Does Energy Consumption Impact The Environment? Evidence from Australia Using the JJ Bayer-Hanck Cointegration Technique and the Autoregressive Distributed Lag Test

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ABSTRACT

This study investigates the impact of energy consumption on environmental pollution in Australia using time series data from 1971 to 2015. Gross domestic product (GDP), total population (TP), and financial development (FD) are included as control variables. In achieving the objective, this study employ unit root test, cointegration test, and autoregressive distributed lag (ARDL) long-run and short-run methodology to examine the nexus between energy consumption, carbon dioxide (CO₂) emissions, Gross Domestic Product (GDP), total population (TP), and financial development (FD). The results of ARDL long-run and short-run reveals that energy consumption is the most substantial determinant that impacts environmental pollution. However, the empirical findings suggest that GDP, TP, and FD are insignificant in contributing to an increase in CO₂ emissions. Thus, this study concludes that policymakers and attention on energy consumption trend and pattern is crucial for effective policies on environmental pollution.

Keywords: Electricity Consumption, Carbon Dioxide Emissions, GDP, Bayer-Hanck Cointegration Technique, Autoregressive Distributed Lag

JEL Classifications: O13, Q43, Q54, Q56

1. INTRODUCTION

Energy use was the part of human civilization and now being QHFHVVLWURPGRDWRGDLIHWFRRPPhuflDOXVHOSDUROHDOGLVLQLQFHUHDVQLWUHQQ(QHJ)(QDVVQ)
the economic development of a country and economic growth is RIIXGDPHDWOVLJLQFDFHJRUKHGDYDFHPHQW.
In 2018, worldwide energy utilization expanded at almost double the normal pace of development since 2010, driven by a vigorous global economy (IEA 2019). Globally, the role of energy is assertive and thus undeniable economic integration as it is essential for producing goods and services.

Many researchers have focused on the economic and environmental impact of energy consumption, which has become an increasingly popular issue of debate. Global energy demand has increased since World War II and is expected to increase by more than one-third by 2035 (Toka et al., 2014). Unfortunately, although industrialization is related to economic development, it has caused higher energy consumption which, in industrialized countries, gives rise to more carbon dioxide (CO₂) emissions (Hossain, 2011). Thus, the worldwide carbon emissions from carbon emission has been, perhaps, the main natural issues of this century because of the higher energy utilization.

Indicated by the International Energy Agency, worldwide energy-related carbon emissions (CO₂) increased by 1.7% in 2018, reaching a high of 33.1Gt of CO₂ (IEA 2019). Moreover, environmental standards have been continuously degraded by increased energy consumption (Dar and Asif, 2018) and therefore, currently, the world is confronting a mounting challenge like air pollution because of environmental degradation and environmental changes throughout the world (Li et al., 2012). On the other hand, the increasing trend of temperature due to climate change eventually increases because of the energy consumption for all sectors; including domestic and industrial (Saboori and Sulaiman, 2013).
Population growth is another important aspect that increases energy consumption (Khan et al., 2020). Even though, population growth influences the economic aspects of a country, it impacts the natural environment by utilizing more energy for domestic and business purposes (Zaharia et al., 2019). Population growth will drive higher energy demand and can therefore have negative consequences for the climate. Additionally, the improvement in the financial sector of a nation assumes a significant role in achieving financial growth (Sadorsky, 2010). It is significant because it increases the economic growth of a nation’s monetary framework. However, financial development can also influence people to purchase goods with high energy use like cars, air conditioners, refrigerators, or washing machines leading to higher energy consumption (IEA, 2019).

The interaction between changing climate, population, and economic growth increases energy consumption and may have an adverse role in the natural environment.

The amount of CO₂ emissions from energy consumption has rapidly increased in Australia in recent years. Australia is the world’s twentieth largest consumer of energy and fifteenth in terms of per capita energy use (Geoscience Australia, 2020). Australia’s primary energy consumption is dominated by coal (around 40%), oil (34%), and gas (22%). Coal produces approximately 75% of the energy for electricity generation, followed by gas (16%), hydro (5%), and wind (2%) (Geoscience Australia, 2020). Figure 1 shows the trend of energy consumption, carbon emissions, and GDP growth from 1971 through 2015.

Energy consumption has increased by nearly 20% since the 1970s increasing from 4405.7 to 5483.82 oil equivalent per capita. Similarly, carbon emissions have increased by nearly 15% from 13.06 to 15.34 metric tons per capita. Likewise, GDP has doubled, with 27954.01 to 55079.90 per capita (constant 2010 US$).

