The Relationship Between Economic Growth, Energy Consumption and Environmental Pollution Based on ARDL Model

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ABSTRACT
This paper investigated the dynamic relationship among the per capita national income, energy consumption and environmental pollution based on the ARDL model for Liaoning Province. The results of the ARDL model estimation did not clearly confirm the EKC hypothesis that the relationship between economic growth and environmental pollution was inverted U-shaped, but it was estimated that is likely to be the case. The long-run results indicate energy consumption has a positive and significant impact on environmental pollution. The impact of energy consumption on the environmental pollution emissions showed a significant positive relationship at the 5% level, and 1% increase in the energy consumption will lead to 0.77% increase in the environmental pollution emissions. CUSUM and CUSUMSQ tests results show that all coefficients of the model are stable.

Keywords: economic growth, Kuznets curve, ARDL model, environmental pollution, Liaoning Province

1. INTRODUCTION
Economic development is dependent on energy, and energy consumption inevitably leads to environmental pollution. In recent decades, the word is facing challenges to find a solution to make a balance sustainable economic development and environmental damage. The research on the long-run relationship between economic growth, energy consumption and environmental pollution has important theoretical and practical significance for ensuring the high quality and stable economic growth, reducing energy consumption, optimizing energy structure and reducing environmental pollution. Many theories have been employed to study and assess the relationship between the environment and economic growth. The environmental Kuznets curve(EKC) theory, first introduced by Grossman & Krueger(1991), it means that environmental pollution increases during the early stages of economic growth, but that environmental pollution naturally decreases as economic growth progresses and income levels rise[1].

The Environmental Kuznets Curve theory is found to be the best theory to describe the relationship between economic growth and environmental degradation, in which the environment will become better when the economy grows highly[2]. Liaoning Province is one of the important industrial bases in the northeast China, and plays a very important role in the country's economic development. Liaoning's per capita GDP increased from 11177 yuan in 2000 to 54,745 yuan in 2017, and the energy consumption increased from 987.72 million tons in 2000 to 202.513 million tons in 2017. However, rapid economic growth is usually accompanied by increased energy consumption and many cause unexpected effects on energy resources and the environment. The study examines the dynamic relationships between economic growth, environmental pollution and energy consumption for Liaoning Province based on Environmental Kuznets Curve approach and Autoregressive Distributive Lag (ARDL) bound testing for a long-run relationship. The results of this study do not clearly show the existence of an EKC for Liaoning Province. However, it is estimated that a further economic growth will result in an inverted U-shaped. The long-run results indicate energy consumption has a significant impact on environmental pollution, and the impact of energy consumption on the environmental pollution emissions showed a significant positive relationship at the 5% level, and 1% increase in the energy consumption will lead to 0.77% increase in the environmental pollution emissions.

The paper is organized as follows. Section 2 reviews relevant literature. In section 3 , the ARDL model is constructed considering the economic development of Liaoning Province, and the empirical results are discussed in section 4. Finally, conclusions are summarized in section 5.

2. LITERATURE REVIEW
In general, numerous studies have been conducted on the relationship between economic growth, energy consumption and environmental pollution. The
environmental Kuznets curve theory is considered as
the relationship between economic growth and
environment and is one of the most heavily debated
issues within environmental economics[3,4,5,6,7].
Environmental Kuznets curve theory reveals the
relationship between economic growth and
environmental pollution, which represents a reduced
form that conceals other phenomena such as technology,
product composition, environmental regulations, or
demands of society[4,8]. In this sense, this reduced
form does not allow initial identification of the effects
of economic policy. To illustrate this hypothesis, the
authors applied the cross-section panel approach, taking
as variables some comparable measures of the partners,
among which was air pollution in several urban areas.
In the analysis of [4], it was observed that sulfur
dioxide and smog in the air increase with the presence
of lower GDP per capita. However, this contamination
decreases as income increases, indicating statistical
evidence of the existence of a relationship between the
ECK and the two environmental quality indicators used.
The inflection point or the level at which pollution
indicators begin to decrease was determined in a range
of GDP per capita between 4000 and 5000 dollars. On
the contrary, for the specific case of sulfur dioxide and
smog, a point of change was not identified; however,
the relationship between pollution with these indicators
and GDP per capita was perceived as a monotonous
increase. In the same way, Alvarado & Toledo
documented the intensity of toxic pro duction for the
manufacturing sectors in several countries[9]. This
document aimed to determine the environmental effect
that manufacturing industries received and to analyze
whether their contribution to pollution varied with
respect to different incomes. The results obtained
indicated the existence of a relationship between the
ECK and the intensity of toxic elements per unit of
GDP. By employing the Bayer-Hanck combined
cointegration and Autoregressive Distributed Lag
(ARDL) techniques, You W, Lv Z and Saint Akadiri
et al. find a non-significant negative impact of
globalization on CO2 emissions in Turkey[10,11,12].
By using a similar approach, Destek and Ozsoy
investigate the impact of globalization on the
environmental indicators by incorporating urbanization
and energy consumption in the framework of the EKC
hypothesis[13]. Moreover, the nexus of electricity
consumption and the environment in the context of
pollutant emissions has been well covered for different
cases. For instance, Cowan et al find the Granger
causality from electricity consumption to CO2
emissions in India[11]. Also, Salahuddin et al
implement the ARDL approach to study the effect of
electricity consumption on carbon emissions, the
statistical evidence of Granger causality from electricity
consumption to CO2 emissions is significant and
positive[12]. Although the subject of this study is an
extensively evaluated area in the educational and
research arena, the relationship between economic
growth and urbanization has received continuous
attention from policy makers and in academic circles. In
our study, we accomplish the ARDL-bound testing
approach to explore the linkage between energy
consumption, economic growth, and environmental
pollution for Liaoning Province, and to find out the
potential causes of contaminated environment and
provide solution for the hidden issues of fumes.

