Coal Consumption Environmental Kuznets Curve (EKC) in China and Australia: Evidence From ARDL Model

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In this study, coal consumption (CS) for EKC is analyzed for two countries which are China and Australia by ARDL model (Autoregressive Distributed Lag Model). China and Australia are among the countries which are heavily dependent on coal for energy demands. China is the current leader in the world for coal consumption. In this study, we aim to analyze the effect of economic growth on CS for China and Australia. The importance of the study is that it is the first study for time series studies in the literature of single country studies that analyze CS EKC. Analysis of CS EKC is important since the world is still heavily depended on coal for energy demands. CS EKC is verified for Australia between GDP (gross domestic product per capita), CS and square of GDP (GP) for the period between 1980 and 2016. CS EKC is verified for China between GDP, CS, GP and energy consumption (ENEC) for the period between 1980 and 2014.

Keywords: China, Australia, environmental Kuznets hypothesis, ARDL, coal consumption

INTRODUCTION

In this study, the relationship between CS and growth (GH) is analyzed for Australia and China. Both countries are heavily depended on coal for energy demands. Both countries invested in renewable energy projects in the recent years and continue to invest. This is the first study for time series studies in the literature of single country studies that analyze CS EKC. The only study in the literature that analyzed CS EKC is a panel study for China by Hao et al.(2016). Hao et. al. (2016) analyzed a panel of 29 Chinese provinces by Spatial Durbin Model and confirmed CS EKC relationship between CS and GH for the period between 1995 and 2012. There is a vast amount of studies in the literature of EKC for China but the study of Hao et. al. (2016) is the only study that analyze CS EKC for China. There is no study in the literature for Australia that analyze CS EKC. This study is the first study for Australia that analyze CS EKC. Reduced model of EKC is used for the analysis of both countries and ENEC variable is added to the analysis of China. The main conclusion of the study is that CS EKC is confirmed for Australia and China. For the literature of EKC in China, Alam et. al. (2016) confirmed EKC hypothesis for China for the period between

1970 and 2012. Liu et. al. (2016) did not confirm EKC hypothesis for China for the period between 1997 and 2010. Wang et. al. (2011) did not confirm EKC hypothesis for China for the period between 1995 and 2007. For Australia, Marques et al. (2018), Shahbaz et al. (2017) and Leal et al. (2018) studied EKC hypothesis. Marques et al. (2018) confirmed EKC for Australia and Shahbaz et al. (2017) did not confirm EKC for Australia for the periods 1965 and 2016, and 1970 and 2012 respectively. Leal et al. (2018) confirmed that growth had positive impact on emissions (ES) for Australia.

There is a research gap to analyze the relationship between CS and GH in the literature for single country studies by taking the EKC hypothesis as basis. The contribution of this study it fills the gap in the literature by analyzing the relationship between CS and GH in China and Australia by taking the EKC hypothesis as basis for the periods 1980 to 2014, and 1980 to 2016 respectively.

LITERATURE REVIEW

Further literature for China, Jalil and Mahmud (2009) investigated the EKC relationship between emissions, GDP, ENEC and trade openness (TS) for China for the period between 1975 and 2005. Jalil and Mahmud (2009) confirmed the EKC hypothesis for China by using ARDL methodology. Jalil and Mahmud (2009) also found that there is unidirectional causality running from GDP and ENEC to ES, and there is no causal relationship between ES and TS.

Pao and Tsai (2011) investigated the EKC relationship between ES, ENEC, foreign direct investment (FIN) and GDP for a panel of countries for the period between 1980 and 2007. Pao and Tsai (2011) confirmed the EKC hypothesis for China by using panel cointegration framework.

Wang et al. (2014) investigated the relationship between urbanization (UBN), ENEC and emissions for a panel of 30 China provinces for the period between 1995 and 2011. Wang et al. (2014) confirmed bi-directional causality between UBN and ENEC, UBN and ES, and ENEC and ES in the long run. Wang et al. (2014) also confirmed bi-directional causality between emissions and UBN, ENEC and ES, and unidirectional causality from UBN to ENEC in the short run.