The projected per capita energy consumption in Australia, Table 1, shows an increasing trend until 2011 with from 4605.2 to 5745.23 kg of equivalent per capita. However, there is some downward trends were apparent in the years 2013, 2014, and 2015 with 16.10, 15.40, and 15.34 respectively. And there has been seen a steady rise since the 1970s in economic growth (GDP per capita).

A small number of investigations have been carried out on energy consumption and its impact on the environment (Dar and Asif, 2017; Farhani and Ben Rejeb, 2012; Hasnisah, et al., 2019; Khan et al., 2020). However, to our knowledge, there is no studies focusing on Australian evidence with the latest large-scale time-series data. Also, to the best of our knowledge, population has not previously been considered as an exploratory variable for energy consumption. Thus, this study employs more explanatory variables compared to previous studies (Salahuddin and Khan, 2013).

The main objective of this study is to examine the impact of energy consumption on the environment in the Australian context using the time series data for 45 years from 1971-2015, using...
cointegration and the autoregressive distributed lag (ARDL) approach. The organization of this study is as follows: Section 2 shows the past work, i.e., the literature review; Section 3 describes the data and the methodology. Section 4 demonstrates the empirical results and section 5 presents the conclusion.

2. LITERATURE REVIEW

Energy consumption increases carbon dioxide (CO₂) emissions. In the last decade, numerous studies have examined the causal relationships between energy consumption, carbon emissions, and economic growth. In the case of Australia, the literature on energy economics has been relatively scarce until recently.

A large number of empirical studies have analysed the causality between energy consumption, carbon emissions, and economic growth. Farhani and Rejeb (2012) investigated the relationship between EC, GDP, and CO₂ from 1973-2008 in 15 MENA countries. They used panel unit root tests, cointegration methods, DQGF D X VD OL W W H V W W R Q G W K H D FX VD O LW E H W ZH H1NH QGLQ were that there is short-run causality from energy consumption and to CO₂ emissions and results indicate that an increase in energy consumption may lead to an increase in CO₂ emissions.

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In their empirical investigation, they found that 1% increase in per capita energy use will lead to a 0.843% increase in energy consumption globally, 0.993% in the European and North American regions, 0.744% in Latin America and the Caribbean, DQGQDDOLQWKHOLGGOHDTVWHQ1RWKSULFDQQG XEFSAHAR regions. They concluded through the EKC hypothesis that per capita energy use has a positive impact on carbon emissions and follows the U-shaped pattern.

Focusing on industrialized countries, Hussain (2011) investigated the relationship between carbon emissions, energy consumption, trade openness, and urbanization using the Johansen Fisher panel vector auto regression (PV AR) in 116 countries. He found that 1% increase in carbon emissions would decrease energy consumption by 0.07% globally. EC does not cause carbon emissions in the MENA region. Acheampong (2018), in another study, examined the dynamic causal relationship between economic growth, carbon emissions, and energy consumption using a panel vector auto regression (PV AR) in 116 countries. He found that 1% increase in carbon emissions would decrease energy consumption by 0.07% globally. EC does not cause carbon emissions in the MENA region. Acheampong (2018), in another study, examined the dynamic causal relationship between economic growth, carbon emissions, and energy consumption using a panel vector auto regression (PV AR) in 116 countries. He found that 1% increase in carbon emissions would decrease energy consumption by 0.07% globally. EC does not cause carbon emissions in the MENA region. Acheampong (2018), in another study, examined the dynamic causal relationship between economic growth, carbon emissions, and energy consumption using a panel vector auto regression (PV AR) in 116 countries. He found that 1% increase in carbon emissions would decrease energy consumption by 0.07% globally. EC does not cause carbon emissions in the MENA region.

On the other hand, increasing population is another contributor to energy consumption (Khan et al., 2020). According to Khan et al. (2020), an increase in the population increases high energy use and high CO₂ emissions. According to Khan et al. (2020), an increase in the population increases high energy use and high CO₂ emissions.

