A Vector Error Correction Model of the Australian Coking Coal Export

Md. Liakat Ali[1]

Abstract
This article examines the long-run equilibrium relationships between the Australian coking coal export and selected variables. Upon testing appropriate co-integration and vector error-correction models, we detected that the exchange rate of A$/US$, Australian coking coal price and world supply of coking coal have negative impact on Australian coking coal export in the long-run as well as short-run. On the other hand, world demand of coking coal and USA coking coal price have positive relationships with the Australian coking coal export in the long-run and short-run. All these relationships are statistically significant at the 1% level.

JEL Classification: F12, F31

Keywords: Vector error-correction, Co-integration, Exchange rate, Coking coal price, Coking coal export

[1] Western Sydney University (City campus), 255 Elizabeth Street, NSW- 2000, Australia.
mdliakat@yahoo.com.au

1. Introduction

Australia is the largest coking coal exporter in the world. According to the Australian Economy 2019, Australia had exported coking coal 54.19% of global share between the periods of 2017-18. In the same period, Australian had earned A$37.5 billion by exporting 182 Mt (Million tonne) coking coal in the world market. The value of coking coal export increased by 393.42 per cent between the years of 2001-02 to 2017–18 and earned A$ 29.9 billion more than the year of 2001-02.

Australia produces two type of coal, however, hard coal (black coal) and brown coal. Australian hard coal is mostly exported and brown coal is for domestic use. It is important to note that hard coal is calculated as the sum of coking coal and steam coal. Coking coal is used primarily to produce the coke required in iron and steel making, while steam coal is mainly used for electricity generation. Sometimes, coking coal is used as an input in the power sector to produce electricity, but coking coal could not be replaced by steam coal because high quality coking coal is required in iron and steel making. A large volume of coking coal is required in Asia as the Asian economy is booming. Most Australian coking coal is exported to Asia, around 80% of its total export. In 2017, India is by Australia's most important customer receiving 22.75% of Australian total coking coal exports (ABARES, 2019). Japan and China remain second and third importers of Australian coking coal, although India and China have abundant coal resources, but high-quality coking coal is very scarce. The Asian economies, especially Japan, India, China, Republic of Korea and China Taipei, however, depend on Australian coking coal for their economic growth. The reason is that Australian coking coal is high quality and competitively cheaper.

Australia also has a huge deposit of coal under its surface. At the end of 2018, Australia had a recoverable Economic Demonstrated Resources (EDR) of hard coal (steam coal and coking coal) deposit of 76.2 billion tonnes. In addition to the EDR deposit, there is another 8.3 billion tonnes of Sub-economic Demonstrated Resources (SDR) in Australia (IEA, 2018). In fact, with total identified resources of hard coal of around 114 billion tonnes, Australia's total coal resources are substantially larger than it is estimated; that means, if Australia keeps her production at the 2018 rate of around 501 Mt per year, the EDR will be adequate to support about 152 years of supply. Thus, the deposit of the coal will support Australian economy more than 152 years.

Australia is one of the few countries in the world where more coal is exported than is used in the country. Australia is the fourth largest producer and the largest exporter of hard coal (black coal) in the world. According to the ABARE Energy Projections 2018, Australian coal production is projected to increase at an average annual rate of 1.8 per cent over the period of 2018–2030 and domestic consumption is projected to decline at an average annual rate of 0.8 per cent during the period of 2018–2030. Australian coal exports are projected to increase at an average annual rate of 2.4 per cent during the period of 2018-2030. This increase in export reflects strong growth in demand for coal in China, India and other developing economics that have to be met by imports. The Australian hard coal industry is well positioned to take advantage of the expected growth in the world coal consumption over the next decades.

The world coking coal export increased by 158.58 Mt between the years 2000 and 2017 and in the same period Australian coking coal export increased by 78.04 MT. Australia is exporting more than fifty per cent of world's total coking coal export (72.62% in 2016 and 67.65% in 2017). It is; therefore, critically important for the Australian coal companies, Australian government and related parties to know what are the key factors affecting on the

Australian coking coal export. Accordingly, they can take special measures to prevent risk and enhance export. This study historically examines the factors affecting on Australian coking coal export.

1.1 Australian Coking Coal Exports by Destination

Table 1 Australian coking coal exports by destination

Name of Country	Unit	2015	Rank	% of Export	2016	Rank	% of Export	2017	Rank	% of Export
China	Mt	43.39	1	23.20%	37.95	3	20.19%	38.40	3	21.59%
India	Mt	42.60	2	22.78%	43.75	1	23.27%	40.27	1	22.75%
Japan	Mt	39.83	3	21.30%	41.91	2	22.29%	39.22	2	22.16%
South Korea	Mt	20.46	4	10.94%	20.23	4	10.76%	18.74	4	10.59%
China Taipei	Mt	9.80	5	5.24%	9.39	5	4.99%	8.78	5	4.96%
Netherland	Mt	6.70	7	3.58%	8.09	6	4.30%	8.37	6	4.75%
Brazil	Mt	5.61	8	3.01%	6.36	8	3.38%	6.28	7	3.55%
France	Mt	3.62	9	1.94%	3.89	9	2.07%	2.95	9	1.67%
Spain	Mt	1.31	11	0.70%	0.93	14	0.50%	1.16	12	0.65%
United Kingdom	Mt	1,25	12	0..67%	1.08	15	0.57%	1.13	13	0.64%
Turkey	Mt	1.25	13	0.67%	2.03	10	1.08%	0.81	15	0.46%
Poland	Mt	1.24	14	0.66%	1.40	12	0.74%	1.23	11	0.69%
Sweden	Mt	1.02	15	0.55%	1.36	13	0.72%	1.06	14	0.60%
Other Asia & Oceania	Mt	2.78	10	1.48%	1.83	11	0.97%	1.90	10	1.07%
Rest of the world	Mt	6.8	6	6.8%	7.80	7	4.15%	6.90	7	3.90%