Wang et al. (2016a) confirmed the long run relationship between ES, GDP and ENEC for China for the period between 1990 and 2012 by VECM and Johansen Multivariate cointegration tests. Wang et al. (2016a) confirmed bi-directional causality between GDP and ENEC, unidirectional causality from ENEC to ES, and no causality between GDP and ES. Wang et al. (2016b) confirmed the long run relationship between ES, GDP and ENEC for China for the period between 1995 and 2012 by panel cointegration test. Wang et al. (2016b) confirmed bi-directional causality between GDP and ENEC, ES and ENEC, and unidirectional causality from ENEC to ES. Kang et al. (2016) examined the EKC hypothesis in China by spatial panel model for the period 1997 to 2012. Kang et al. (2016) an inverted N relationship between GH and ES. Kang et al. (2016) found that CS and UBN positively and significantly affected ES in China and TS negatively affected ES in China. Stern and Zha (2016) examined the relationship between PM 2.5 particulate pollution, PM 10 particulate pollution and GH for 50 Chinese cities for the period 2013 to 2014. Stern and Zha (2016) concluded that the relatonship between GH and particulate pollutants was inverted U shaped but the coefficients of GH were not statistically significant.

Wang et al. (2017) examined the EKC hypothesis for a panel of 30 Chinese provinces for the period 2000 to 2013. Wang et al. (2017) confirmed the EKC relationship between UBN and manufacturing sector emissions. Wang et al. (2017) examined the relationship between GH and ES, and found that the EKC hypothesis existed in heat and electricity production sectors. Riti et al. (2017) examined the EKC hypothesis in China for the period 1970 to 2015. Riti et al. (2017) confirmed the EKC hypothesis in China by using multiple cointegration techniques. Zhang et al. (2017) examined the relationship between water pollution and GH for panel data of Chinese provinces. Water pollution was examined in terms of chemical oxygen demand discharge and ammonia nitrogen. The time period for chemical oxygen demand discharge was 1990 to 2014, and the time period for ammonia nitrogen was 2001 to 2014. Zhang et al. (2017) confirmed the EKC relationship between GH and chemical oxygen demand discharge, and growth and ammonia nitrogen in China. Causality was confirmed from GH to chemical oxygen demand discharge and ammonia nitrogen in the long run. Pal and Kumar (2017) examined the relationships between ES, GH, ENEC and TS for China and India for the period 1971 to 2012. Pal and Kumar (2017) found N shaped relationship between ES and GH for India and China. Wang and Ye (2017) examined the EKC hypothesis for the city level ES and investigated the relationship between ES and GH. Wang and Ye (2017) did not confirm the EKC relationship between ES and GHh for city level analysis . Wang and Ye (2017) suggested that application of energy efficiency and carbon tax policies would help to reduce ES levels in China.

Sarkodie and Strezov (2018) examined the EKC relationship and environmental sustainability curve relationship (ESU) in Ghana, the USA, China and Australia for the period 1971 to 2013. Sarkodie and Strezov (2018) confirmed the EKC hypothesis for China and Australia but did not confirm for the USA and Ghana. ESU was examined with the relationship between biocapacity (hectares per person) and GH, biocapacity and ENEC, and biocapacity and emissions. Sarkodie and Strezov (2018) confirmed ESU in Australia and the USA. Dong et al. (2018) examined the relationship between ES, GH, fossil fuel consumption, nuclear ENEC and renewable ENEC for the period 1993 to 2016. Dong et al. (2018) confirmed the EKC hypothesis in China. Xu (2018) examined the relationship between sulfur dioxide emissions (SO2), GH and FIN in China for the period 1985 to 2015 for a panel data of 29 Chinese provinces. The EKC hypothesis for SO2 is only confirmed at 5 provinces out of 29 provinces. Du et al. (2018) examined the EKC hypothesis for a panel of 27 capital cities in China for the period 2001 to 2015. Du et al. (2018) found an N shaped relationship between haze pollution and GH. Hao et al. (2018) examined the EKC hypothesis between environmental quality and GH for a panel of 30 Chinese provinces for the period 2006 to 2015. Hao et al. (2018) used environmental quality index which was constructed upon eight environmental factors. Hao et al. (2018) did not confirm the EKC hypothesis in China but confirmed an N shaped relationship between environmental quality and GH.

He and Lin (2019) examined the relationships between ES, GH and energy intensity for a panel of 30 Chinese provinces for the period 2003 to 2017. He and Lin (2019) confirmed the EKC relationship between GH and ES. He and Lin (2019) also confirmed the effect of GH on ES is non-linear. Jiang et al. (2019) performed decoupling analysis and the EKC hypothesis analysis between ES and GH for Guangdong for the period 1995 to 2014. Jiang et al. (2019) confirmed expansive weak decoupling between ES and GH, and confirmed the EKC relationship between ES and GH for Guangdong. Wang and He (2019) examined the relationship between ES and GH for a panel of 30 Chinese provinces for the period 1995 to 2013 by spatial data analysis. Wang and He (2019) found an N shaped relationship between ES and GH.