Numerous analysts have expanded their examination for energy use and carbon emissions. Shahbaz et al. (2016) investigated the relationship between carbon emissions, energy consumption, trade openness, and urbanization using the Johansen Fisher panel vector auto regression (PV AR) in 116 countries. They found that 1% increase in carbon emissions would decrease energy consumption by 0.07% globally. EC does not cause carbon emissions in the MENA region. Acheampong (2018), in another study, examined the dynamic causal relationship between economic growth, carbon emissions, and energy consumption using a panel vector auto regression (PV AR) in 116 countries. He found that 1% increase in carbon emissions would decrease energy consumption by 0.07% globally. EC does not cause carbon emissions in the MENA region.

There is increasing interest in testing the environmental Kuznets curve (EKC) hypothesis for environmental quality and economic growth. In a recent study (Hasniah et al., 2019) of 13 GHYHORSLOQIFRXQWULHLQVLDWKHVXGFRQUPHSH the inverted U-shape EKC hypothesis. The results from FMOLS and DOLS long-run estimates indicated that a 1% increase in energy use from electricity consumption contributed 38.7% and 36.49% of carbon emissions in the long-run for 13 A sia n countries. However, it failed to prove that renewable energy is capable of contributing positively to the environment and therefore it is LQVLJQLQDFQW1HYHUKHOHVVDQHFRQPHWLUFV of economic growth and energy use on carbon emissions in 58 countries from 1990 to 2012 was undertaken by Kais and Sami.
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(2017) explored the long-run dynamics of CO₂ emissions, globalization, tested as contributing factors over 1970-2012. The Cointegration and causality tests and impulse response function explained that a 1.35% increase in CO₂ emissions is associated with a 1% rise in energy consumption. In conclusion, increasing energy consumption and population growth has been shown to be stable.

In contrast, using the Johansen cointegration technique, VAR, and impulse response, Salahuddin and Khan (2013) suggest that there is no stable long-run relationship between economic growth, energy consumption, and impulse response. Salahuddin and Khan (2013) suggest that the linkages between CO₂ emissions, economic growth, and population growth along with the effects of pollution (proxy by CO₂ emissions) in Australia. Further, this study will investigate the long-run and short-run relationship between energy consumption and environmental pollution (proxy by CO₂ emissions) in Australia. With 45 years of data from 1971-2015 and employing the cointegration technique of Johansen and Juselius (JJ) and Bayer-Hanck (BH), this study will investigate the long-run relationship between energy consumption and CO₂ emissions.

3.1. Stationarity and unit root test

The statistical properties, i.e. stationary properties, should be revealed before undertaking the analysis of the data to ensure that the variables follow the correct model. The stationary levels for the time series analysis are determined by the Phillip Perron (PP) (Phillips and Perron, 1988) unit root tests. They test the null hypothesis: a series has a unit root against the alternative that there is stationarity. Hence, the PP test is considered an alternative as it allows an opportunity to control for higher-order serial correlation without using the Augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1979) and Phillips–Perron (PP) (Phillips and Perron, 1988) unit root tests. They test the null hypothesis: a series has a unit root (non-stationary) while the alternative is that there is stationarity.

The ADF test is mostly a non-robust test for the unit root. So, to be sure, an additional test for the unit root, the Phillip Perron (PP) test, is undertaken. The PP test is a non-parametric statistical method that takes care of serial correlation without using the ODDJHGGLuHUHQFHVRlWKHGSHSQGHQWYDLUDEOH*XMUDUDUO of the data over the period of 1971-2015. The dependent variable CO₂ emissions per capita is a proxy for environmental pollution and an independent variable is energy consumption (EC). The control variables are Gross Domestic Product (GDP) per capita (constant 2010 US $), Total Population (TP), and the Financial Development (FD) (% of GDP). The general form of the empirical equation is modelled as follows:

\[
\text{LnCO₂} = \beta_0 + \beta_1 \text{LnEC} + \beta_2 \text{LnGDP} + \beta_3 \text{LnTP} + \beta_4 \text{LnFD} + \epsilon_t
\]  

To get the direct elasticities of coefficients and to make the estimation process smooth we take the log of the variables are taken which helps to select suitable time series models derived from eq (2)

\[
\text{LnCO₂} = \beta_0 + \beta_1 \text{LnEC} + \beta_2 \text{LnGDP} + \beta_3 \text{LnTP} + \beta_4 \text{LnFD} + \epsilon_t
\]  

3.1.1. Zivot-Andrews unit root test

The ADF model tests unit root as follows

\[
\Delta y_t = \mu + \delta y_{t-1} + \beta_i + \sum_{i=1}^{k} d_i \Delta y_{t-i} + \epsilon_t
\]  

where, \( \mu \) is the intercept, \( \delta \) the drift, \( \beta_i \) the slope coefficients, \( d_i \) the lag operator, \( \epsilon_t \) the white noise disturbance. The ADF’s null hypothesis is that \( \delta = 0 \) against the alternative hypothesis of \( \delta \neq 0 \). If we do not reject the null, the series is non-stationary whereas rejection means the series is stationary.