Source: Adapted from Australian Coal Information (2018, p.1II: 50)

In 2016 and 2017 India was the number one coking coal importer from Australia. In 2017, India imported Australian coking coal 40.27 Mt, around 22.75% of Australian total coking coal export. In 2016, Australia exported coking coal to India 43.75 Mt, around 23.27% of its total coking coal export. In 2017, Australia exported coking coal to India 3.48 Mt less than the previous year. This is because of the fall of domestic demand and international demand for Indian steel made goods. In 2017 and 2016, Japan is the second largest importer of Australian coking coal around 39.22 Mt.in 2017 and 41.91 Mt in 2016. China is the third largest importer of Australian coking coal. Australia exported coking coal to China 38.40 Mt in 2017 and 37.95 Mt in 2016 respectively. The Republic of Korea is the fourth largest importer of Australian coking coal. At the end of 2017, Korea imported Australian coking coal 18.74 Mt, around 10.59% of Australian total coking coal export but in 2016, it had imported 20.23 Mt coking coal from Australia. In 2017, Australia exported coking coal to Korea 1.49 Mt less than the previous year because the fall of international demand for Korean steel made products such as, car.

Asia is the Australian coking coal main market. In 2017, Australia had exported its coking coal 77.09% to four Asian countries (India 22.75%, Japan 22.16%, China 21.59% and Republic of Korea 10.59%). Asia is projected to account for the majority of the increase in world coking coal consumption and trade over the next decade and Australia will continue to be a major exporter of coking coal to Asian countries.

1.2 Literature Review

A number of empirical studies have been found in relation to export and exchange rate volatility that there is a remarkable link between exchange rate and exports. McKenzie (1998) and Arize and Malindretos (1998) both analysis the Australian dollar volatility and its export and they find some limited evidence of a positive impact of exchange rate volatility on Australian export flows at the aggregate and sectoral levels. A study done by Mcloughlin (2007) found that there is a negligible effect on Australian merchandise export relationship between the Australian real exchange rate and the relative terms of trade. Freebairn (1991) analyses the historical relationship between Australian's real exchange rate and its term of trade, especially focusing on commodity prices. He uses data from 1902 to 1988 and finds a correlation of 0.43 between these two series. Freebairn concludes that the Australian dollar is, in fact, a 'commodity currency'. Dungey (1998) finds that Australia-specific factor accounts for roughly 80% of the fluctuations in the A$/US$ rate and on the other hand a US factor explains the remaining 20%.

The volatility of Australian dollar has generally been perceived as one of the main determinants for Australian international trade, which is true for coal trade. Graham and Waring (1988) suggest that Australian coal supply is largely dependent on the effects of Australian dollar exchange rate and coal price. They find that if the Australian dollar rate begins to appreciate, Australian coal would not be affected substantially in the short term and in the long term, unless US$ rises to a level that are sufficiently large to affect the A$. As a result, the growth in Australian coal production may be slower. Mimuroto (2000) analyses the coal price and the factors behind the price fluctuations. He finds that the exchange rate of the Australian dollar and coal productivity appear to have the stronger direct control power to fix future coal price. However, Australian coal is contributing a significant amount to the health of the Australian economy, but little research has been done in this context. Most studies have been done in the field of exchange rate volatility, exchange rate impact on macroeconomic, exchange rate volatility effect on international trade and benefit of hedging. There is a big gap in existing literature to measure how the Australian dollar exchange rate against the US$, the Australian coking coal price, competitors coking coal price, world demand and supply of coking coal effects on Australian coking coal export. This study will address the existing gap.

1.3 Australian coking coal export and related variables: hypothesized relations

There are fundamental advantages that have allowed the Australian coking coal export to hold its leading position in the world market, but it has to compete with other countries around the world.

Based on "simple and intuitive financial theory'' (Mukherjee and Naka, 1995; Chen et al; 1986), we hypothesize a relationship between the Australian coking coal export and several related variables: exchange rate, coking coal price, demand and supply of coking coal in the world market.

Appreciation of the Australian dollar leads to a relative increase in price of Australian products in foreign markets, a decrease in demand for Australian exports, and hence lowers cash flows into the country. At the same time, stronger Australian dollar lowers the cost of imported goods, which constitute almost all of product inputs. The relationship between exchange rates and coal exports in the case of Australia thus becomes an issue for empirical studies. However, exchange rate of Australian dollar against the US$ has a big impact on Australian coking coal export because the world export price for coking coal is usually denominated in US dollars. The fact is that the Australian coking coal exporters gain more value when the US$ is stronger (i.e., A$ is weaker) and they lose when the US$ is weaker (i.e., A$ is stronger). It sounds like a paradox, but this is the reality for any Australian coal exporters. As such, we hypothesize that coal exports are negatively related to appreciating currency and decreasing money supply and positive effect on exchange rate when falling coal exports.

The intuition behind the relationship between Australian coking coal prices and exports are straightforward. As increase the price of coking coal leads to increase export but exchange rate plays a vital role between exports and prices. The Australian coking coal exporters how much gain or loss the revenues it depends on the price and exchange rate at the time of selling the coal. Additionally, exchange rates and coal prices are determined by various factors.

