ is the past shock of Australian exchange rate; $\sigma^2_{\text{Exchane Rate},1,t-1}$ is the past variance of Australian exchange rate; $\sigma^2_{\text{S\&P/ASX 200 Energy},t-1}$ is the past variance of S&P/ASX 200 energy price dynamics; $\sigma^2_{\text{Trade Balance},t-1}$is the past variance of Australian trade balance value; $\sigma^2_{\text{Coal Mining Export},t-1}$ is the past variance of Australian coal mining export value; $\sigma^2_{\text{Oil and Gas},t-1}$is the past variance of Australian oil and gas export value; $\sigma^2_{\text{Work Hours},t-1}$ is the past variance of the aggregate monthly hours worked per person; $\sigma^2_{\text{RBA Interbank Cash Rate},t-1}$ is the past variance of RBA interbank cash rate; $\sigma^2_{\text{Government Bond Rate},t-1}$ is the past variance of ten-year government bond interest rate; $\sigma^2_{\text{RBA Broad Money Growth ate},t-1}$ is the past variance of RBA broad money growth rate.

Table 2 and Table 3 summarize the estimation output as follows.

Table 2 Mean Equation Estimation

Variables	Estimated Coefficient	Standard Deviation	Z-Statistics	P-Value
$r_{\text{Exchange Rate},t-1}$	85.65	49.63	1.73	0.04
$r_{\text{S\&P/ASX 200 Energy},t}$	28.40	15.70	1.81	0.04
$r_{\text{Trade Balance},t}$	16.70	32.60	0.51	0.30
$r_{\text{Coal Mining Export},t}$	21.80	6.20	3.52	0.02
$r_{\text{Oil and Gas Export},t}$	4.90	16.40	0.30	0.38
$r_{\text{Work Hours},t}$	9.30	5.00	1.86	0.03
$r_{\text{RBA Interbank Cash Rate},t}$	-6.84	5.96	-1.15	0.13
$r_{\text{Government Bond Rate},t}$	4.68	9.11	0.51	0.30
$r_{\text{RBA Broad Money Growth Rat},t}$	-3.28	6.38	-0.51	0.30
$D_{\text{Iraq War}}$	17.13	11.43	1.50	0.07
$D_{\text{Financial Crisis}}$	-8.42	16.93	-0.50	0.31

At 10% level of significance, Australian exchange rate $r_{\text{Exchange Rate},t}$ is auto-correlated with its past price $r_{\text{Exchange Rate},t-1}$ with order 1 significantly. It is negatively correlated with RBA interbank cash rate $r_{\text{RBA Interbank Cash Rate},t}$, RBA broad money growth rate $r_{\text{RBA Broad Money Growth Rat},t}$ and financial crisis dummy variable $D_{\text{Financial Crisis},t}$ insignificantly; positively correlated with Australian trade balance value $r_{\text{Trade Balnce},t}$, Australian oil and gas export value $r_{\text{Oil and Gas},t}$ and ten year government bond interest

rate $r_{\text{Government Bond Rate,t}}$ insignificantly; but positively correlated with S&P/ASX 200 Energy price $r_{S\&P/ASX\ 200\ Energy,t}$, Australian coal mining export value $r_{\text{Coal Mining Export,t}}$, the aggregate monthly hours worked per person $r_{\text{Work Hours,t}}$ and Iraq war dummy variable $D_{\text{Iraq War}}$ significantly.

Table 3 Variance Equation

Variables	Estimated Coefficient	Standard Deviation	Z-Statistics	P-Value
Constant	17.02	14.90	1.14	0.13
$\varepsilon^2_{\text{Exchane Rate,1,t-1}}$	14.99	16.46	0.91	0.18
$\sigma^2_{\text{Exchane Rate,1,t-1}}$	60.00	26.00	2.31	0.01
$\sigma^2_{\text{S\&P/ASX 200 Energy,t-1}}$	-2.42	4.08	-0.59	0.28
$\sigma^2_{\text{Trade Balance,t-1}}$	6.32	8.36	0.76	0.22
$\sigma^2_{\text{Coal Mining Export,t-1}}$	1.70	11.50	0.15	0.44
$\sigma^2_{\text{Oil and Gas Export,t-1}}$	4.67	4.68	1.00	0.16
$\sigma^2_{\text{Work Hours,t-1}}$	-2.10	1.04	-2.02	0.02
$\sigma^2_{\text{RBA Interbank Cash Rate,t-1}}$	-1.20	1.11	-1.08	0.14
$\sigma^2_{\text{Government Bond Rate,t-1}}$	3.46	10.30	0.34	0.37
$\sigma^2_{\text{RBA Broad Money Growth ate,t-1}}$	-2.21	1.28	-1.73	0.04

At 10% level of significance, the current variance of Australian exchange rate $\sigma^2_{\text{Exchane Rate,1,t}}$is positively correlated with its short-term past shocks $\varepsilon^2_{\text{Exchane Rate,1,t-1}}$, past variances of Australian trade balance $\sigma^2_{\text{Trade Balance,t-1}}$, ten year government bond interest rate $\sigma^2_{\text{Government Bond Rate,t-1}}$, coal mining export $\sigma^2_{\text{Coal Mining Export,t-1}}$, oil and gas mining export $\sigma^2_{\text{Oil and Gas,t-1}}$ insignificantly and its long-term past variance $\sigma^2_{\text{Exchane Rate,1,t-1}}$ significantly; negatively correlated with past variances of RBA interbank cash rate $\sigma^2_{\text{RBA Interbank Cash Rate,t-1}}$ insignificantly, aggregate monthly hours worked per person $\sigma^2_{\text{Work Hours,t-1}}$ and RBA broad money growth rate $\sigma^2_{\text{RBA Broad Money Growth ate,t-1}}$ significantly.