PP model tests the unit root as follows

\[
\delta_t = \mu + \delta y_{t-1} + \beta_i + \epsilon_t
\]  

3.1.2. Zivot-Andrews unit root test

ADF test and PP test may provide biased and spurious results due to not having information about structural breakpoints that occurred in the series (Baum, 2003). Following Zivot-Andrews

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\[
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3.2. Zivot-Andrews unit root test

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(ZA) (Zivot and Andrew, 1992) structural break unit root test, we have applied the ZA unit root test prior for cointegration have been applied, stemming in the variables.

Zivot-Andrew method contains consistency of structural breaks inside series which is performed by running the following equations adapted from Ertugrul et al. (2016).

\[
\Delta y_t = c + c + \beta_t + dD_u_t + dD_t + \sum_{i=1}^{k} d_{j} \Delta Y_{t-i} + \epsilon_t \tag{7}
\]

Where DU is shift dummy variable showing shift occurred at each point break date and DT is trend shift dummy variables (Ertugrul et al., 2016). They can be identified as:

\[
DU_t = \begin{cases} 
1 & \text{if } t > TB \\
0 & \text{if } t < TB 
\end{cases} \quad \text{and} \quad DT_t = \begin{cases} 
1 & \text{if } t > TB \\
0 & \text{if } t < TB 
\end{cases} \tag{8}
\]

The null hypothesis of unit root break date is \( c = 0 \) which indicates that the series is not stationary with a drift not having information about structural breakpoint while \( c < 0 \) hypothesis implies that the variable is found to be trend-stationary with one unknown time break. It is necessary to choose a region where the endpoints of the sample period are excluded (Shahbaz et al., 2013).

### 3.2. Cointegration Analyses

The long-term relationship between energy consumption and the environment in this study is investigated by using cointegration approaches i.e. Johansen and Juselius (JJ) test and Bayer-Hanck (BH) cointegration test.

#### 3.2.1. JJ cointegration testing approach

Johansen and Juselius (1990) cointegration method is used to estimate the long-run relationship among the series. The Johansen and Juselius cointegration technique is constructed on trace and \( \lambda_{max} \) statistics. Trace statistics investigates the null hypothesis of \( r \) cointegrating relations against the alternative of \( N \) cointegrating relations and is computed as:

\[
\lambda_{trace} = N \sum_{i \geq r+1} \log(1-\lambda_i) \tag{8}
\]

Where \( N \) is the number of observations, is the ordered Eigen-value of matrices.

The maximum Eigen-value statistics tests the null hypothesis of \( r \) cointegrating relations against the

\[
\lambda_{max} = N \log(1-\lambda_{r+1}) \tag{9}
\]

Where \( N \) is the number of observations, is the ordered Eigen-value of matrices.

#### 3.2.2. Bayer-Hanck (BH) cointegration testing approach

The Bayer and Hanck (2013), cointegration tested blend various test statistics ranging from Engle and Granger (1987); Johansen (1991); Boswijk (1995) and Banerjee et al. (1998). The current study also used the BH cointegration test to assess possible cointegration between the environment and energy consumption.

Bayer and Hanck (2013) proposed a combination of the computed \( V \) cointegration tests Engle and Granger (1987); Johansen (1991); Boswijk (1995) and Banerjee et al. (1998) respectively. According to Bayer and Hanck (2013), the decision rule holds that where the calculated Fisher statistic is greater than the critical values, the null hypothesis of cointegration can be rejected.

### 3.3. Lag Length Test

The lag order selection results are based on the Akaike Information Criterion (AIC) which affords the best model. The AIC criteria for estimation is selected.

### 3.4. Long-run and Short-run Dynamics

A test for testing the stationarity properties of the series and various cointegration approaches, we applied ARDL testing to examine the long-run relationship among the variables stands as a single long-run relationship equation. If one cointegrating vector was estimated, the long-run relationship and short-run dynamics (i.e. traditional ARDL) of the cointegrating vector was reparametrized into the Error Correction Model (ECM). The reparametrized result gave a long-run relationship model, the vector error correction term could be estimated.