Australia is by far the largest exporter of coking coal globally, accounting for nearly 60% of overall supply. Its main competitors in volume terms are the United States (coking coal exports of 50 Mt. in 2017) and Canada (coking coal exports of 29 Mt. in 2017). A direct relationship exists between the Australian coking coal export and its main competitors coking coal prices. An increase in competitor's prices, under general circumstances, is likely to increase Australian coking coal exports that would have a positive effect upon Australian coking coal exports. On the other hand, the rise of Australian coking coal price compared to competitor's prices lead to decrease of Australian coking coal exports that would have a negative effect upon Australian coking coal exports.

In general, export depends on demand and supply. The fact is that the world main coking coal exporters are Australia, USA, Canada and Russia ((IEA, Coal Information 2018). On the other hand, the world main importers of coking coal are China, Japan, India, Republic of Korea, Germany and France (IEA, Coal Information 2018). Import demands are expected to grow by around 97 Mt from 2018 to 2030, an average annual growth rate of 2.3%. This represents annual growth of around 7.5 Mt (ABS, 2018). This growth represents a potentially significant opportunity for Australian coking coal exporters. The booming Asian economy is creating new demand for coking coal, but the source of supply is not increasing as fast as demand is increasing and, as a result, the price of coking coal is going higher and higher (BP Statistic, 2018). The main underlying assumption is that when the world demand for coking coal increases, the exports of Australian coking coal increase. On the other hand, the supply of coking coal in the world markets increase, the Australian coking coal exports increase. It indicates that the world demand for coking coal has a positive relationship with the Australian coking coal export.

2. Research Methodology

Using Johansen's vector error-correction model, this paper examines the dynamic relationships between the Australian coking coal export and effective variables in which determine the Australian coking coal exports. Although Engle and Granger's (1987) two-step error-correction model may also be used in a multivariate context, the VECM yields more efficient estimator of co-integrating vectors. This is because the VECM is a full information maximum likelihood estimation model, which allows for testing for co-integration in a whole system of equations in one step and without requiring a specific variable to be normalized. This allows us to avoid carrying over the errors from the first step into the second, as would be the case if Engle-Granger's methodology is used. It also has the advantage of not requiring a priori assumptions of endogenity or exogenity of the variables. The VECM is of the form

$$\Delta Y_t = \sum_{j=1}^{k-1} \Gamma j^{\Delta Y_{t-j}} + \alpha\beta' \; Y_{t-k} \; + \mu + \epsilon_t \qquad (1)$$

Where, $\sum_{j=1}^{k-1} \Gamma j^{\Delta Y_{t-j}}$ and $\alpha\beta' \; Y_{t-k}$ are the vector autoregressive (VAR) component in first difference and error-correction components, respectively, in levels of EQ. (1). Y_t is a $\rho \times 1$ vector of variables and is integrated of order one. μ is a $\rho \times 1$ vector of constants. K is a lag structure, while ϵ_t is a $\rho \times 1$ vector of white noise error terms. Γ_j is a $\rho \times \rho$ matrix that represents short-terms adjustments among variables across ρ *equations at the jth lag.* β' is a $\rho \times r$ matrix of speed of adjustment parameters representing the speed of error correction mechanism. A larger α suggests a faster convergence toward long-run equilibrium in case of short-run deviations from this equilibrium.

Before estimating the VECM, we first need to check for stationarity and unit roots through performing the augmented Dickey-Fuller (ADF) and Phillips-Peron (PP) tests on the variables in levels and first differences. Only variables integrated of the same order may be co-integrated, and the unit root tests will help us determine which variables are integrated of order one, or I(1).

The choice of lag lengths may be decided using Sim's likelihood ratio test. However, for simplicity, in this article we will use the multivariate forms of the Akaike information criterion (AIC) and Schwartz Bayesian criterion (SBC), where AIC = T ln(residual sum of squares) + 2n and SBC = T ln(residual sum of squares) + nln(T). The AIC and SBC are model selection criteria developed for maximum likelihood estimation techniques. In minimizing the AIC and SBC, we minimize the natural logarithm of the residual sum of squares adjusted for sample size, T, and the number of parameters included, n.

The model is estimated by regressing the ΔY_t matrix against the lagged differences of ΔY_t and Y_{t-k} and determines the rank of $\Pi = \alpha\beta'$. The eigenvectors in β' are estimated from the canonical correlation of the set of residuals from the regression equations. To determine the rank of π, which will give the order of cointegration, r, we calculate the characteristic roots or eigenvalues of π, $\lambda_i^{\wedge}$. Furthermore, we test for r using the λ_{trace} and λ_{max} test statistics, where, λ_{trace} = - T $\sum_{i=r+1}^{p} \; In \, (1 - \; \lambda_I^{\wedge})$ and λ_{max} = -T In (1- $\lambda_{r+1}^{\wedge}$). The choice of the number of maximum co-integrating relationships will be based on the λ_{trace} tests. The λ_{max} test is used to test specific alternative hypotheses. We will reject models where π has a full rank since in such a situation Y_t is stationary and has no unit root, and so there would be no error-correction.

Having determined the order of co-integration, we select and analyse the relevant co-integrating vector and speed of adjustment coefficients. A number of methods that can be used to test co-integration are the Engle-Granger two-step method, Johansen test, Phillips-Ouliaris co-integration test and so on. We choose the Johansen co-integration test in our study because this method is very common in the field of finance research and it also easy to explain. Johansen co-integration test is multivariate approach; all the variables are considered as explicitly endogenous, so that no arbitrary normalization has to be made without testing.