3.3.2. Model of Transmission Mechanism from S&P/ASX All Ordinaries Gold Volatility to Australian Exchange Rate

Mean Equation of Australian exchange rate:

$$r_{\text{Exchane Rate,2,t}} = \beta_{2,0} + \beta_{2,1} r_{\text{Exchange Rate,2,t-1}} + \beta_{2,2} r_{S\&P/ASX\ All\ Ordinaries\ Gold,t} + \beta_{2,3} r_{\text{Trade Balance,t}} + \beta_{2,4} r_{\text{Metal Ore Mining Export,t}} + \beta_{2,5} r_{\text{Work Hours,t}} + \beta_{2,6} r_{\text{RBA Interbank Cash Rate,t}} + \beta_{2,7} r_{\text{Government Bond Rate,t}} + \beta_{2,8} r_{\text{RBA Broad Money Growth Rat,t}} + \beta_{2,9} D_{\text{Iraq War}} + \beta_{2,10} D_{\text{Financial Crisis}} + \varepsilon_{\text{Exchane Rate,2,t}} + \rho_1 \varepsilon_{\text{Exchane Rate,2,t-1}}$$

$$\varepsilon_{\text{Exchane Rate,2,t}} = \sigma_{\text{Exchane Rate,2,t}} \epsilon_{\text{Exchane Rate,2,t}}$$

Where $r_{\text{Exchane Rate},2,t}$ is the Australian exchange rate; $r_{S\&P/ASX\ All\ Ordinaries\ Gold,t}$ is the S&P/ASX All Ordinaries Gold price index, $r_{\text{Metal Ore Mining Export},t}$ is the Australian metal ore export value.

Conditional Variance Equation of Australian exchange rate:

$$\sigma^2_{\text{Exchane Rate},2,t} = \alpha_{2,0} + \alpha_{2,1}\varepsilon^2_{\text{Exchane Rate},2,t-1} + \alpha_{2,2}\sigma^2_{\text{Exchane Rate},2,t-1} + \alpha_{2,3}\sigma^2_{S\&P/ASX\ All\ Ordinaries\ Gold,t-1} + \alpha_{2,4}\sigma^2_{\text{Trade Balance},t-1} + \alpha_{2,5}\sigma^2_{\text{Metal Ore Mining Export},t-1} + \alpha_{2,6}\sigma^2_{\text{Work Hours},t-1} + \alpha_{2,7}\sigma^2_{\text{RBA Interbank Cash Rate},t-1} + \alpha_{2,8}\sigma^2_{\text{Government Bond Rate},t-1} + \alpha_{2,9}\sigma^2_{\text{RBA Broad Money Growth ate},t-1}$$

Where $\sigma^2_{\text{Exchane Rate},2,t}$ is the current variance of Australian exchange rate; $\varepsilon^2_{\text{Exchane Rate},2,t-1}$ is the past shock of Australian exchange rate; $\sigma^2_{\text{Exchane Rate},2,t-1}$ is the past variance of Australian exchange rate; $\sigma^2_{\text{Metal Ore Mining Export},t-1}$ is the past variance of Australian metal ore export value.

Table 4 and Table 5 summarize the estimation output as the following.

Table 4 Mean Equation

Variables	Estimated Coefficient	Standard Deviation	Z-Statistics	P-Value
$r_{\text{Exchange Rate},2,t-1}$	80.49	5.68	14.17	0.01
$r_{\text{S\&P/ASX All Ordinaries Gold},t}$	45.91	15.07	3.05	0.01
$r_{\text{Trade Balance},t}$	15.90	3.76	4.23	0.01
$r_{\text{Metal Ore Mining Export},t}$	19.20	7.97	2.41	0.01
$r_{\text{Work Hours},t}$	5.19	3.41	1.52	0.06
$r_{\text{RBA Interbank Cash Rate},t}$	-13.47	3.98	-3.39	0.01
$r_{\text{Government Bond Rate},t}$	1.27	0.76	1.66	0.05
$r_{\text{RBA Broad Money Growth Rat},t}$	-6.95	5.03	-1.38	0.08
$D_{\text{Iraq War}}$	11.96	11.86	1.01	0.16
$D_{\text{Financial Crisis}}$	-7.76	13.67	-0.57	0.29

At 10% level of significance, Australian exchange rate $r_{\text{Exchange Rate},t}$ is auto-correlated with its past price $r_{\text{Exchange Rate},t-1}$ with order 1 significantly. It is negatively correlated with RBA interbank cash rate $r_{\text{RBA Interbank Cash Rate},t}$, RBA broad money growth rate $r_{\text{RBA Broad Money Growth Rat},t}$ significantly and financial crisis dummy variable $D_{\text{Financial Crisis},t}$ insignificantly; positively correlated with Iraq war dummy variable $D_{\text{Iraq War}}$ insignificantly; but positively correlated with S&P/ASX All Ordinaries Gold price $r_{S\&P/ASX\ All\ Ordinaries\ Gold,t}$, Australian coal mining export value $r_{\text{Coal Mining Export},t}$, aggregate monthly hours worked per person $r_{\text{Work Hours},t}$, Australian trade balance value

$r_{\text{Trade Balnce,t}}$, Australian metal ore mining export value $r_{\text{Metal Ore Mining Export,t}}$ and ten year government bond interest rate $r_{\text{Government Bond Rate,t}}$ significantly.

Table 5 Variance Equation

Variables	Estimated Coefficient	Standard Deviation	Z-Statistics	P-Value
Constant	5.54	8.47	0.65	0.26
$\varepsilon^2_{\text{Exchane Rate,1,t-1}}$	15.00	21.28	0.71	0.24
$\sigma^2_{\text{Exchane Rate,2,t-1}}$	60.00	35.28	1.70	0.04
$\sigma^2_{\text{S\&P/ASX All Ordinaries Gold,t-1}}$	12.60	307.00	0.04	0.48
$\sigma^2_{\text{Trade Balance,t-1}}$	7.04	6.87	1.02	0.15
$\sigma^2_{\text{Metal Ore Mining Export,t-1}}$	1.99	1.41	1.41	0.08
$\sigma^2_{\text{Work Hours,t-1}}$	-3.65	8.77	-0.42	0.34
$\sigma^2_{\text{RBA Interbank Cash Rate,t-1}}$	-5.81	86.10	-0.07	0.47
$\sigma^2_{\text{Government Bond Rate,t-1}}$	5.57	124.00	0.04	0.48
$\sigma^2_{\text{RBA Broad Money Growth ate,t-1}}$	-4.61	8.62	-0.53	0.30

At 10% level of significance, the current variance of Australian exchange rate $\sigma^2_{\text{Exchane Rate,1,t}}$is positively correlated with its short-term past shocks $\varepsilon^2_{\text{Exchane Rate,1,t-1}}$, past variances of Australian trade balance $\sigma^2_{\text{Trade Balance,t-1}}$, ten-year government bond interest rate $\sigma^2_{\text{Government Bond Rate,t-1}}$, S&P All Ordinaries Gold $\sigma^2_{\text{S\&P/ASX All Ordinaries Gold,t-1}}$ insignificantly and its long-term past variance $\sigma^2_{\text{Exchane Rate,1,t-1}}$, past variance of Metal Ore mining export $\sigma^2_{\text{Metal Ore Mining Export,t-1}}$ significantly; negatively correlated with past variances of RBA interbank cash rate $\sigma^2_{\text{RBA Interbank Cash Rate,t-1}}$, aggregate monthly hours worked per person $\sigma^2_{\text{Work Hours,t-1}}$ and RBA broad money growth rate $\sigma^2_{\text{RBA Broad Money Growth ate,t-1}}$ significantly.