Sarkodie et al. (2020) examined the EKC hypothesis in China for ES and ecological footprint for the period 1961 to 2016. Sarkodie et al. (2020) confirmed the EKC relationship between ES and GH, and ES and ecological footprint in China. Lahiani (2020) examined the relationship between ES, financial development (FID), GH and ENEC for China for the period 1977 to 2013. Lahiani (2020) confirmed that there was asymmetric relationship between ES and FID, and increase in FID resulted in reduction of ES.

Further literature for Australia, Salahuddin and Khan (2013) investigated the EKC hypothesis between the variables of GDP, ES and ENEC for the period between 1965 and 2007. Salahuddin and Khan (2013) did not confirm the long run relationship and the EKC hypothesis between the variables by Johansen cointegration tests. Salahuddin and Khan (2013) did not confirm causal relationship between ES and GDP, and confirmed bi-directional causal relationship between GDP and ENEC.

Further literature for studies that investigate the EKC hypothesis, Beşe and Kalayci (2019) examined the EKC hypothesis for Denmark, Spain and UK, and did not confirm the EKC hypothesis for these countries for the period 1960 to 2014. Solarin et al. (2017) examined the relationship between ES, GH, UBN and hydroelectricity consumption (HCS) for India and China for the period 1965 to 2013. Solarin et al. (2017) confirmed the EKC hypothesis for China and India. Solarin et al. (2017) also confirmed the causal relationship from HCS to ES in the long run, the causal relationship from GH to HCS, the causal relationship from HCS to GH, the causal relationship from UBN to ES and the causal relationship from emissions to UBN for China and India. Beşe and Kalayci (2019b) investigated the EKC hypothesis for Egypt, Kenya and Turkey for the period 1971 to 2014 by Johansen cointegration model. Beşe and Kalayci (2019b) did not find any evidence for the EKC hypothesis in these countries. Ng et al. (2020) examined the EKC hypothesis for 76 countries for the period 1971 to 2014. Ng et al. (2020) confirmed the EKC relationship between GH and ES for Australia, Uruguay, China, Turkey, Congo Democratic Republic, Myanmar, Costa Rica, Korea, Gabon, India and Hong Kong.

MATERIALS AND METHODS

Augmented Dickey and Fuller (1981) unit root test methodology is used to determine the stationary levels of variables which are GDP, GP, ENEC and CS. GDP, GP and CS are stationary at first difference for Australia, and GDP, GP, CS and ENEC are stationary at first difference for China (see Table 1 and Table 2).

Cointegration analysis for the study is carried out by ARDL bounds test by Pesaran et. al. (2001). ARDL bounds test is used to determine the symmetric relationships between the variables. In this study, ARDL bounds test is used to examine the symmetric relationships between GDP, GP, CS and ENEC for China, and between GDP, GP and CS for Australia. ARDL methodology is a commonly used methodology in the EKC literature according to Shahbaz and Sinha (2019).

ARDL-ECM (error correction model) is applied to calculate short run and long run coefficients of the variables after cointegration is found by ARDL bounds test between variables.

The stability of the models is examined by Breusch Godfrey Serial Correlation Test (B Test), Breusch Pagan Godfrey Heteroskedasticity Test (BG Test), CUSUM test (C Test), normality test, Ramsey Reset test (R Test) and CUSUM of squares test (C squares Test).

Two models are used in the study. Both models are the reduced model of EKC model in the literature. The variables are CS (coal consumption in thousand metric tons), GDP (in constant 2010 $US), GP and ENEC (kg of oil equivalent per capita) in this study. For China, the relationship between CS, GDP, GP and ENEC is examined. For Australia, the relationship between CS, GDP and GP is examined. Two models that are used in the study are as below. First model is for China, and second model is for Australia. $\boldsymbol{m_0}$, $\boldsymbol{m_1}$, $\boldsymbol{m_2}$ and $\boldsymbol{m_3}$ are estimated parameters for China, and $\boldsymbol{m_0}$, $\boldsymbol{m_1}$ and $\boldsymbol{m_2}$ are estimated parameters for Australia. $\boldsymbol{e_t}$ is error term and t is time index for China and Australia. Time period of the analysis is between 1980 and 2014 for China and is between 1980 and 2016 for Australia. Time period is determined according to the availability of the data from data sources. Data for coal consumption is obtained from US energy information administration website. Data for GDP and ENEC is obtained from World Bank's website.