Johansen's co-integration test starts in the VAR of order ρ given by:

$$y_t = \mu + A_1 \, y_{t-1} + \text{----------} + A_p \, y_{t-p} + \varepsilon_t \qquad (2)$$

Where, y_t is an nx1 vector of variables that are integrated of order one commonly denoted I(1) and ε_t is an nx1 vector of innovations. This VAR can be written as:

$$\Delta y_t = \mu + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \, \Delta y_{t-1} + \varepsilon_t \tag{3}$$

Where

$$\Pi = \sum_{i=1}^{p} A_i \text{ -I and } \Gamma_i = - \sum_{j=i+1}^{p} A_j \tag{4}$$

When the coefficient matrix Π reduces rank r < n, the nXr matrices α and β each with rank r such that Π= **αβ′**and **β′** y_t is stationary. Where **α** is the adjustment parameters in the vector error correction model, r is the number of co-integrating relationships and each Colum of β is a co-integrating vector. The trace and maximum eigenvalue test are below:

$$J_{trace} = \text{-T} \sum_{i=r+1}^{n} In\,(1- \hat{\lambda}_i) \tag{5}$$

$$J_{\max} = \text{-T IN } (1- \hat{\lambda}_{r+1}) \tag{6}$$

Where, $\hat{\lambda}_i$ is the ith largest canonical correlation and T is the sample size. The trace test checks the null hypothesis of r co-integration vectors against the alternative hypothesis of n co-integration vectors. On the contrary, the maximum eigenvalue test tests the null hypothesis of r co-integrating vectors against the alternative hypothesis of r + 1 co-integrating vectors.

Tests on the parameters of the co-integrating vector may be performed using the likelihood ratio test. This is crucial because we would like to test whether Australian coking coal exports contribute to the co-integrating relation and also if the related variables are significant in the co-integrating relationship. The null hypothesis in such a situation would be a linear restriction represented by H_0 : β = H ꝕ, where β is a (p + 1) X r cointegrating matrix, H is a (p + 1) X s matrix with (p + 1 - s) restrictions and ꝕ is a s X r matrix for a case without a linear trend. The likelihood ratio is given by LR = T $\sum_{i=1}^{r}$ In [(1- $\hat{\lambda}_{Hj}$)/ (1- $\hat{\lambda}_I$)] and follows a x^2 distribution with r (p + 1 - s) degrees of freedom. The $\hat{\lambda}_{Hj}$ are eigenvalues based on restricted eigenvectors; the $\hat{\lambda}_I$ are those based on unrestricted eigenvectors.

For the next step, we run the Wald test for estimating short-run effects between variables. Finally, we check the Breusch-Godfrey Lagrange Multiplier (LM) test for serial correlation (Breusch 1978: Godfrey 1978) and the Breusch-Pagan-Godfrey test for heteroscedasticity (Breusch and Pagan 1979). Simultaneously, we also check Jarque-Bera for normality (Hendry and Juselius 2001), and CUSUM test (Brown, Durbin and Evans 1975) for stability, as well as to find whether the model is robust and to measure its goodness of fit.

2.1 Sources of Data

The Australian coking coal exports and relevant variables are presented in Table 2.

Table 2 lists the variables, how they are measured and the sources of the data

Variable	Name	Unit	Source
ACCE	Australian Coking Coal Export	Metric Tonne	Department of Industry, Innovation and Science
ADER	Australian Dollar Exchange Rate against the US Dollar	Based A$/US$	Reserve Bank of Australia (RBA)
ACCP	Australian Coking Coal Price	US$ per Tonne	Department of Industry, Innovation and Science
USACCP	USA Coking Coal Price	US$ per Tonne	Bureau of Economic Analysis, U.S Department of Commerce
WDCC	World Demand Coking Coal	Metric Tonne	International Energy Agency
WSCC	World Supply Coking Coal	Metric Tonne	International Energy Agency

Source: Developed for this study

The data used for this analysis are secondary data. The quarterly data of Australian coking coal export, Australian coking coal price, USA coking coal price, world demand coking coal, world supply coking coal and the Australian dollar exchange rate against the US dollar are used over the last 24 years (1996-2019) which are collected from the Department of Industry, Innovation and Science, Australia, Bureau of Economic Analysis, U.S Department of Commerce, International Energy Agency (IEA) and the Reserve Bank of Australia (RBA). These entire organisations are reliable sources of data. The quarterly data for Australian coking coal price and Australian coking coal export are available in the data bank of Department of Industry, Innovation and Science. But they do not maintain weekly or monthly data of above set; as a result, the exchange rate of Australian dollar against the US dollar also needs to be considered quarterly for this reason. RBA does not maintain quarterly exchange rate of Australian dollar against the US dollar in its data bank, but it reserves monthly exchange rate. For necessity of econometric analysis, the monthly exchange rates are converted to quarterly exchange rate. Please note that the exchange rate of Australian dollar uses spot rate as it in the international market. The quarterly data are available in Bureau of Economic Analysis, U.S Department of Commerce, and International Energy Agency. However, all data set are converted to real set of data (constant 2019 Q_4 price). Please note that the data are normally distributed and seasonally adjusted. SPSS and E-views software are used to finalise the analysis and these software are very commonly used in the time series analysis.

Table 3 Descriptive statistics of variables (at level)

Variables	Mean	Std. Dev.	Minimum	Maximum
ACCE	124000000	36459242	71496000	188000000
ADER	0.7650	0.139969	0.51	1.04
ACCP	91.64458	56.55789	32.85	198.47
USACCP	89.87958	45.6781	42.98	205.02
WDCC	215000000	45127975	168000000	294000000
WSCC	231000000	51214160	179000000	327000000

Source; Developed for this study

Table 4 Descriptive statistics of variables (first difference)

Variables	Mean	Std. Dev.	Minimum	Maximum
ACCE	4595783	10775986	-16810000	32027000
ADER	0.001739	0.072529	-0.150000	0.120000
ACCP	5.273913	33.97465	-51.0400	110.7100
USACCP	3.863043	25.79915	-59.6600	52.64000
WDCC	5252304	15341383	-32151000	49915000
WSCC	57291.30	17320141	-24414000	65305000

Source: Developed for this study

3. Results

3.1 Unit Root Test

The first step in time series analysis is to test unit root. In time series models in econometrics, a unit root is a feature of processes that evolve through time that can cause problems in statistical inference if it is not taking proper caution. A linear stochastic process has a unit root if 1 is a root of the process's characteristic equation. This process is non-stationary and the other roots of the characteristic equation lie inside the unit circle that is, have a modulus less than one-then the first difference of the process will be stationary.