3.3.3. Model of Transmission Mechanism from S&P/ASX Mid Cap 50 Resources Volatility to Australian Exchange Rate

Mean Equation of Australian exchange rate:

$$r_{\text{Exchane Rate,3,t}} = \beta_{3,0} + \beta_{3,1} r_{\text{Exchange Rate,3,t-1}} + \beta_{3,2} r_{\text{S\&P/ASX All MidCap 50 Resources,t}} + \beta_{3,3} r_{\text{Trade Balance,t}} + \beta_{3,4} r_{\text{Metal Ore Mining Export,t}} + \beta_{3,5} r_{\text{Work Hours,t}} + \beta_{3,6} r_{\text{RBA Interbank Cash Rate,t}} + \beta_{3,7} r_{\text{Government Bond Rate,t}} + \beta_{3,8} r_{\text{RBA Broad Money Growth Rat,t}} + \beta_{3,9} D_{\text{Iraq War}} + \beta_{3,10} D_{\text{Financial Crisis}} + \varepsilon_{\text{Exchane Rate,3,t}} + \rho_1 \varepsilon_{\text{Exchane Rate,3,t-1}}$$

$$\varepsilon_{\text{Exchane Rate,3,t}} = \sigma_{\text{Exchane Rate,3,t}} \epsilon_{\text{Exchane Rate,3,t}}$$

Where $r_{\text{Exchane Rate,3,t}}$ is the Australian exchange rate; $r_{\text{S\&P/ASX All MidCap 50 Resources,t}}$ is the S&P/ASX Mid Cap 50 resource price index.

Conditional Variance Equation of Australian exchange rate:

$$\sigma^2_{\text{Exchane Rate},3,t} = \alpha_{3,0} + \alpha_{3,1}\varepsilon^2_{\text{Exchane Rate},3,t-1} + \alpha_{3,2}\sigma^2_{\text{Exchane Rate},3,t-1} + \alpha_{3,3}\sigma^2_{S\&P/ASX\ All\ MidCap\ 50\ Resources,t-1} + \alpha_{3,4}\sigma^2_{\text{Trade Balance},t-1} + \alpha_{3,5}\sigma^2_{\text{Metal Ore Mining Export},t-1} + \alpha_{3,6}\sigma^2_{\text{Work Hours},t-1} + \alpha_{2,7}\sigma^2_{\text{RBA Interbank Cash Rate},t-1} + \alpha_{2,8}\sigma^2_{\text{Government Bond Rate},t-1} + \alpha_{2,9}\sigma^2_{\text{RBA Broad Money Growth ate},t-1}$$

Where $\sigma^2_{\text{Exchane Rate},3,t}$ is the current variance of the Australian exchange rate; $\varepsilon^2_{\text{Exchane Rate},3,t-1}$ is the past shock of theAustralian exchange rate; $\sigma^2_{\text{Exchane Rate},3,t-1}$ is the past variance of Australian exchange rate.

Table 6 and Table 7 summarize the estimation output as the following.

Table 6 Mean Equation

Variables	Estimated Coefficient	Standard Deviation	Z-Statistics	P-Value
$r_{\text{Exchange Rate},3,t-1}$	81.63	5.71	14.29	0.01
$r_{\text{S\&P/ASX All MidCap 50 Resources},t}$	11.60	6.41	1.81	0.04
$r_{\text{Trade Balance},t}$	15.80	3.75	4.21	0.01
$r_{\text{Metal Ore Mining Export},t}$	26.40	7.76	3.40	0.01
$r_{\text{Work Hours},t}$	8.47	5.05	1.68	0.05
$r_{\text{RBA Interbank Cash Rate},t}$	-20.88	5.88	-3.55	0.02
$r_{\text{Government Bond Rate},t}$	15.60	8.06	1.94	0.03
$r_{\text{RBA Broad Money Growth Rat},t}$	-10.40	7.88	-1.32	0.09
$D_{\text{Iraq War}}$	14.90	11.33	1.31	0.09
$D_{\text{Financial Crisis}}$	-4.82	20.98	-0.23	0.41

At 10% level of significance, Australian exchange rate $r_{\text{Exchange Rate},t}$ is auto-correlated with its past price $r_{\text{Exchange Rate},t-1}$ with order 1 significantly. It is negatively correlated with RBA interbank cash rate $r_{\text{RBA Interbank Cash Rate},t}$, RBA broad money growth rate $r_{\text{RBA Broad Money Growth Rat},t}$ significantly and financial crisis dummy variable $D_{\text{Financial Crisis},t}$ insignificantly; positively correlated with S&P/ASX Mid Cap 50 resource price $r_{S\&P/\text{ASX All MidCap 50 Resources},t}$, Australian trade balance $r_{\text{Trade Balance},t}$, Australian metal ore mining export value $r_{\text{Metal Ore Mining Export},t}$, aggregate monthly hours worked per person $r_{\text{Work Hours},t}$, ten year government bond interest rate $r_{\text{Government Bond Rate},t}$ and Iraq war dummy variable $D_{\text{Iraq War}}$ significantly.