If the cointegration was established among the variables, the run

\[
\begin{align*}
&n\text{CO}_2 = \beta_0 + \beta_1 \text{lnCO}_2 + \beta_2 \text{lnEC}_2 + \beta_3 \text{lnGDP}_2 - 1 \\
&\quad + \beta_4 \text{lnTP}_2 - 1 + \beta_5 \text{lnFD}_2 - 1 + \sum_{i=1}^{q} \beta_i \text{lnCO}_2 + \sum_{j=1}^{T} \delta_i \text{lnEC}_2 - j \\\n&\quad + \sum_{k=1}^{q} \mu_k \text{lnGDP}_2 - k + \sum_{n=1}^{q} \mu_n \text{lnFD}_2 - n + \epsilon_t
\end{align*}
\]

in the following equations.
4. EMPIRICAL RESULTS AND ANALYSIS

The empirical results were obtained from STATA 14.2 software. The descriptive statistics between the variables were measured in natural logarithms and were found to be normally distributed (See Table 2) within a reasonable range. This would allow the \( \Delta \) test, which shows the speed of adjustment of the variables toward long-run convergence.

4.1. ADF & PP Unit Root and ZA Structural Break Test

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Moreover, we have applied Zivot and Andrews (1992) structural break unit root test was applied to examine the status of the unit-root test and the presence of a structural break in our series.

EMPIRICAL RESULTS AND ANALYSIS

The results of the unit root test are reported in Table 3. We can see that the ADF and PP tests indicate that the variables are stationary DW\( \Delta \)GLUHUFHVLH,

Moreover, we have applied Zivot and Andrews (1992) structural break unit root test was applied to examine the status of the unit-root test and the presence of a structural break in our series.

These results in Table 4 suggest that we can reject the null of unit URRW DWD WJQL FQOHY HDLQFH WKHFDOFXODWHG\( \Delta \) value at the level is below the critical values, the variables are non-stationary. The null hypothesis can be rejected when the critical value of this test is below the test statistic value.

<table>
<thead>
<tr>
<th>Period</th>
<th>Mean 2.7425</th>
<th>Median 2.7470</th>
<th>Maximum 2.9014</th>
<th>Minimum 2.4689</th>
<th>Standard Deviation 0.8384</th>
</tr>
</thead>
</table>

Table 2: The descriptive statistics

<table>
<thead>
<tr>
<th>Descriptive</th>
<th>lnCO₂</th>
<th>lnEC</th>
<th>lnGDP</th>
<th>lnTP</th>
<th>lnFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>2.7425</td>
<td>8.5293</td>
<td>10.5424</td>
<td>16.6808</td>
<td>4.0740</td>
</tr>
<tr>
<td>Median</td>
<td>2.7470</td>
<td>8.5350</td>
<td>10.4938</td>
<td>16.6872</td>
<td>4.1495</td>
</tr>
<tr>
<td>Maximum</td>
<td>2.9014</td>
<td>8.6936</td>
<td>10.9165</td>
<td>16.9859</td>
<td>4.9154</td>
</tr>
<tr>
<td>Minimum</td>
<td>2.4689</td>
<td>8.2914</td>
<td>10.1759</td>
<td>16.3756</td>
<td>3.1634</td>
</tr>
<tr>
<td>St. Deviation</td>
<td>0.1151</td>
<td>0.1080</td>
<td>0.2429</td>
<td>0.1752</td>
<td>0.6036</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.8384</td>
<td>-0.3660</td>
<td>0.1933</td>
<td>-0.0026</td>
<td>-0.1445</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>2.9239</td>
<td>2.0997</td>
<td>1.6004</td>
<td>1.8855</td>
<td>1.4821</td>
</tr>
<tr>
<td>Variance</td>
<td>0.0133</td>
<td>0.0116</td>
<td>0.0590</td>
<td>0.0307</td>
<td>0.3643</td>
</tr>
<tr>
<td>Observations</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
</tr>
</tbody>
</table>

4.3. Bayer –Hanck Cointegration Test

The third approach of cointegration is Bayer and Hanck cointegration test. To enhance the power of the cointegration, this study uses the cointegration test suggested by Bayer and Hanck (2013) to check the presence of cointegrating relationships among the series of variables. J(J) and J(j) cointegration has a null hypothesis that if the trace and max value are greater than 5% critical value, we reject the null hypothesis of no cointegration. This test also supported the JJ and ARDL cointegration test which also revealed the presence of a long-run relationship between the study variables.