Unit roots can be tested in time-series by using various methods such as Augmented Dickey-Fuller (ADF) test, Dicker-Fuller GLS (ERS), Phillips-Perron (PP), Kwiatkowski-Philips-Schmidt-Shin (KPS) and Ng-Perron. The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) methodologies are employed in this study to test the unit root. The null hypothesis states that there is a unit root of the variable.

Table 5 Results of Unit Root Test

At Level							
Variable	**ADF test Statistic**	**Critical Value 1%level**	**Critical Value 5% level**	**PP test Statistic**	**Critical Value 1% Level**	**Critical Value 5% Level**	**Results**
1.ACCE	-0.685399 (0.8315)	-3.7529	-2.9980	-0.4000 (0.8936)	-3.529	-2.9980	Non-stationary
2. ADER	-1.681425 (0.4263)	-3.7695	-3.004	-1.3951 (0.5667)	-3.7529	-2.9980	Non-stationary
3. ACCP	-1.316687 (0.6039)	-3.7529	-2.9980	-1.3166 (0.6039)	-3.7529	-2.9980	Non-stationary
4. USACCP	-1.3260 (0.5995)	-3.7529	-2.9980	-1.3260 (0.5995)	-3.7529	-2.9980	Non-stationary
5. WDCC	0.410944 (0.9775)	-3.8573	-3.0403	0.50980 (0.9832)	-3.7529	-2.9980	Non-stationary
6. WSCC	1.1174 (0.9963)	-3.7695	-3.004	0.9499 (0.9943)	-3.7529	-2.9980	Non-stationary

Source: Table 5 was generated for this study

Note: All the unit root tests are conducted with a Intercept specification and statistical significant at the 1% and 5% levels respectively. Reported in the brackets are respective probability values.

Result of Unit Root:

All variables are non-stationary in both tests (ADF test and PP test). According to the statistical procedures the non-stationary series need to have taken 1st difference to see whether the data are stationary or non-stationary. The most commonly outcomes in time series data are that 1st difference data are found stationary. This case the series are said to be integrated of order I (1) and no further unit root testing is required.

Table 6: Results of unit root test (1st difference)

First Difference							
Variable	**ADF test Statistic**	**Critical Value 1%level**	**Critical Value 5% level**	**PP test Statistic**	**Critical Value 1% Level**	**Critical Value 5% Level**	**Results**
1.ACCE	-6.339 0.000	-3.7695	-3.004	-10.326 0.000	-3.7695	-3.004	Stationary
2. ADER	-3.2503 0.0304	-3.2195	-3.004	-3.2713 0.0291	-3.7695	-3.004	Stationary
3. ACCP	-5.1798 0.000	-3.7695	-3.004	-5.1798 0.000	-3.7695	-3.004	Stationary
4. USACCP	-4.3794 -0.002	-3.7695	-3.0403	-4.3794 0.000	-3.7695	-3.004	Stationary
5. WDCC	-3.945 -0.0386	-3.8573	-3.0403	-5.5983 0.000	-3.7695	-3.004	Stationary
6. WSCC	-7.2336 0.000	-3.7695	-3.004	7.257 0.000	-3.7695	-3.004	Stationary

Source: Developed for this study

Note: All the unit root tests are conducted with an Intercept specification and statistical significant at the 1% and 5% levels respectively. Reported in the brackets are respective probability values.

The first differences of all variables in this data set are considered; the non-stationarity hypothesis is rejected at the 1% and 5% level of significance and all data are stationary accepted. Therefore, it is concluded that all the series are generated by an I(1) process and further unit root tests are not required.

3.3 Co-integration

According to the time series analysis, the next procedure is to check whether the variables have long-run relationships or short-run relationships. It is important to find out suitable lag length before estimation co-integration equation. The length criterion technique is used through unrestricted VAR. Thus, the order of optimal lag length is confirmed by the Schwarz information criterion (SC). Most of the criteria suggest lag 1. So, the order of optimal lag is 1 for this series of Australian coking coal export. Lag 1 is used for estimating the Johansen co-integration and VECM tests. The optimal lag order is sensitive for both estimations. According to Hendry and Juselius (2001), it is also possible to regard this time series analysis as determining a long-run equilibrium relationship where the differenced variables are stationary. The Johansen co-integration (Johansen 1988) rank tests (trace and maximum eigenvalue) confirm the long equilibrium association between variables. The test also suggests that three (3) co-integrating ranks at the 5% significance level of the series. Level of significance determines by Mackinnon, Haug, and Michelis (1999) *p*-value. It implies that the calculated co-integrating rank is applied to estimate the long-run effects of VECM estimations. The study reveals that, in the system, there is a long-run relationship running from ADER, ACCP, USACCP, WDECC and WSCC to ACCE. Next, we proceed using the VECM technique for finding the causality between concerned variables, as in Engle and Granger's (1987) representations theory.