Table 7 Variance Equation

Variables	Estimated Coefficient	Standard Deviation	Z-Statistics	P-Value
Constant	6.09	8.03	0.76	0.22
$\varepsilon^2_{\text{Exchane Rate},3,t-1}$	15.00	15.41	0.97	0.17
$\sigma^2_{\text{Exchane Rate},3,t-1}$	60.00	34.10	1.76	0.04
$\sigma^2_{\text{S\&P/ASX All MidCap 50 Resources},t-1}$	3.22	7.77	0.41	0.34
$\sigma^2_{\text{Trade Balance},t-1}$	7.39	5.34	1.38	0.08
$\sigma^2_{\text{Metal Ore Mining Export},t-1}$	20.90	14.10	1.48	0.07
$\sigma^2_{\text{Work Hours},t-1}$	-4.18	4.05	-1.03	0.15
$\sigma^2_{\text{RBA Interbank Cash Rate},t-1}$	-10.10	94.20	-0.11	0.46
$\sigma^2_{\text{Government Bond Rate},t-1}$	6.58	132.00	0.05	0.48
$\sigma^2_{\text{RBA Broad Money Growth ate},t-1}$	-37.20	100.00	-0.37	0.35

At 10% level of significance, the current variance of Australian exchange rate $\sigma^2_{\text{Exchane Rate},1,t}$is positively correlated with its short-term past shocks $\varepsilon^2_{\text{Exchane Rate},1,t-1}$, past variances of ten-year government bond interest rate $\sigma^2_{\text{Government Bond Rate},t-1}$ insignificantly and its long-term past variance $\sigma^2_{\text{Exchane Rate},1,t-1}$, past variances of Australian trade balance $\sigma^2_{\text{Trade Balance},t-1}$, metal ore mining export $\sigma^2_{\text{Metal Ore Mining Export},t-1}$significantly; negatively correlated with past variances of RBA interbank cash rate $\sigma^2_{\text{RBA Interbank Cash Rate},t-1}$, aggregate monthly hours worked per person $\sigma^2_{\text{Work Hours},t-1}$ and RBA broad money growth rate $\sigma^2_{\text{RBA Broad Money Growth ate},t-1}$ insignificantly.

The short-term persistence in terms of ARCH effects varies across the three volatilities of Australian mining product price dynamics. S&P/ASX All Ordinaries gold price displays the most significant sensitivity to innovations while S&P/ASX Mid Cap 50 Resources exhibits the least sensitivity. The long-term persistence in terms of GARCH effects also varies across the three volatilities of Australian mining product price dynamics. S&P/ASX 200 Energy price shows the most significant auto-correlation with past volatility while S&P/ASX Mid Cap 50 Resources exhibits the least volatility.

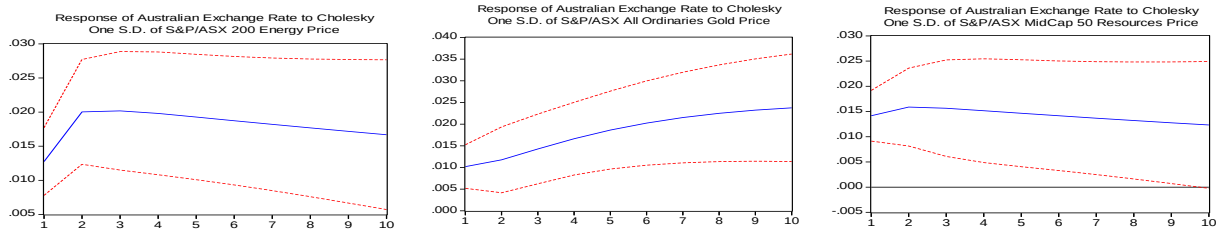
The majority of the empirical results is consistent with the theory. Intuitively, price increases in Australian mining product stocks and exports indicate increases in oil product demand and economic booms, thus result in Australian currency appreciation; trade balance surplus leads to currency appreciation while trade balance deficit leads to currency depreciation; increases in aggregate monthly hours worked per person indicate economic boom, hence, more foreign investors are attracted to invest in domestic market and the Australian dollar appreciates; decreases in short-term interest rate in terms of RBA interbank cash rate stimulate the domestic economy, hence, the Australian dollar appreciates; increases in long-term interest rate in terms of ten-year government bond interest rate indicate profitability in domestic investment and production, hence, the Australian dollar appreciates; the outbreak of war in Iraq leads to increases in Australian mining product prices and appreciation of the Australian currency due to oil demand increases during the war; the global financial crisis incurs

decreases in Australian mining product prices due to production stagnation and decreases in demand.

Since mining product exports account for a significant portion of Australian exports, higher volatility in mining product prices usually leads to higher volatility in the Australian exchange rate. As a kind of time series data, Australian exchange rate is generally auto-correlated with its past values. Greater variances of trade balance and mining product exports are directly associated with greater variance of the Australian exchange rate. RBA interbank cash rate and RBA broad money growth rate represent short-term monetary policy tools of the Reserve Bank of Australia, while aggregate monthly hours worked per person is an indicator of Australian government's short-term fiscal policy, hence, appropriate implementation of these short-term policies in terms of volatilities in these policy indicators should stabilize the exchange rate dynamics. However, the ten-year government bond interest rate is a long-term indicator of monetary policy and fiscal policy, implementation of long-term policy tends to change economic agents' expectations, hence, greater volatility in this indicator will lead to greater volatility in the Australian exchange rate.

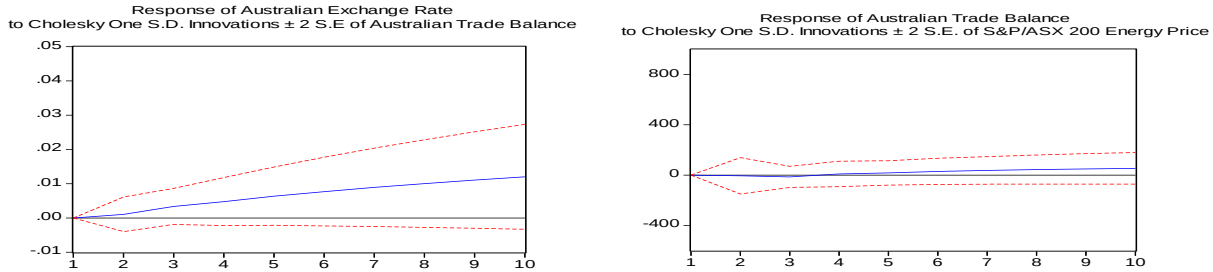
3.3.4. Impulse Response Analysis

Graph 2 Direct Responses of Australian Exchange Rate to S&P/ASX 200 Energy Price, S&P/ASX All Ordinaries Gold Price, S&P/ASX Mid Cap 50 Resources Price