$$\ln(\boldsymbol{CS})_t = \boldsymbol{m_0} + \boldsymbol{m_1}\ln(\boldsymbol{GDP})_t + \boldsymbol{m_2}\ln(\boldsymbol{GDP})_t^{\ 2} + \boldsymbol{m_3}\ln(\boldsymbol{ENEC})_t + \boldsymbol{e_t} \quad (1)$$

$$\ln(\boldsymbol{CS})_t = \boldsymbol{m_0} + \boldsymbol{m_1}\ln(\boldsymbol{GDP})_t + \boldsymbol{h_2}\ln(\boldsymbol{GDP})_t^{\ 2} + \boldsymbol{e_t} \quad (2)$$

For first model, ARDL model is as below.

$$\Delta LnCS_t = U_0 + U_1\, LnCS_{t-1} + U_2\, LnGDP_{t-1} + U_3\, LnGDP_{t-1}{}^2 + U_4\, LnENEC_{t-1} + \textstyle\sum_{i=1}^{e} U_{5i}\, LnCS_{t-i} + \sum_{i=0}^{d} U_{6i}\, LnGDP_{t-i} + \sum_{i=0}^{p} U_{7i}\, LnGDP_{t-1}{}^2 + \sum_{i=0}^{w} U_{8i}\, LnENEC_{t-i} + \mu_t \quad (3)$$

Long run coefficients are shown by $U_1, U_2, U_3 and U_4$. Short run coefficients are shown by $U_5, U_6, U_7 and U_8$. White noise residuals are shown by μ_t.

- Hypothesis of no cointegration is $H_0 = U_1 = U_2 = U_3 = U_4 = 0$.
- Hypothesis of cointegration is $H_1 = U_1 \neq U_2 \neq U_3 \neq U_4 \neq 0$.

Long run coefficients of first model is calculated as below after cointegration between the variables is verified.

$$LnCS_t = A_0 + + \textstyle\sum_{i=1}^{e} A_{1\,i} LnCS_{t-i} + \sum_{i=0}^{d} A_{2\,i} LnGDP_{t-i} + \sum_{i=0}^{p} A_{3i}\, LnGDP_{t-i}{}^2 + \sum_{i=0}^{w} A_{4\,i} LnENEC_{t-i} + \mu_t \quad (4)$$

Short run coefficients of first model is calculated as below after cointegration between the variables is verified.

$$LnCS_t = D_0 + \sum_{i=1}^{e} D_{1\,i} \Delta LnCS_{t-i} + \sum_{i=0}^{d} D_{2i}\, \Delta LnGDP_{t-i} + \sum_{i=0}^{p} D_{3i}\, \Delta LnGDP_{t-i}{}^2 + \sum_{i=0}^{w} D_{4i}\, \Delta LnENEC_{t-i} + nECT_{t-1} + \mu_t \quad (5)$$

Error correction model of first ARDL model is calculated as below after cointegration between the variables is verified.

$$ECT_t = LnCS_t - \sum_{i=1}^{e} R_{1\,i} \Delta LnCS_{t-i} - \sum_{i=0}^{d} R_{2i}\, \Delta LnGDP_{t-i} - \sum_{i=0}^{p} R_{3i}\, \Delta LnGDP_{t-i}{}^2 - \sum_{i=0}^{w} R_{4i}\, \Delta LnENEC_{t-i} \quad (6)$$

For second model, ARDL model is as below.

$$\Delta LnCS_t = U_0 + U_1\, LnCS_{t-1} + U_2\, LnGDP_{t-1} + U_3\, LnGDP_{t-1}{}^2 + \sum_{i=1}^{e} U_{4i}\, LnCS_{t-i} + \sum_{i=0}^{d} U_{5i}\, LnGDP_{t-i} + \sum_{i=0}^{p} U_{6i}\, LnGDP_{t-1}{}^2 + \mu_t \quad (7)$$

Long run coefficients are shown by $U_1, U_2\, and\, U_3$. Short run coefficients are shown by $U_4, U_5, and\, U_6$. White noise residuals are shown by μ_t.