Table 7 Johansen co-integration rank test (trace and maximum eigenvalue)

Trace Test				
Hypothesized No. of CE (s)	Elgen-Value	Trace Statistic	0.05 Critical Value	*P*-value
None*	0.982395	190.2954	95.7536	0.0000
At most 1*	0.841695	101.4168	69.8188	0.0000
At most 2*	0.751029	60.8656	47.8561	0.0019
At most 3	0.562923	30.2764	31.7970	0.1040
At most 4	0.327581	12.06823	15.49471	0.1537
At most 5	0.140739	3.337008	3.841466	0.0677
Maximum Eigenvalue Test				
Hypothesized No. of CE (s)	Elgen-Value	Trace Statistic	0.05 Critical Value	*P*-value
None*	0.982395	88.8709	40.0775	0.0000
At most 1*	0.841695	40.5511	33.8768	0.0006
At most 2*	0.751029	30.5892	27.58434	0.0199
At most 3	0.562923	18.20823	21.13162	0.1222
At most 4	0.327581	8.73122	14.26460	0.3092
At most 5	0.140739	3.337008	3.841466	0.0677

Source; Developed for this study

Trace and maximum Eigenvalue tests indicate three (3) co-integrating eqn(s) at the 0.05 level. *Denotes rejection of the hypothesis at the 0.05 level: **Mackinnon, Haug, and Michelis (1999) *p*-values

Table 8: Co-integrating relationships

1 Cointegrating Equation(s) Log Likelihood – 1229.815

Normalized cointegrating coefficients (standard error in parentheses)

ACCE	ADER	ACCP	USACCP	WDCC	WSCC
1.000000	-1.95E+08	-2626990.	4108004.	3.700416	-4.122092
	(1.5E+07)	(130042.)	(183010.)	(0.25940)	(0.20506)

Source: Develop for this study

In the long-run, Australian dollar exchange rate has a negative relationship with the Australian coking coal export. It explains that when the Australian dollar value increases against the US dollar, the export of Australian coking coal decrease because coal exporters earn less revenue to export same amount of coking coal. Similarly, Australian coking coal price has a negative relationship with the Australian coking coal export in the long run. The relationship indicates that when the coking coal price goes down, the Australian coking coal export also goes down. United States of America (USA) is the second largest coking coal exporter (IEA, 2019). The price of USA coking coal has a positive relationship with the Australian coking coal export. It explains that when the prices of USA coking coal increase the importers are more interested to import from Australia. The world demand coking coal has a positive relationship with the Australian coking coal export and the world supply has a negative relationship the Australian coking coal export. It indicates that when the demand of coking coal increases in the world market, the Australian coking coal export increases, oppositely, when the supply of coking coal increase in the world market, the Australian coking coal export decreases. All the coefficients are statically significant at the 1% level.

3.4 Results of VECM

Table 9 VECN long-run representation:

Australian coking coal exports (ACCE) as a dependent variable

	Coefficient	Std. Error	t-statistic	Probability
ECT	-0.144833	0.064875	2.232495	0.0454*

Source; Developed for this study

Significant at the * 5% level

The calculated coefficient of the error correction term (ECT) is -0.1448, which means that 14.48% of the disequilibrium from the previous quarter's shock intersects back to the long-run equilibrium in the current quarter. The negative sign of the coefficient and significance level of probability value imply the existence of co-integration among variables. In other words, the variables have long-run relationships, running from independent variables to the dependent variable at the adjustment speed of 14.48% towards the equilibrium.

We conclude that there are three co-integrating vectors r=3. As a result of VECM model estimation (1), we have obtained 3 co-integrating equations (t-statistics in parentheses)

ACCE= -412000000 ADER (1.2208)	-9487391 ACCP (3.37933*)	+17188849USACCP (4.6636*)	-242000000 (7)
WDCC = -292000000 ADER (0.85702)	-875552 ACCP (3.09375*)	16095891 USACC (4.33226*)	-213000000 (8)
WSCC = -314000000 ADER (O.81239)	- 9524189 ACCP (2.95815)	17622686 USACCP (4.16929)	-248000000 (9)

According to the Engle-Granger terminology, equilibrium equations (7), (8) and (9) explain causal behaviour of Australian coking coal export with related variables in the long-run relationships. Dynamics of Australian coking coal export in the short-run depends on deviations of variable levels from these long-run equilibrium equations, occurred in the previous period. The equation seven defines the long-run equilibrium relationships among ACCE, ADER, ACCP and USACCP. All the variables in this time series are not statistically significant. ACCP and USACCP have significant relationships with the ACCE. But ADER has no significant relationship with the ACCE. The number eight equation combines WDCC, ADER, ACCP and USACCP. The significant relationships exist among WDCC, ACCP and USACCP. On the other hand, ADER has not significant relationship with WDCC. The number nine equation defines the long-run equilibrium relationship among WSCC, ADER, ACCP and USACCP. There are significant relationships among WSCC, ACCP and USACCP. WSCC has no significant relationship with the ADER.

In process of VEC model estimation, we have obtained the estimation of adjustment speeds and coefficients of short-run effects that are presented in Table 10.