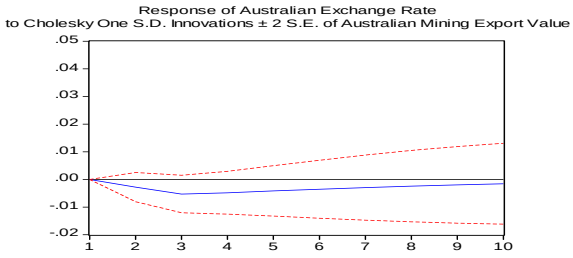


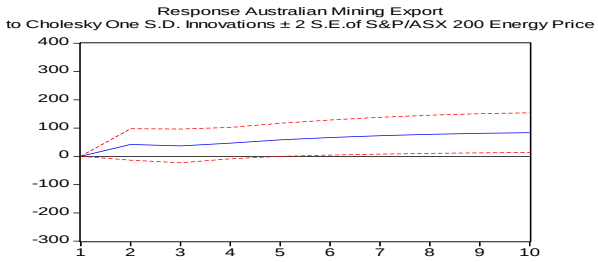
Graph 2 indicates that the volatility of Australian exchange rate increases in response to the volatility of mining product stocks in the short term, although the volatility impact decays for S&P/ASX 200 Energy Price and S&P/ASX Mid Cap 50 Resources Price while aggregates for S&P/ASX All Ordinaries Gold Price in the long term.

Graph 3 Indirect Responses of Australian Exchange Rate to S&P/ASX 200 Energy Price through Australian Trade Balance

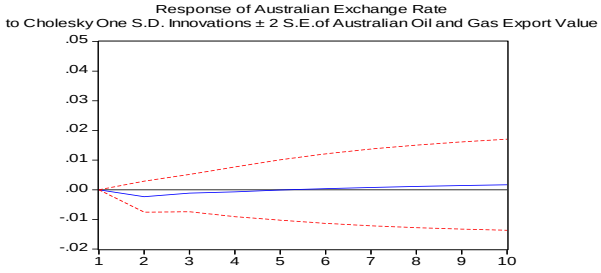


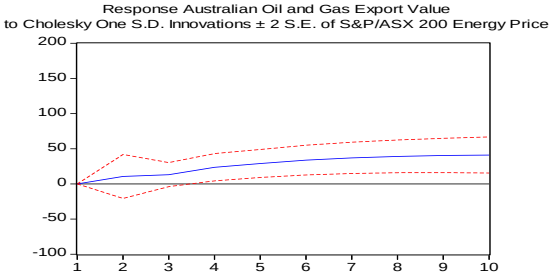
Graph 4 Indirect Responses of Australian Exchange Rate to S&P/ASX 200 Energy Price through Australian Mining Export Value



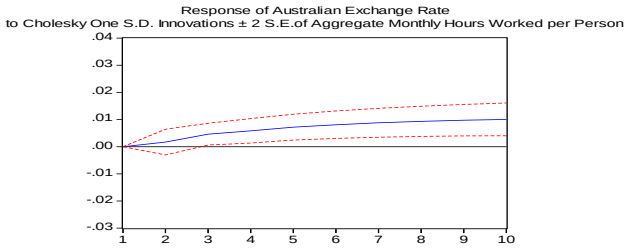


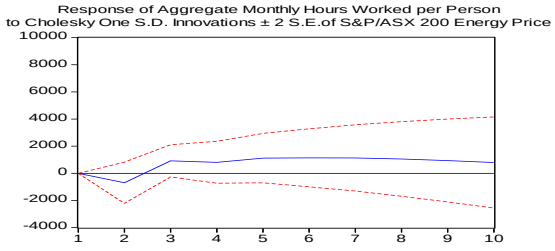
Graph 5 Indirect Responses of Australian Exchange Rate to S&P/ASX 200 Energy Price through Australian Oil and Gas Export Value



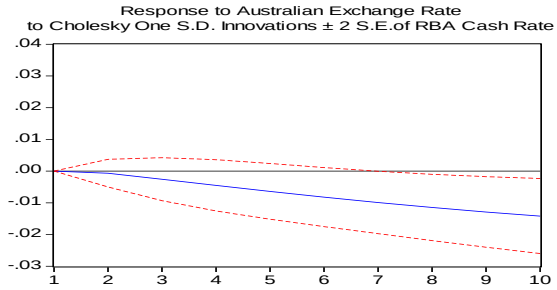


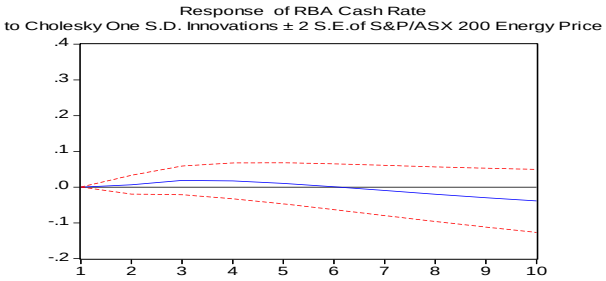
Graph 6 Indirect Responses of Australian Exchange Rate to S&P/ASX 200 Energy Price through Aggregate Monthly Hours Worked per Person



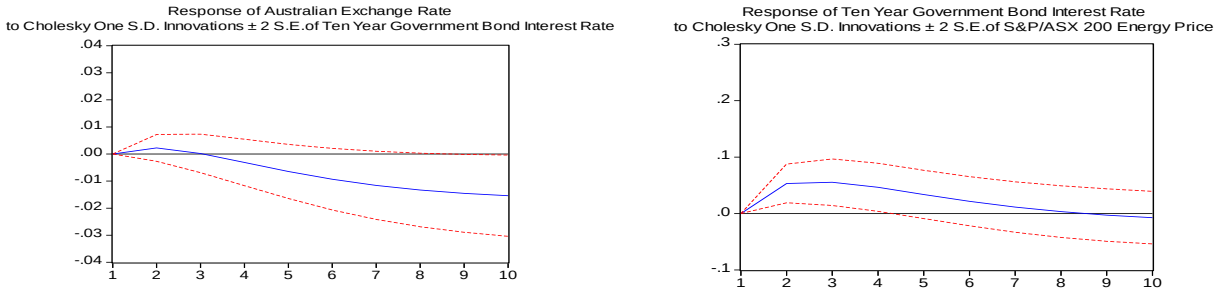


Graph 7 Indirect Responses of Australian Exchange Rate to S&P/ASX 200 Energy Price through RBA Interbank Cash Rate