- Hypothesis of no cointegration is $H_0 = U_1 = U_2 = U_3 = 0$.
- Hypothesis of cointegration is $H_1 = U_1 \neq U_2 \neq U_3 \neq 0$.

Long run coefficients of second model is calculated as below after cointegration between the variables is verified.

$$LnCS_t = A_0 + \sum_{i=1}^{e} A_{1\,i} LnCS_{t-i} + \sum_{i=0}^{d} A_{2\,i} LnGDP_{t-i} + \sum_{i=0}^{p} A_{3i}\, LnGDP_{t-i}{}^2 + \mu_t \quad (8)$$

Short run coefficients of second model is calculated as below after cointegration between the variables is verified.

$$LnCS_t = D_0 + \sum_{i=1}^{e} D_{1\,i} \Delta LnCS_{t-i} + \sum_{i=0}^{d} D_{2i}\, \Delta LnGDP_{t-i} + \sum_{i=0}^{p} D_{3i}\, \Delta LnGDP_{t-i}{}^2 + nECT_{t-1} + \mu_t \quad (9)$$

Error correction model of second ARDL model is calculated as below after cointegration between the variables is verified.

$$ECT_t = LnCS_t - \sum_{i=1}^{e} R_{1\,i} \Delta LnCS_{t-i} - \sum_{i=0}^{d} R_{2i}\, \Delta LnGDP_{t-i} - \sum_{i=0}^{p} R_{3i}\, \Delta LnGDP_{t-i}{}^2 \quad (10)$$

TABLE 1
STATIONARY LEVELS FOR CHINA

Variable	Level	First Difference
CC	0.740734	-4.371451 (1%)
GDP	0.904630	-4.320487 (1%)
GP	1.445236	-3.563160 (5%)
ENC	0.207433	-3.102568 (5%)

Notes: The statistical significance of results are shown in parentheses.

TABLE 2
STATIONARY LEVELS FOR AUSTRALIA

Variable	Level	First Difference
CC	-2.352509	-7.186485(1%)
GDP	-0.830792	-4.281287(1%)
GP	-0.761263	-4.220965(1%)

Notes: The statistical significance of results are shown in parentheses.

RESULTS

CS, GDP, GP and ENEC NEXUS – ARDL Model for China

The relationship between CS, GDP, GP and ENEC is examined by ARDL model. According to ARDL bounds test results, there is cointegration and long run relationship between CS, GDP, GP and ENEC since F-statistics bounds test result is 4.737007 which is higher than 4.35 which is I1 bound value of 5%. After cointegration is found, ARDL-ECM is applied to find the coefficients of the variables (see Table 3). The coefficient of CointEq(-1) is negative and significant at 5%. This shows there is long run relationship between variables. The long run coefficients of LNGDP, LNGP and LNENEC are significant at 5%. Also, the coefficient of LNGDP is positive and the coefficient of LNGP is negative. This result confirms coal consumption EKC for China. Stability test results of the model is given in Table 4. C and C Squares test results are given in Figure 1 and Figure 2 respectively.

TABLE 3
ARDL-ECM TEST RESULTS FOR CHINA

	Variable	Coef.	Standard Error	t-Stat.	Probability
Short-run Coefficients	D(LNGDP)	2.579127	1.536386	1.678697	0.1052
	D(LNGP)	-0.202243	0.115005	-1.758565	0.0904
	D(LNENEC)	1.727421	0.131236	13.162718	0.0000
	CointEq(-1)	-0.624760	0.151159	-4.133123	0.0003
Long-run Coefficients	LNGDP	0.860133	0.289061	2.975609	0.0062
	LNGP	-0.056637	0.022872	-2.476277	0.0201
	LNENEC	1.379005	0.131555	10.482362	0.0000
	C	1.490930	1.713012	0.870356	0.3921

TABLE 4
THE STABILITY TEST RESULTS FOR CHINA

	F-statistic	Jarque-Bera
R Test	2.848766 (0.1039)	-
BG Test	0.455451 (0.8573)	-
B Test	0.195552 (0.6621)	-
Normality Test	-	1.999416 (0.367987)

Notes: The probability of results are shown in parentheses.