Table 10 Results of Error-Correction Model

Error Correction	D (ACCE)	D(WDCC)	D(WSCC)	D(ADER)	D(ACCP)	D(USACCP)
D (ACCE (-1))	-0.423532 (0.23061) [-1.83655]	-1.895523 (0.63702) [-2.97559]	-0.610545 (0.53721) [-1.13651]	-2.52E-10 (4.5E-09) [-0.05611]	1.98E-06 (2.4E-06) [0.83446]	1.21E-07 (1.3E-06) [0.09382]
D (WDCC (-1))	-0.294285 (0.13806) [-2.13160]	0.143203 (0.38136) [0.37550]	0.792092 (0.32161) [2.46293]	6.40E-09 (2.7E-09) [2.37968]	3.03E-06 (1.4E-06) [2.13329]	1.83E-06 (7.7E-07) [2.36243]
D (WSCC (-1))	0.207101 (0.21207) [0.97656]	0.744615 (0.58581) [1.27108]	-0.441991 (0.49402) [-0.89468]	-4.15E-09 (4.1E-09) [-1.00473]	-2.74E-06 (2.2E-06) [-1.25242]	-5.38E-07 (1.2E-06) [-0.45215]
D (ADER (-1))	-26124889 (1.2E+07) [-2.12973]	12826392 (3.4E+07) [0.37853]	-20944419 (2.9E+07) [-0.73296]	0.032174 (0.23902) [0.13461]	117.5572 (126.370) [0.93026]	46.35502 (68.8503) [0.67327]
D (ACCP (-1))	-289768.1 (75342.2) [-3.84603]	-603569.8 (208118.) [-2.90013]	-529191.6 (175508.) [-3.01519]	-0.001502 (0.00147) [-1.02343]	-0.600547 (0.77616) [-0.77374]	-0.901435 (0.42288) [-2.13168]
D (USACCP (-1))	145358.9 (90941.9) [1.59837]	219376.8 (251209.) [0.87328]	126699.5 (211848.) [0.59807]	0.001615 (0.00177) [0.91162]	0.159553 (0.93687) [0.17030]	0.748448 (0.51043) [1.46630]
C	7803689. (957842.) [8.14716]	11911916 (2645854) [4.50211]	9080655 (2231276) [4.06971]	-0.004268 (0.01866) [-0.22869]	-3.653213 (9.86754) [-0.37023]	-1.306321 (5.37612) [-0.24299]

Source: Developed for this study

Short-run Coefficient

ACCE is the target variable (i.e., dependent variable)

$$ACCE_t = -0.14483ECT_{t-1} - 0.423532ACCE_{t-1} + 0.294285WDCC_{t-1} - 0.207101WSCC_{t-1} - 26124889ADER_{t-1} - 289768ACCP_{t-1} + 145358USACCP_{t-1} + 7803689 \quad (10)$$

The parameters of the long-run and short-run equations show that each unit increase Australian dollar value against the US dollar, Australian coking coal exports decrease by 195 Mt (million tonne) in the long-run and 26.12 Mt in the short-run. This finding is consistent with other author's findings. For example, Adam et al (2017) find that each 1% increase in rupiah/US dollar is always followed by 0.24% fall in export. Li et al (2007) explain that agricultural trade flows are quite significantly negative relationship with the exchange rate. The findings of this research explain that one-dollar price increase of Australian coking coal, the export decreases by 2.63 Mt in the long-run and 0.29 Mt in the short-run. On the other hand, one-dollar price increase in USA coking coal, Australian coking coal exports increase by 4.10 Mt in the long-run and 0.15 Mt in the short-run. These findings are similar to the other authors, for example, Gabor et al (2012), recommend that wheat price and wheat export have a positive relationship exist. On the other hand, Obsdia finds that competitor's price has positive relationship with export. Therefore, increase of coal price of United States, Canada and Colombia can push Australian coal export upward if the price of Australian coal remains constant or lower (Wolde, 2010). In general, the volume of export from a country is determined by world demand and world supply. The main underlying assumption is that when the world demands for coking coal increase, the export of Australian coking coal also increase. On the other hand, when supply of coking coal increase in the world market, demand for Australian coking coal decrease. This study finds similar to the assumption. Each 1% increase of world demand coking coal is always followed by 3.7% increase export of Australian coking coal in the long-run and 0.29% increase in the short-run. Conversely, each 1% increase supply of world coking coal, Australian coking coal export decrease by 4.12% in the long-run and 0.21% decrease in the short-run.

4. Robustness check of the model

This study conducted a robustness check through the post-estimation technique of the model. The R^2 and adjusted R^2 of the ordinary least squares (OLS) model through the VECM parameter of this study are quite high; i. e., 96% and 93%, respectively. R^2 is more than 60%, this means that the model is best fit. The F-statistic of the model is positive and larger enough with the significant corresponding probability value (0.000001), which is less than 5%, implying that all the independent variables have jointly influenced the dependent variable - Australian coking coal export. The result of Durbin-Watson is found 1.7926; it means that there is no serial correlation problem in the model and that the series is stationary in nature. Therefore, the study demonstrates the serial correlation of the series, the normality test of the residuals and the stability condition of the model.