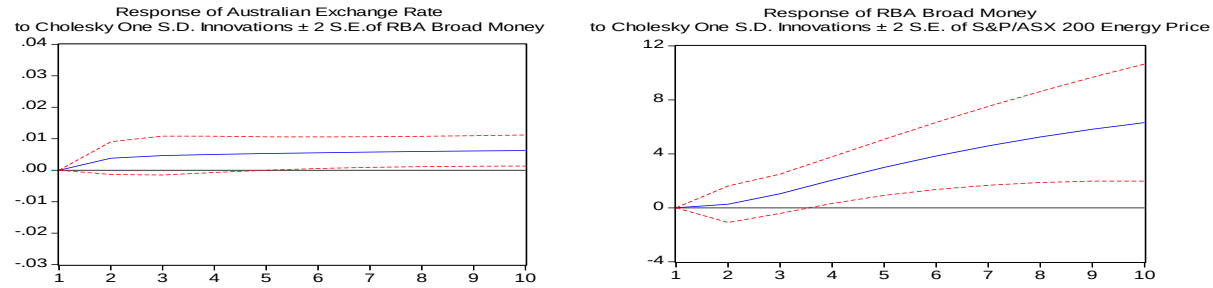




Graph 8 Indirect Responses of Australian Exchange Rate to S&P/ASX 200 Energy Price through Ten Year Government Bond Interest Rate

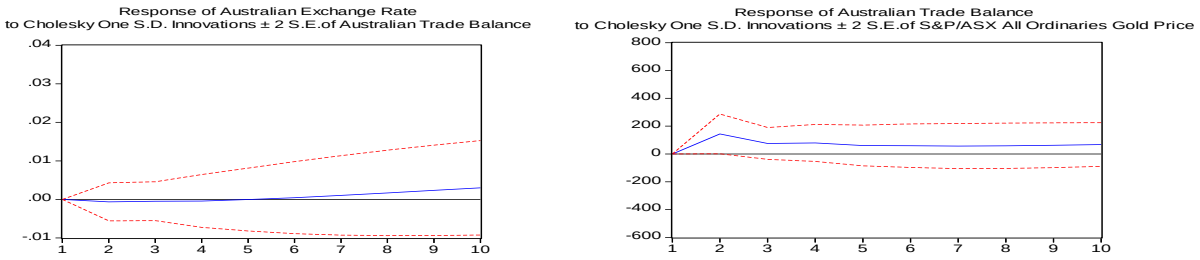


Graph 9 Indirect Responses of Australian Exchange Rate to S&P/ASX 200 Energy Price through RBA Broad Money

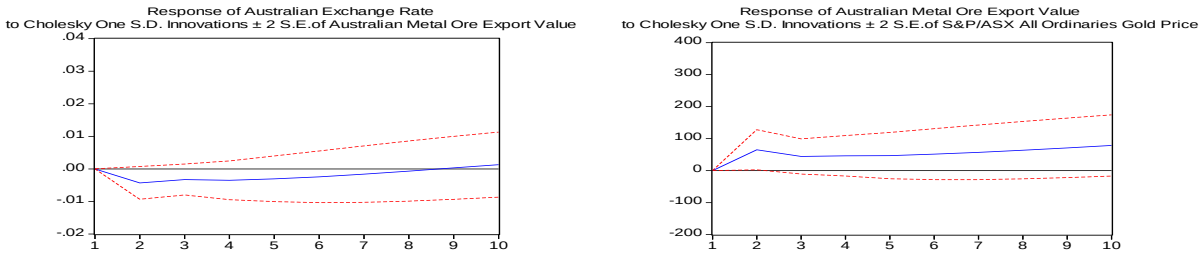


From Graph 3 to Graph 9, the intermediate variables in terms of Australian trade balance, Australian mining export value, Australian oil and gas export value and ten-year government bond interest rate all exaggerate the volatility during the volatility transmission process from S&P/ASX 200 Energy Price dynamics to Australian exchange rate dynamics; while the intermediate macro-economic policy variables in terms of aggregate monthly hours worked per person, RBA interbank cash rate and RBA broad money alleviate some volatilities during the volatility transmission process.

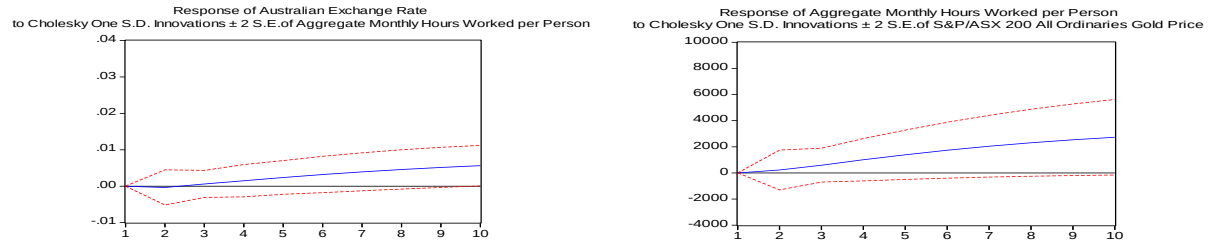
Graph 10 Indirect Responses of Australian Exchange Rate to S&P/ASX All Ordinaries Gold Price through Australian Trade Balance



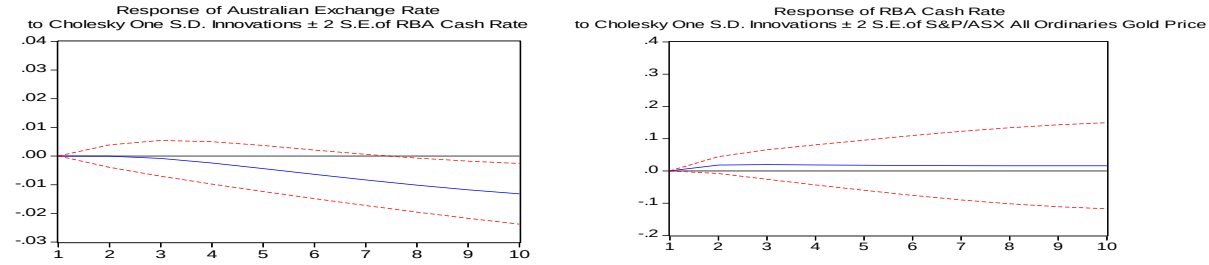
Graph 11 Indirect Responses of Australian Exchange Rate to S&P/ASX All Ordinaries Gold Price through Australian Metal Ore Export Value