FIGURE 1
C TEST FOR CHINA

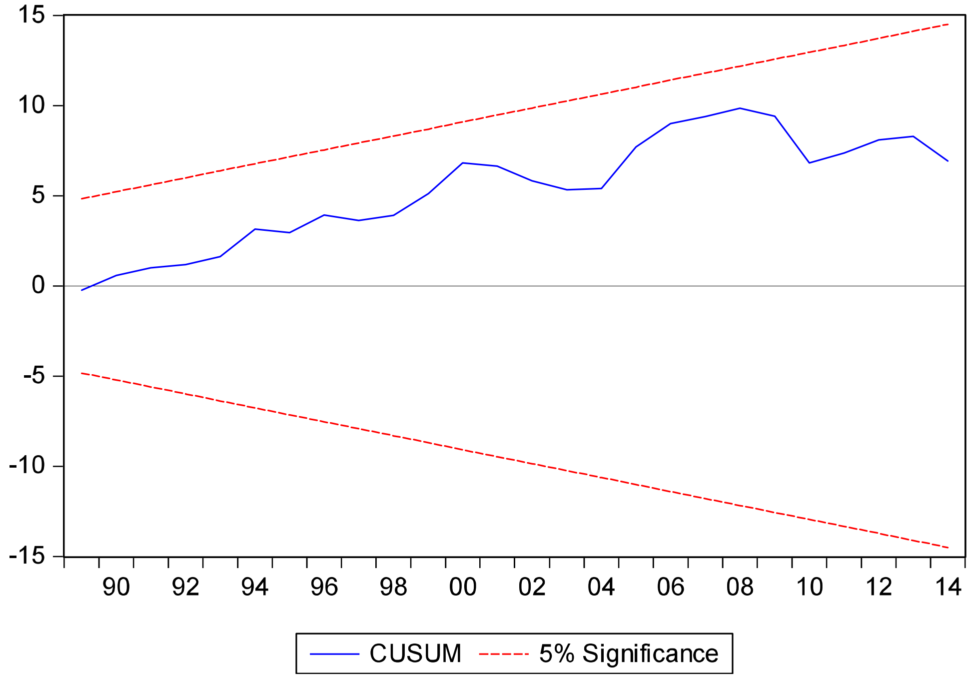
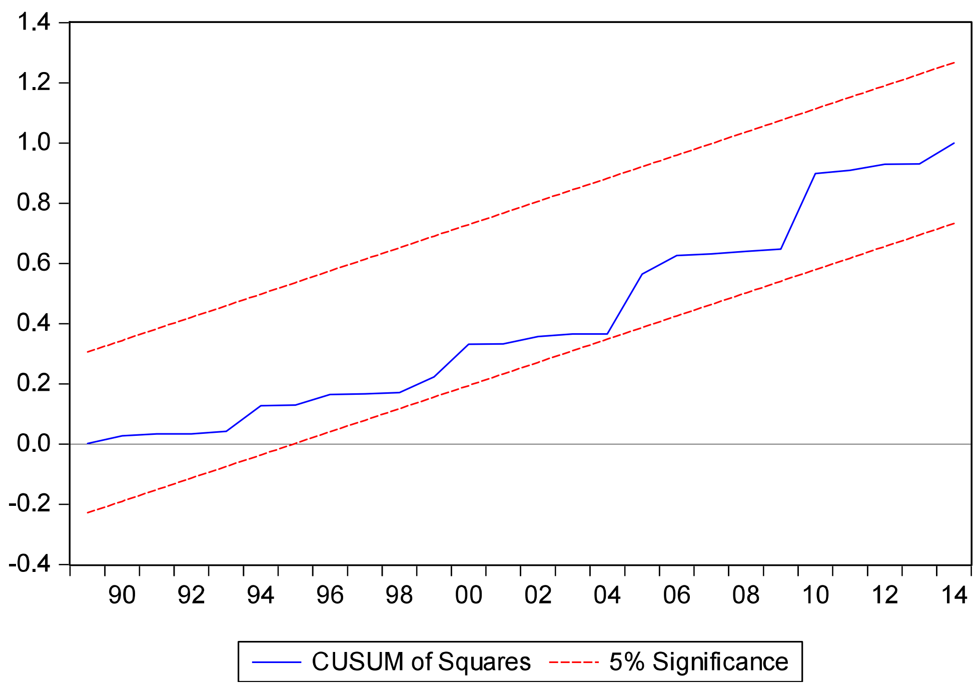