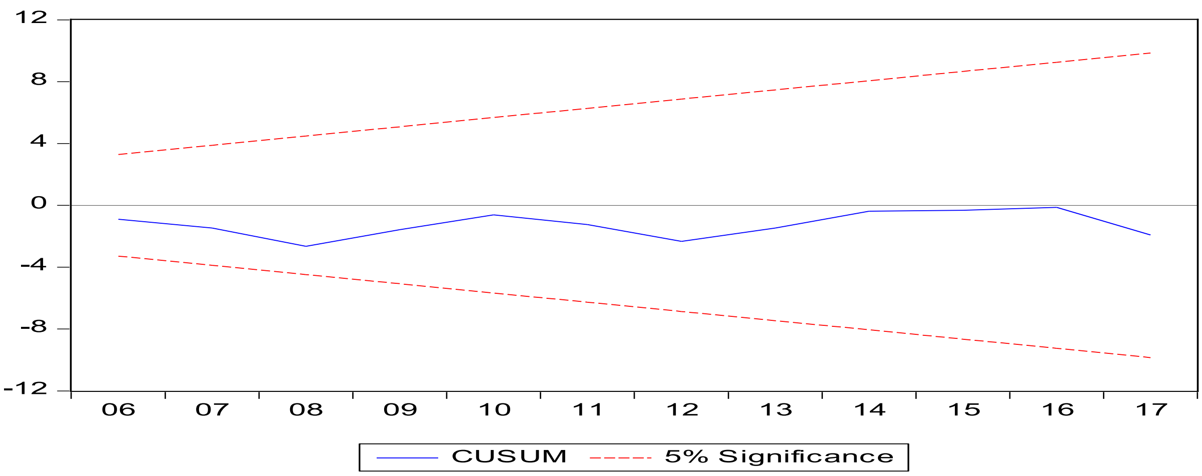
Table 11 Diagnostic test result

Probability	Jarque-Bera	$Obs^* R^2$
Normality	0.831235	0.65993
Serial Correlation	0.072538	0.78771
Heteroscedasticity	12.3624	0.4170
R^2= 96%	Adjusted R^2=93%	DW= 1.7926

Source: Developed for this study

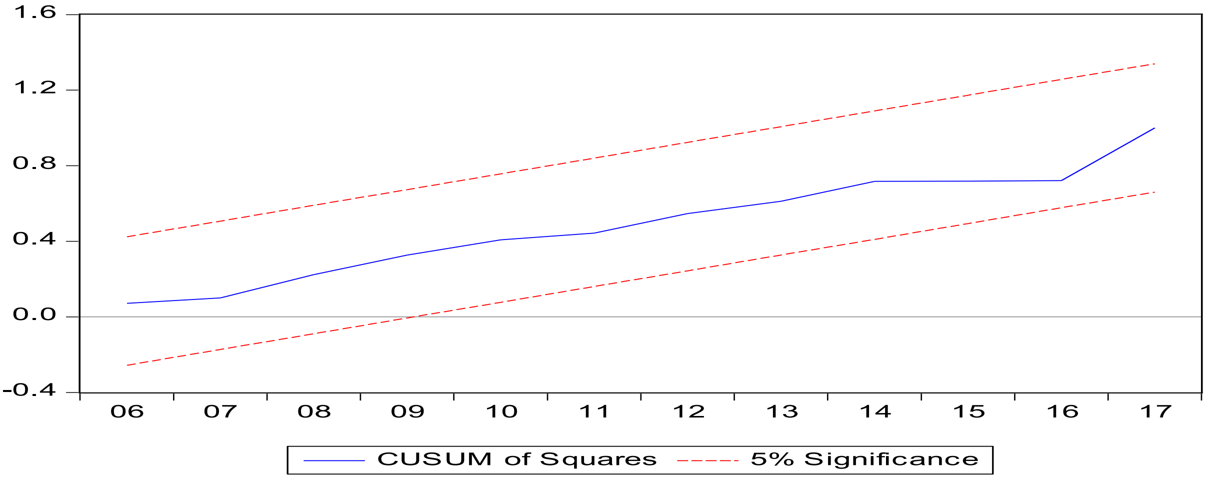
Breusch-Godfrey LM (Breusch 1978; Godfrey 1978) and Breusch and Pagan (1978) heteroscedasticity tests' finding ($Obs^* R^2$ and probability value) infer that there is no serial correlation and heteroscedasticity problem in the model. The Jarque Bera test also verifies the normality of the residuals (Hendry and Juselius 2001). On the other hand, the CUSUM and CUSUM square tests imply that the model is stable (Brown, Durbin, and Evans 1975), because the blue lines do not cross the red lines in figure 1 and 2. All of the diagnostic findings suggest that our model is robust and of good fit examining the effects of exchange rate of A$/US$, price of Australian coking coal, USA coking coal price, world demand and supply of coking coal on Australian coking coal export.

Figure1. Stability test (CUSUM)



Source: Developed for this study

Figure 2. Stability test (CUSUM Square).



Source: Developed for this study

5. Concluding Remarks

This paper examined the impact of Australian dollar exchange rate, Australian coking coal price, USA coking coal price, world demand for coking coal and world supply of coking coal on Australian coking coal export, employing a co-integration and vector error correction model (VECM) approach. Using Johansen's methodology for multivariate co-integration analysis and quarterly time-series data, this article has identified several factors that have a long-run equilibrium effect on Australian coking coal export. Consequently, after running VECM, the analysis implies that there is a long-run relationship running from ADER, ACCP, USACCP, WDCC and WSCC to ACCE. The main findings of this research explain that the exchange rate of A$/US$, Australian coking coal price and world supply of coking coal have negative impact on Australian coking coal export in the long-run as well as short-run. On the other hand, world demand of coking coal and USA coking coal price have positive relationships with the Australian coking coal export in the long-run and short-run. All these relationships are statistically significant at the 1% level. This study also confirms that all the independent variables determine the Australian coking coal export. Australia is the number one coking coal exporter in the world. Australia earned A$ 41.10 billion by exporting coking coal in the financial year 2017-18. The weaker Australian dollar, higher price of coking coal and rapid production growth are the driving forces to earn large amount of money.

These results have important policy implications. In view of the Australian economy's dependence on exports, our empirical results indicate a currency appreciation has an adverse effect on Australian coking coal exports and production. Thus, if policy makers wish to promote exports, they could focus their efforts on exchange rate volatility. Apparently, the RBA has been pursuing the asymmetric policy of intervening to prevent excessive appreciation of Australian dollar. The Australian coal industry is contributing a large amount of money to the Australian economy and if the Australian coal industry uses the findings in this study, they will be able to earn more revenue by exporting the same volume of coal and therefore, will bring the benefit for Australian coal industry, Australian government and the people of Australia.

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