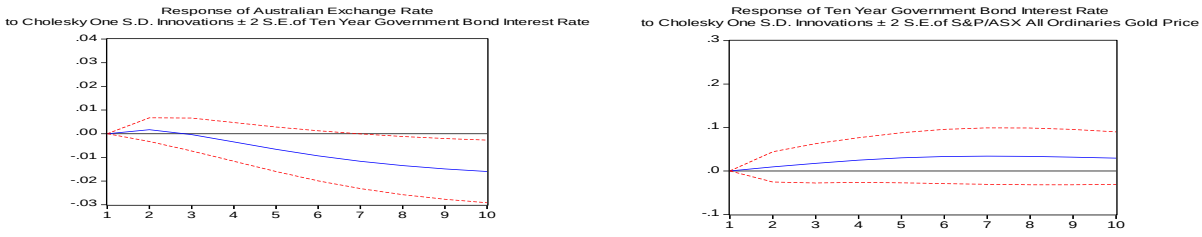
Graph 12 Indirect Responses of Australian Exchange Rate to S&P/ASX 200 All Ordinaries Gold Price through Aggregate Monthly Hours Worked per Person



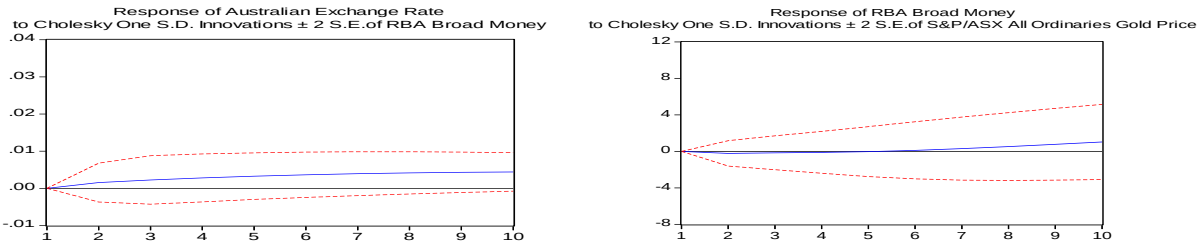
Graph 13 Indirect Responses of Australian Exchange Rate to S&P/ASX All Ordinaries Gold Price through RBA Cash Rate



Graph 14 Indirect Responses of Australian Exchange Rate to S&P/ASX All Ordinaries Gold Price through Ten Year Government Bond Interest Rate

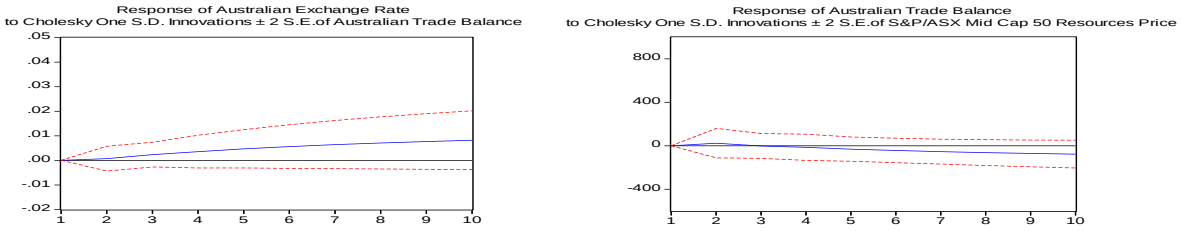


Graph 15 Indirect Responses of Australian Exchange Rate to S&P/ASX All Ordinaries Gold Price through RBA Broad Money

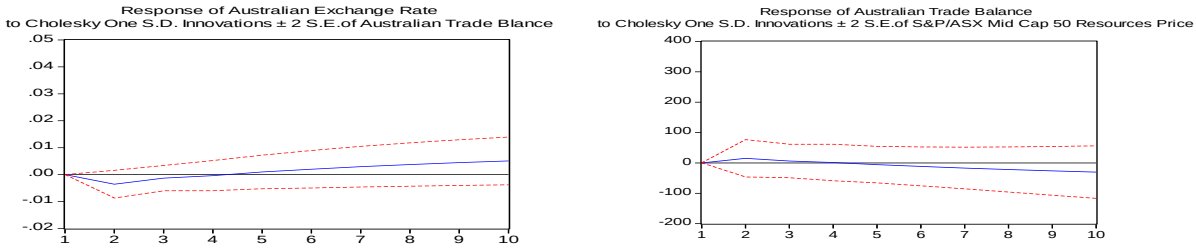


From Graph 10 to Graph 15, the intermediate variables in terms of Australian trade balance, Australian mining export value, Australian oil and gas export value and ten-year government bond interest rate all exaggerate the volatility during the volatility transmission process from S&P/ASX All Ordinaries Gold price dynamics to Australian exchange rate dynamics; while the intermediate macro-economic policy variables in terms of aggregate monthly hours worked per person, RBA interbank cash rate and RBA broad money alleviate some volatilities during the volatility transmission process.