FIGURE 2
C SQUARES TEST FOR CHINA



CS, GDP and GP NEXUS – ARDL Model for Australia

The relationship between CS, GDP and GP is examined by ARDL model for Australia. ARDL bounds test is applied to analyze the cointegration between variables. According to bounds test results, there is cointegration between variables since F-statistics bounds test result is 5.052469 which is higher than 4.85 which is I1 bound value of 5%. ARDL-ECM is applied to calculate the long run and short run coefficients of the variables after cointegration is found between the variables (see Table 5). The coefficient of CointEq(-1) is negative and significant at 5% which shows that there is long run relationship between the variables. The coefficient of GDP is positive and significant at 5%, and the coefficient of GDP2 is negative and significant at 5%. This result confirms coal consumption EKC for Australia. Stability test results of the model is given in Table 6. C Test and C Squares Test results are given in Figure 3 and Figure 4 respectively.

TABLE 5
ARDL-ECM TEST RESULTS FOR AUSTRALIA

	Variable	Coef.	Standard Error	t-Stat.	Probability
Short-run Coefficients	D(GDP)	2.767263	0.940153	2.943417	0.0060
	D(GP)	-0.132191	0.044886	-2.945050	0.0060
	CointEq(-1)	-0.342809	0.106128	-3.230160	0.0029
Long-run Coefficients	GDP	8.072309	1.808034	4.464688	0.0001
	GP	-0.385610	0.088699	-4.347403	0.0001
	C	-38.296592	9.188446	-4.167907	0.0002

TABLE 6
THE STABILITY TEST RESULTS FOR AUSTRALIA

	F-statistic	Jarque-Bera
R Test	2.215318 (0.1468)	-
BG Test	1.867364 (0.1550)	-
B Test	2.361122 (0.1345)	-
Normality Test	-	0.976463 (0.613711)

Notes: The probability of results are shown in parentheses.

FIGURE 3
C TEST FOR AUSTRALIA

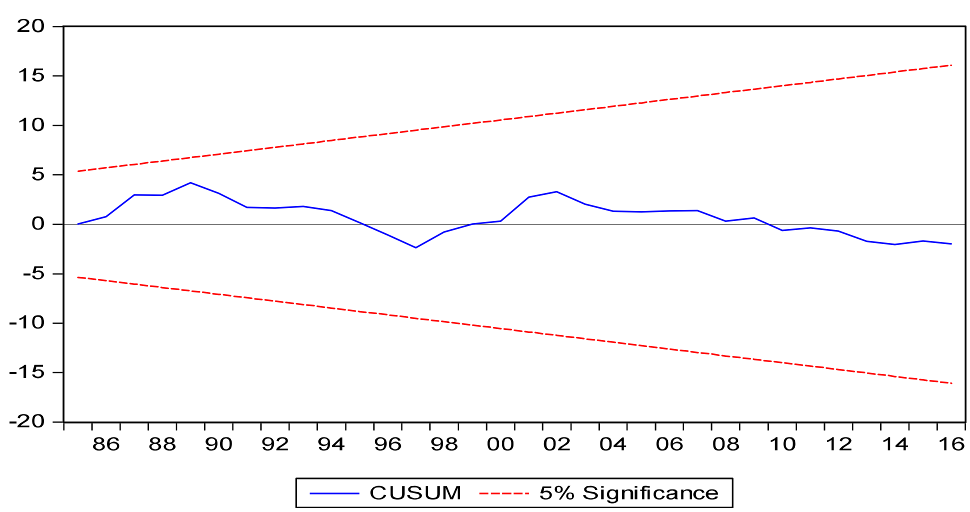
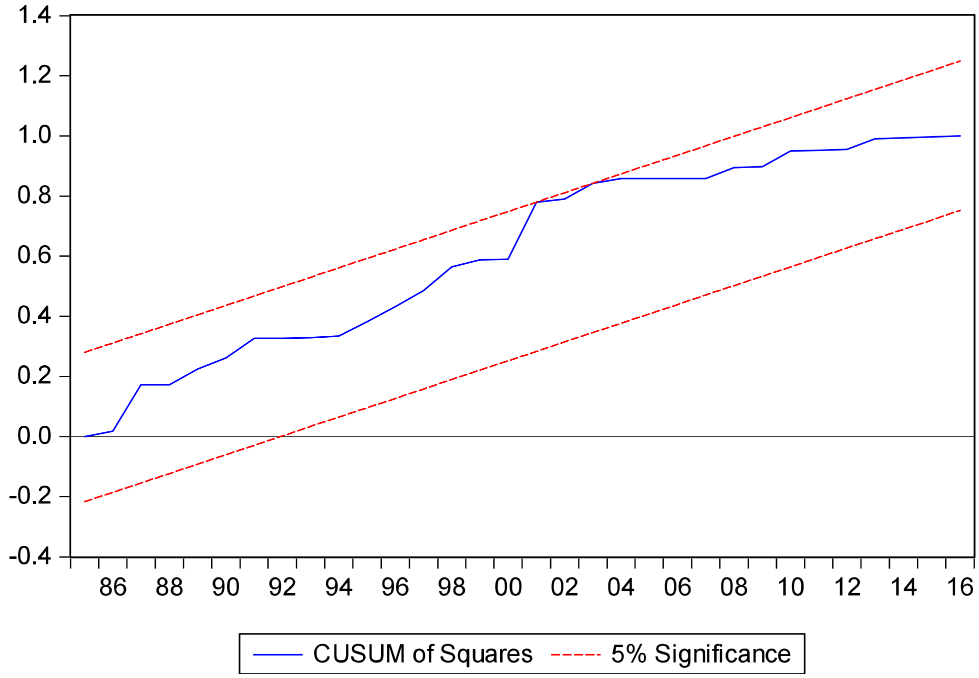