3. ANALYSIS MODEL

Autoregressive distribution lag (ARDL) is a least-square
estimation model, whose main idea is to determine
whether there is a co-integration relationship between
variables based on boundary test, and estimate the
correlation coefficient between variables. Initially
proposed by Charemza & Deadman[14], and later
perfected and popularized by Pesaran et al.[15]. The
advantages of the ARDL model are as follows: (1) when
testing the long-term relationship between variables, it is
unnecessary pre-test on time series; (2) the ARDL
estimation results are robust enough even in small samples;
(3) when the explanatory variable is endogenous, the
ARDL model can also obtain an unbiased and effective
estimate; (4) ARDL method overcomes the problems that
non-stationary time series brought, such as spurious
regression problem[15].

In light of the real situation of the economic and social
development of Liaoning Province, the model variable
selection is as follows. Sulfur dioxide and TSP(total
suspended particulate) emissions from Liaoning Province
are taken as an analytical variable, and its value is taken as
natural log, and LnE represents environmental pollution.
The basic model of this paper is set as follows:

\[
\ln E_t = \beta_0 + \beta_1 \ln X_t + \beta_2 (\ln X_t)^2 + \\
+ \beta_3 \ln E_{t-1} + \epsilon_t
\]

(1)

Where \( E_t \) is Sulfur dioxide and TSP emissions \( X_t \)
represents per capita real GDP \( E_{t-1} \) stands for the energy
consumption \( \epsilon_t \) is the standard error term and \( t \) refers to
the time period. \( \beta_1, \beta_2 \) and \( \beta_3 \) represent the long-run
elasticity estimates of the Sulfur dioxide and TSP
emissions with respect to real GDP, the square of real
GDP and energy consumption respectively.

Generally, it is expected that the higher level of energy
consumption should result in greater economic activity and
stimulate the Sulfur dioxide and TSP emissions. Therefore,
it is expected that \( \beta_2 \) to be positive. Under the EKC
hypothesis, the sign of \( \beta_1 \) is expected to be positive which
captures the initial increase in the Sulfur dioxide and TSP
emissions as income increases, whereas a negative sign is
expected for \( \beta_2 \) which reflects the inverted U-shape pattern,
one income passes the threshold level [2]. On the basis of
the above mode, to examine long-run equilibrium
relationship between the Sulfur dioxide and TSP emissions,
economic growth and energy consumption, we adopted ARDL framework as follows:

\[
\ln E_t = \alpha_0 + \sum_{i=1}^{p} \beta_i \ln X_{t-i} + \sum_{i=1}^{q} \delta_i \ln \ln t + \sum_{i=0}^{p} \sigma_i (\ln (X_t))^2 + \sum_{i=0}^{p} \epsilon_i \ln \ln t + \alpha_1 \ln X_t + \alpha_2 (\ln X_t)^2 + \alpha_3 \ln \ln t + \mu_t
\]  
(2)

Where, \( \Delta \) represents the first difference and \( \alpha_i \) is drift component and \( \mu_1 \) white noise. The terms \( \beta_i, \delta_i, \sigma_i, \epsilon_i \) denote the error correction dynamics while the terms \( \alpha_2, \alpha_3, \alpha_4 \) correspond to the long run relationship.