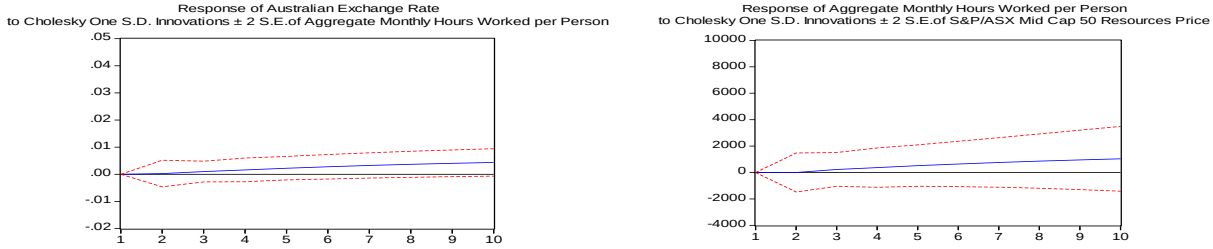
Graph 16 Indirect Responses of Australian Exchange Rate to S&P/ASX Mid Cap 50 Resources Price through Australian Trade Balance



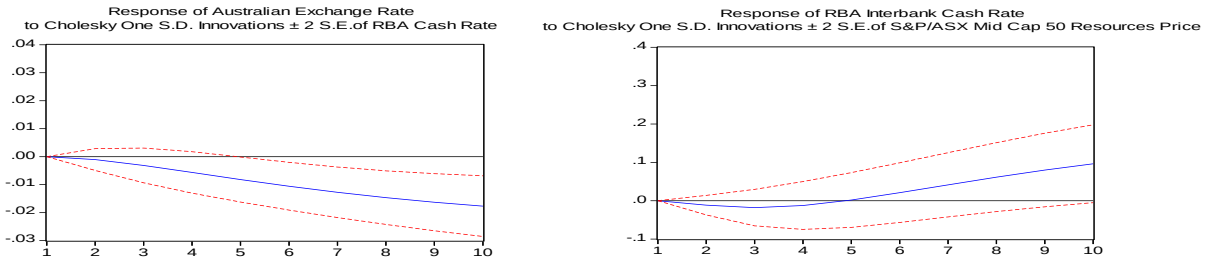
Graph 17 Indirect Responses of Australian Exchange Rate to S&P/ASX Mid Cap 50 Resources Price through Australian Trade Balance



Graph 18 Indirect Responses of Australian Exchange Rate to S&P/ASX Mid Cap 50 Resources Price through Aggregate Monthly Hours Worked per Person

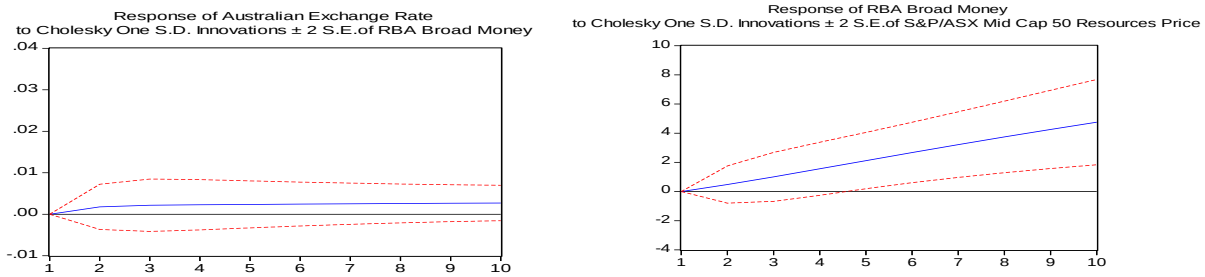


Graph 19 Indirect Responses of Australian Exchange Rate to S&P/ASX Mid Cap 50 Resources Price through RBA Interbank Cash Rate



Graph 20 Indirect Responses of Australian Exchange Rate to S&P/ASX Mid Cap 50 Resources Price through Ten Year Government Bond Interest Rate

Graph 21 Indirect Responses of Australian Exchange Rate to S&P/ASX Mid Cap 50 Resources Price through RBA Broad Money



From Graph 16 to Graph 20, the intermediate variables in terms of Australian trade balance, Australian mining export value, Australian oil and gas export value and ten-year government bond interest rate all exaggerate the volatility during the volatility transmission process from S&P/ASX Mid Cap 50 Resources price dynamics to Australian exchange rate dynamics; while the intermediate macro-economic policy variables in terms of aggregate monthly hours worked per person, RBA interbank cash rate and RBA broad money alleviate some volatilities during the volatility transmission process.

4. Conclusions

This paper initially examines the volatility transmission mechanism from Australian mining stock price dynamics to Australian exchange rate dynamics both directly and indirectly; then tests whether Australian exchange rate volatility increases or decreases in response to Australian mining product price variations via intermediate macro-economic variables using a sample of 10 years data with monthly frequency. The conclusions are the following. The paper concludes that there exist short-term and long-term volatility correlations between Australian exchange rate dynamics and Australian mining product dynamics.

I. The Australian exchange rate is auto-correlated with its past price with order 1. It is negatively correlated with RBA interbank cash rate, RBA broad money growth rate; positively correlated with Australian mining product prices, Australian trade balance, Australian mining export value, aggregate monthly hours worked per person and ten-year government bond interest rate.

II. The current variance of the Australian exchange rate is positively correlated with its short term past shocks, its long-term past variance, past variances of Australian trade balance, ten-year government bond interest rate, Australian mining product prices and, Australian mining export value; negatively correlated with past variances of RBA interbank cash rate, aggregate monthly hours worked per person and RBA broad money growth rate.

III. During the volatility transmission from Australian mining product price dynamics to Australian exchange rate dynamics via intermediate variables, non-policy intermediate variables in terms of Australian trade balance, Australian mining export value, Australian oil and gas export value and ten-year government bond interest rate exaggerate the volatility, while policy intermediate variables in terms of aggregate monthly hours worked per person, RBA interbank cash rate and RBA broad money alleviate some volatility.

IV. Policy makers can formulate monetary and fiscal policies to reduce the volatility of the exchange rate transmitted from mining product price volatility. Specifically, in order to alleviate the negative impacts of Dutch Disease through exchange rate volatility initiated by a mining boom, policy makers should expand broad money supply, decrease short-term interest rate, conduct expansionary fiscal policies and adjust these policies according to new shocks frequently in the short term; implement credible long-term monetary policies in terms of long term interest rate and money supply targets to stabilize economic agents' expectations. Hence, these measures reduce the uncertainties and prevent a sharp appreciation of domestic currency during a mining boom.

The limitations of this paper are the following. More other intermediate macro-economic variables need to be discussed to simulate the indirect volatility transmission channels from mining product price dynamics to exchange rate dynamics. Non-linear functional

forms should be considered when modelling the volatility transmission mechanism. Proxies should be identified to capture the volatility of non-ASX-listed mining product prices. Further research can be conducted from these perspectives.

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