4.4. Lag Length Selection

The ARDL bound test of cointegration can now be co-opted to explore the cointegration between the variables. Primarily we selected the Akaike Information Criterion (AIC) to estimate the lag length of considered variables to examine the long-run relationship between the series. The outcome of the lag length is given in Table 7:
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**Table 3: Unit root test**

<table>
<thead>
<tr>
<th>Tests</th>
<th>lnCO₂</th>
<th>lnEC</th>
<th>lnGDP</th>
<th>lnTP</th>
<th>lnFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At level I (0)</td>
<td>-2.659</td>
<td>-2.482</td>
<td>-0.075</td>
<td>0.310</td>
<td>-0.569</td>
</tr>
<tr>
<td>$\Delta \ln V W G L u H U Q H F H$, Phillips and Perron</td>
<td>-4.005***</td>
<td>-4.561***</td>
<td>-4.728***</td>
<td>-3.796***</td>
<td>-3.870***</td>
</tr>
<tr>
<td>At level I (0)</td>
<td>-2.611</td>
<td>-2.391</td>
<td>-0.093</td>
<td>-0.079</td>
<td>-0.591</td>
</tr>
</tbody>
</table>

Lag order shown in parenthesis. Critical values: 1%: –5.34, 5%: –4.80, 10%: –4.58

**Table 4: Zivot-Andrews structural break trended unit root test**

<table>
<thead>
<tr>
<th>Variable</th>
<th>At level</th>
<th>At first difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>lnCO₂</td>
<td>-1.697</td>
<td>1978</td>
</tr>
<tr>
<td>lnEC</td>
<td>-2.588</td>
<td>2008</td>
</tr>
<tr>
<td>lnGDP</td>
<td>-3.552</td>
<td>1997</td>
</tr>
<tr>
<td>lnTP</td>
<td>-2.735</td>
<td>1997</td>
</tr>
<tr>
<td>lnFD</td>
<td>-3.379</td>
<td>1988</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>T-statistics</th>
<th>Time break</th>
<th>T-statistics</th>
<th>Time break</th>
</tr>
</thead>
<tbody>
<tr>
<td>lnCO₂</td>
<td>-7.445 (0)***</td>
<td>1993</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lnEC</td>
<td>-8.265 (0)***</td>
<td>1989</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lnGDP</td>
<td>-6.402 (0)**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lnTP</td>
<td>-6.421 (0)***</td>
<td>2008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lnFD</td>
<td>-6.372 (0)***</td>
<td>1983</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lag order shown in parenthesis. Critical values: 1%: –5.34, 5%: –4.80, 10%: –4.58

4.6. Diagnostic Test Result

As presented in Table 8, we ran some diagnostic tests were ran to check the serial correlation, heteroscedasticity, and normality using the Breusch-Godfrey LM test for autocorrelation, the Breusch-Pagan / Cook-Weisberg test for heteroscedasticity, and the Jarque-Bera for normality. The Breusch-Godfrey LM test for autocorrelation showed no serial correlation, the Breusch-Pagan / Cook-Weisberg test for heteroscedasticity indicated no heteroscedasticity in the data and the Jarque-Bera test revealed that the residuals were normally distributed.

5. DISCUSSION

The short-run results reveal that the lag value energy consumption causes an increase in carbon emissions. The impact of energy consumption has a positive and significant impact on metric tons per capita CO₂ emissions. The impact of energy consumption on carbon dioxide is given in Table 9.

Once the JJ and BH cointegration approaches confirm the cointegration among the variables, the lag length of all variables were estimated using the ARDL (1 1 1 2 2) approach using the lag length selection results are shown in Table 7 to estimate for the ARDL approach.