In this paper, the boundary test method is used to test the relationship between variables, the value of F statistic is used to test whether there is a long run stable relationship between variables and then the coefficient of the long run relationship between variables in the ARDL model is further estimated.

4. EMPIRICAL RESULTS AND DISCUSSION

The indicators of environmental pollution may use various environmental pollution indicators, such as sulfur oxides (SOx, SO2), nitrogen oxides (NOx, NO2), carbon monoxide (CO), carbon dioxide (CO2) and total suspended particulate(TSP). The paper used sulfur dioxide and TSP data to explain the relationship between economic growth, energy consumption, and environmental pollution. The basic statistics of the variables used for the empirical analysis were the data of Liaoning Province Statistics Bureau data of 2000-2018. The unit root tests of the variables are required before estimating the ARDL model. In this work, the unit root test of variables was performed using the ADF(augmented Dickey–Fuller) and PP(Phillips-Perron) tests. The results of the unit root test are shown in Table 1.

| variable   | ADF  | PP              |
|------------|------|----------------|
|            | t-Statistic | 1st difference | t-Statistic | 1st difference |
| \( \ln E_t \) | -2.571125 | -4.643672** | -1.449989 | -4.878318** |
| \( \ln X_t \) | 1.561488 | -2.966175** | -1.477424 | 2.427644** |
| \( (\ln X_t)^2 \) | 1.472648 | -2.864504** | -1.371011 | 2.509881** |
| \( \ln E_n \) | 1.893041 | -5.787082* | -1.917782 | -5.224284* |

Note: (*) and (**) indicate 1% and 5% level of significance.

The test results show that all variables are not stable at the 5% or 10% level of significance, while the differential variables are stable at the 5% level of significance. Therefore, it was confirmed that all of the time series data recovered stability after the first difference and conforms to the requirements of ARDL model. As a result of estimating ARDL model considering the each variables based on AIC, ARDL (1,3,3,2) was valid for Eq(1). The long-term coefficients of the estimated equation by the optimal ARDL model are shown in Table 2.

| variable   | Coefficient | Std.error | t-Statistic |
|------------|-------------|-----------|------------|
| \( \Delta \) constant | -32.60633 | 9.92318 | 2.734700* |
| \( \ln X_t \) | 11.40416 | 3.187963 | 3.459000* |
| \( (\ln X_t)^2 \) | -0.898732 | 0.284172 | -3.162633* |
| \( \ln E_n \) | 0.774335 | 0.457509 | 2.692501* |

R-squared | 0.9996178 |

Note: (*) indicate 1% level of significance.

Based on the estimated ARDL model, the energy consumption was found to have a significant positive relationship with environmental pollution emissions at the 5% level in the long-run. The coefficient of the per capita real GDP is positive(+) and the coefficient of the per capita real squared is negative(-) at the 1% level. According to Table 3, 1% increase in per capita real GDP will lead to 11.4% increase in the environmental pollution emissions in long-run.

In addition, the impact of energy consumption on the environmental pollution emissions showed a significant positive relationship at the 5% level, and 1% increase in the energy consumption will lead to 0.77% increase in the environmental pollution emissions.

In other words, the economic growth increases environmental pollution emissions, and at the same time, the increase in environmental pollution emissions implies the reverse relation between economic growth and environmental pollution, which reduces GDP by harming people’s health. Economic growth and increased environmental pollution occur almost simultaneously. In other words, economic growth increases energy consumption and increases in energy consumption use increases air pollutants and greenhouse gas emissions.

| variable   | Coefficient | Std.error | t-Statistic |
|------------|-------------|-----------|------------|
| \( \Delta \) constant | 21.40614 | 5.187963 | 3.218324* |
| \( \Delta \ln X_t \) | 1.557953 | 0.169150 | 2.921047** |
| \( \Delta (\ln X_t)^2 \) | -0.824328 | 0.058912 | -3.992623* |
| \( \Delta \ln E_n \) | 1.846066 | 0.130618 | 4.633112* |
| ECM(-1) | -0.617213 | 0.146209 | -4.359389* |

R-squared | 0.999578 |

Adj R- squared | 0.999627 |

Note: (*) and (**) indicate 1% and 5% level of significance.

The coefficients cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) were employed...
to check the stability of the analytical model. The CUSUM and CUSUMSQ statistics tests the stability of the estimated coefficients and the stability of the error term. The analysis results show that the model is stable because the critical line moves within the 5% significance level, and the estimated coefficients of the model are also stable.