FIGURE 4
C SQUARES TEST FOR AUSTRALIA



DISCUSSION

Symmetric relationships between CS, GDP and GP are analyzed for Australia for the period between 1980 and 2016. As being the first in the literature, CS EKC is analyzed for Australia which is one of the most dependent countries on CS for energy demands in the world. CS EKC is confirmed for Australia which indicates a success for Australia for the efforts of reduction of coal consumption for energy demands. Increase of establishment of wind and solar energy systems bring the less usage of coal in Australia. Also, current coal operating plants are closing because operating costs of coal plants cannot compete with renewable energy plants, and the unwillingness of the companies and creditors to invest in coal plants and legislations that support alternative energy systems. Coal plants also cannot compete with market economic systems of renewable energy systems, so coal plants already started to close and by 2050 almost all of the coal plants in Australia are expected to be shut down by not building new coal plants and not extending the operating lives of the current ones.

Symmetric relationships between CS, GDP, GP and ENEC are analyzed for China for the period between 1980 and 2014. As being the first in the literature for time series studies, coal consumption EKC is confirmed for China. China is the leader in coal consumption in the world and is heavily depended on coal consumption for energy demands. China established policies to replace coal consumption with gas, nuclear energy and renewable energy systems. Besides structural changes in the energy market, shifting from manufacturing-based market to service-based market also contribute to the decline of CS in China. Slowing economic growth also contributes to the decline of CS in China. As utilization rates of coal plants in China are decreasing, similar to the scenario in Australia has a chance to happen in China as well. Decreasing prices of renewable energy systems and decreasing financial support for coal plants might increase the closing rates of coal plants in China as expected to happen in Australia. The power generation from coal fired power plants is on the decline but further legislations and financial support are needed to maintain the decline of CS for energy generation in China. China is also investing heavily for hydro energy systems. Besides decreasing the utilization of current coal plants, carbon capture utilization and storage technologies should be used more efficient to combat with climate change. Digitalization of energy transition of renewables will help China to increase its renewable energy share in its energy supply. Energy efficiency standards for coal need to be updated continuously. China should complete its power sector reforms, implement carbon emissions trading, increase energy efficiency standards and apply new carbon pricing policies for iron and steel sectors.

CONCLUSION

In the study, CS EKC is investigated for Australia and China. The main findings of the study are coal consumption EKC is confirmed for Australia and China for the period between 1980 and 2016, and 1980 and 2014 respectively. Since China is the top country for CS and Australia is among the top 10 countries which are heavily dependent on CS for energy demands, the results of the study carry importance to understand current policies. First is that China's policies are successful for reduction of CS and might be sustainable for the foreseeable future. Second is that current market dynamics in Australia are in line with supporting CS reduction. These market dynamics might help current CS reduction policies to end CS in Australia in the foreseeable future.

The time periods analyzed which are from 1980 to 2014 for China, and from 1980 to 2016 for Australia, are the limits of the study. The other limits of the study are China and Australia which are the countries of the study.

For future research directions, nonlinear cointegration models may be used for further studies in Australia and China. Since studies in the context of CS EKC are very limited, the other developing and developed countries should be examined for CS EKC hypothesis.

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