The Table 9 shows the estimated error correction model adjustment of the long-run equilibrium relationship between carbon emissions and energy consumption for Australia. The results of the short-run, independent variables (energy consumption) on dependent variable i.e. carbon emissions (CO₂) for Australia is given in Table 9.
Khanal: Does Energy Consumption Impact the Environment? Evidence from Australia Using the JJ Bayer-Hanck Cointegration Technique and the Autoregressive Distributed Lag Test

Table 9: Short-run dynamics using the ARDL approach

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coeff.</th>
<th>t-stats</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>lnEC</td>
<td>0.5993</td>
<td>2.15</td>
<td>0.040**</td>
</tr>
<tr>
<td>lnGDP</td>
<td>0.0331</td>
<td>0.10</td>
<td>0.919</td>
</tr>
<tr>
<td>lnTP</td>
<td>1.2140</td>
<td>0.96</td>
<td>0.345</td>
</tr>
<tr>
<td>lnFD</td>
<td>0.1443</td>
<td>1.54</td>
<td>0.135</td>
</tr>
<tr>
<td>ECM(–1)</td>
<td>-0.1533</td>
<td>-1.07</td>
<td>0.295***</td>
</tr>
</tbody>
</table>

** for <0.05 and *** for <0.01 significance level

Figure 2: The results of the stability test of CUSUM and CUSUM Q

Table 7: Lags of variables

<table>
<thead>
<tr>
<th>Lag</th>
<th>Selected lags</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 8: Long-run dynamics using the ARDL approach

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coeff.</th>
<th>t-stats</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>2.6316</td>
<td>2.17</td>
<td>0.038**</td>
</tr>
<tr>
<td>lnEC</td>
<td>-0.8585</td>
<td>-0.92</td>
<td>0.930</td>
</tr>
<tr>
<td>lnGDP</td>
<td>-0.2713</td>
<td>-0.19</td>
<td>0.853</td>
</tr>
<tr>
<td>lnTP</td>
<td>-0.2359</td>
<td>-0.92</td>
<td>0.366</td>
</tr>
</tbody>
</table>
| lnFD      | 27.783 | Heteroscedasticity  
** for <0.05 significance level

We implemented the ARDL approach to investigate long-run and short-run relationship. The long-run dynamics from the ARDL results show that the energy consumption causes an increase in carbon emissions in Australia. Results reported for long-run HDFLDPWHGFRHVFLHQWVKRZWKDWQHOUJFRQVXPSWRQK DQGVLVJQLFDFQWDPFWRQPHULFWRQVSGDRI2 of Australia. The impact of energy consumption is positive and VLCFLQDFQDWEDWLVQDFQHOHYHOHQWVKRUWUXQVW the results of the long-run estimates. Our results are consistent with the findings of Shahbaz et al. (2017), Tang and Tan (2015), and Ali et al. (2016) who found evidence that energy consumption...
leads to carbon dioxide (CO\textsubscript{2}) emissions in the long-run. This is because energy consumption has increased by nearly 20 percent since the 1970s increasing from 4405.7 to 5483.82 oil equivalent per capita until 2015.

Likewise, our results reveals that economic growth, total energy consumption, CO\textsubscript{2} emissions, and economic growth and development in the UAE. Energy Sources Part B: Economics Planning and Policy, 13(4), 231-236. The results in the ARDL model. Austraila is one of developed economies in the world and largely depends on energy for the development and economic growth. This dependence causes considerable carbon emissions in the atmosphere. Thus this paper analyses the nexus between energy consumption and carbon emissions for 44 observations.

The results of the cointegration tests showed that the sampled variables were cointegrated and a long-run relationship between the variables existed in Australia. The long-run dynamics from the ARDL results show that the energy consumption causes an increase LQFDUERQPLVQLRLQVQLXSVWXUDOLD7KLXVLJQULVQHPRQV in the amount of energy which LVHHRVGHRRGRGQGDQGUVXHDVQR7KUHHRUHKXKVVLQQLVQUVWUDLD6.

The study overall evaluates the impacts of energy consumption on carbon emissions taking into account economic growth, SRSXODWLRLQDOGQDOQFLDODGYHORSQHWQ+RZHYHUKWUVLQXRIRGVDQGURXJKVLQSVWXUDOLD.

The study explores the linkages between environmental quality, HQQHJDFRQVXPSWLRQHRQORPLFJURZWKQDOQFLDODGYHORSQHWQ and total population for Australia from 1971 to 2015 by employing the ARDL model. Australia is one of developed economies in the world and largely depends on energy for the development and economic growth. This dependence causes considerable carbon emissions in the atmosphere. Thus this paper analyses the nexus between energy consumption and carbon emissions for 44 observations.

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consumption, economic growth, trade openness and urbanization of newly industrialized countries. Energy Policy, 39(11), 6991-6999.


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