5. CONCLUSION

This study examined the long-run relationship between the per capita real GDP, energy consumption and environmental pollution based on the ARDL model for Liaoning Province. Although the EKC hypothesis that the relationship between economic growth and environmental pollution is inverted U-shaped was not clearly confirmed, it is estimated that this is likely to be the case. Increasing the per capita real GDP by 1% can raise the environmental pollution emissions to 11.4%, and 1% increase in the energy consumption will lead to 0.77% increase in the environmental pollution emissions. The result of CUSUM and CUSUMSQ tests indicated that all coefficients in the short and long-run models are stable.

REFERENCES

[1] Dinda S. Environmental Kuznets curve hypothesis: A survey [J], Ecological Economics, 2004, 49(4): 431-455.

[2] Kuznets S. Economic growth and income inequality [J], American Economic Review, 1955, 45(1): 1-28

[3] Grossman G.M., Krueger A.B. Economic Growth and the Environment Quarterly Journal of Economics[J], 1995, 110(2) : 353-377

[4] Chowdhury R R., Moran E F. Turning the curve: A critical review of Kuznets approaches[J], Applied Geography. 2012, 32:3-11.

[5] Correa Restrepo, F. Crecimiento econ ó mico, desigualdad social y medio ambiente: Evidencia emp írico para América Latina[J], Revista Ingenierí as Universidad de Medellín 2007, 6, 12–30.

[6] Delbianco F, Dabús C, Carballo M Á. Income inequality and economic growth: New evidence from Latin America[J], Cuadernos de Economía 2014, 33(63), 381–398.

[7] Galeotti,M.; Lanza,A.; Pauli,F. Reassessing the environmental Kuznets curve for CO 2 emissions: A robustness exercise[J], Ecological Economics. 2006, 57(1), 152–163

[8] De Bruyn S M. Explaining the environmental Kuznets curve: Structural change and international agreements in reducing sulphur emissions[J], Environment and Development Economics. 1997, 2, 485–503

[9] Alvarado R, Toledo E. Environmental degradation and economic growth: Evidence for a developing country[J], Environment Development & Sustainability. 2017, 19, 1205–1218.

[10] You W, Lv Z. 2018. Spillover effects of economic globalization on CO2 emissions: a spatial panel approach[J], Energy Economics. 2018, 73, 248–257.

[11] Cowan W N, Chang T, Inglesi-Lotz R. The nexus of electricity consumption, economic growth and CO2 emissions in the BRICS countries[J], Energy Policy 2014, 66, 359–368.

[12] Salahuddin M., Alam K., Ozturk I. The effects of electricity consumption, economic growth, financial development and foreign direct investment on CO 2 emissions in Kuwait[J], Renew. Renewable and Sustainable Energy Reviews. 2018, 81, 2002–2010.

[13] Destek M A, Ozsoy F N. Relationships between economic growth, energy consumption, globalization, urbanization and environmental degradation in Turkey[J], International Journal of Energy and Statistics, 2015, 3(4), 1550017.

[14] Wojciech W. Charemza and Derek F. Deadman. New Directions in Econometric Practice, General to Specific Modelling, Cointegration and Vector Auto Regression[J], Pakistan Development Review, 2015,54(1), 73-85.

[15] Pesaran M H, Shin Y An autoregressive distributed lag modeling approach to cointegration analysis[M], Econometrics and economic theory in the 20th century, 1999, 31(7) 371-413.

[16] Mohammadi H, Amin M D. Long-run relation and short-run dynamics in energy consumption-output relationship: International evidence from country panels with different growth rates [J], Energy Economics, 2015(52): 118-126.

[17] Pesaran M H, Shin Y, Smith R J. Bounds testing approaches to the analysis of level relationships [J], Journal of Applied Econometrics, 2001, 16(3): 289-326.

[18] Lee C C. Energy consumption and GDP in developing countries: A cointegrated panel analysis [J], Energy Economics, 2005,27(3): 415-427

[19] Pesaran M H, Shin Y, Smith R J. Bounds testing approaches to the analysis of level relationships [J], Journal of Applied Econometrics, 2001, 16(3): 289-326.
[20] Altinay, G. and Karagol, E. Electricity Consumption and Economic Growth: Evidence from Turkey[J], Energy Economics 2005, 27: 849–856.

[21] Yildirim, E., Sukruoglu, D., Aslan, A. Energy Consumption and Economic Growth in the next 11 Countries: the Bootstrapped Autoregressive Metric Causality Approach[J], Energy Economics, 2014, 44: 14-21.