

Jamel, Lamia; Derbali, Abdelkader

Article

Do energy consumption and economic growth lead to environmental degradation? Evidence from Asian economies

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GENERAL & APPLIED ECONOMICS | RESEARCH ARTICLE

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Lamia Jamel and Abdelkader Derbali

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*Corresponding author: Abdelkader Derbali, Department of Finance, Higher Institute of Management of Sousse, Sousse University, Tunisia
E-mail: derbaliabdelkader@outlook.fr

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GENERAL & APPLIED ECONOMICS | RESEARCH ARTICLE

Do energy consumption and economic growth lead to environmental degradation? Evidence from Asian economies

Lamia Jamel¹ and Abdelkader Derbali^{2*}

Abstract: The main purpose of this study is to investigate empirically the impact of energy consumption and economic growth on the environmental degradation as measured by CO₂ emissions. We utilize the cointegration test, the fully modified OLS, and the panel causality to examine the causality between environmental pollution and economic aggregates from a panel data of eight Asian countries during the period 1991–2013. We find that the cointegration tests confirm long run relationship among environmental degradation and energy consumption and economic growth along with financial development, trade openness, capital stocks, and urbanization as control variables. In addition, FMOLS results confirm that economic growth and energy consumption have a positive and significant impact on environmental degradation. Besides, panel causality through VECM verifies that bidirectional causal connection is found between energy consumption and economic growth and environmental degradation.

Subjects: Asian Studies; Development Studies, Environment, Social Work, Urban Studies; Economics; Energy policy and economics

Keywords: environmental degradation; economic growth; energy consumption; Asian countries

JEL classification: C3; F1; G2; O4; Q4; Q5

ABOUT THE AUTHORS

Lamia Jamel is a PhD degree in Economics at the Faculty of Economic Sciences and Management of Sousse, Tunisia. He is one of the Editorial Board members in the Cogent Economics and Finance, International Journal of Risk and Contingency Management, International Journal of Sustainable Economies Management, International Journal of Food and Beverage Manufacturing and Business Models, and International Journal of Managerial Studies and Research.

Abdelkader Derbali is an assistant professor in Finance at the Higher Institute of Management of Sousse, Tunisia. He is one of the Editorial Board members in the African Journal of Accounting, Auditing and Finance, in Cogent Economics and Finance, and in International Business Review. He has published articles, among others, in Research in International Business and Finance, The Journal of Energy Markets, International Journal of Economics and Accounting, International Journal of Critical Accounting, and International Journal of Trade and Global Market.

PUBLIC INTEREST STATEMENT

This paper investigates empirically the impact of energy consumption and economic growth on the CO₂ emissions. We use the cointegration test, the fully modified OLS, and the panel causality to examine the causality between environmental pollution and economic aggregates from a panel data of eight Asian countries over the period 1991–2013. The empirical findings show that the cointegration tests confirm long run relationship among environmental degradation and energy consumption and economic growth along with financial development, trade openness, capital stocks, and urbanization as control variables. In addition, FMOLS results confirm that economic growth and energy consumption have a positive and significant impact on environmental degradation. Besides, panel causality through VECM verifies that bidirectional causal connection is found between energy consumption, economic growth, and CO₂ emissions.

1. Introduction

The natural environment plays an important role in supporting economic activity. It contributes directly by providing resources and raw materials such as water, timber, and minerals that are needed as inputs for the production of goods and services and indirectly through the services provided by ecosystems, including carbon sequestration, water purification, flood risk management, and nutrient cycling. Natural resources are therefore essential to ensure economic growth and sustainable development, not only today but for future generations.

The relationship between economic growth and the environment is complex. Several challenges come into play, including the size and composition of the economy, particularly the share of services in gross domestic product (GDP), as opposed to primary industries and manufacturing, and technological changes have the potential to reduce the environmental impacts of the decisions of production and consumption, while also driving economic growth.

Thus, natural capital is different from other types of capital for a number of reasons. Some elements of natural capital have critical thresholds beyond which abrupt and dramatic changes may occur; some finite limits, such as changes in natural capital that are potentially irreversible impacts and extend through many generations. Therefore, natural capital is used to generate economic growth. It must be used in a sustainable and effective way to ensure long-term growth. This is particularly evident in the context of non-renewable resources like oil and minerals, but the renewable resource consumption rates, such as forests and fisheries, and services such as biodiversity and carbon sequestration by the ecosystems must also be considered in relation to their rate of charging and replenishment and the critical thresholds they exhibit.

The empirical findings of the causal linkage among energy consumption, CO₂ emissions, and economic growth have indicated mixed results, which calls for additional study to explain this nexus. Various current studies focused on the association among economic growth, energy consumption, and CO₂ emissions with different econometric approaches such as, structural break unit root test, cointegration for long run relationship between the variables in the presence of structural breaks, ordinary least squares (OLS) and error correction model (ECM) for long run and short run impacts, the vector error correction model (VECM) and Granger causality (GC) approach for causal relationship, and innovative accounting approach (IAA) to test the robustness of causality analysis (Apergis & Payne, 2009; Baranzini, Weber, Bareit, & Mathys, 2013; Charfeddine & Ben khediri, 2015; Chen, Kuo, & Chen, 2007; Ghosh, 2010; Omri, 2013; Stern, 1993; Wolde-Rufael, 2005; Yuan, Zhao, Yu, & Hu, 2007).

The main objective of this paper is to investigate empirically how economic growth and energy consumption lead to environmental degradation? To do this, we employ the cointegration test, the fully modified OLS, and the panel causality to examine this causality from a panel date of eight Asian countries over the period 1991–2013.

The empirical findings show that the cointegration tests verify long run relationship among environmental degradation and energy consumption, environmental degradation, and economic growth along with, financial development trade openness, capital stocks, and urbanization as control variables. Then, to examine long run elasticity, fully modified OLS is used to confirm that all economic growth and energy consumption have a positive and significant impact on environmental degradation. Additionally, panel causality through VECM confirms that a bidirectional causal connection is found between energy consumption and environmental degradation and economic growth and environmental degradation.

The rest of the paper is organized as follows: Section 2 presents a review of related literature on the linkage between economic and energy indicators and environmental degradation (CO₂ emissions). In Section 3, we present an overview of Asian economies. In Section 4, we develop the

methodology. In Section 5, we illustrate the data used for empirical evidence. Section 6 presents the empirical results and a discussion of the study. Concluding remarks are presented in Section 7.

2. Literature review

The subject of the effect of energy consumption and economic growth on CO₂ emissions has been well-documented in the econometric energy literature. Different contributions have focused on different countries, time periods, and have used different proxy variables for macroeconomic and energy indicators. In the next paragraphs, we will review some of the previous studies related to the effect of economic growth, energy consumption, capital, financial development, and population on CO₂ emissions.

The investigation of the causal nexus between economic growth and environmental degradation is studied in several empirical works. This causality is based on the environmental Kuznets curve (EKC) hypothesis. This hypothesis supposes that the connection between economic growth and environmental degradation is significant on a high and positive level. Grossman and Krueger (1991) and Selden and Song (1994) prove that the causality between economic growth and environmental degradation is positively significant. Their empirical evidence indicates that an increase in economic growth increases environmental degradation measured by the environmental degradation.

Menyah and Wolde-Rufael (2010a, 2010b) use the GC to examine the effect of GDP, consumption of nuclear energy, and consumption of renewable energy on CO₂ emissions in the United States during the period 1960–2007. They show that GDP and consumption of nuclear energy increase CO₂ emissions. However, the renewable energy decreases environmental pollution.

Zhang and Lin (2012) develop a study to investigate the impact of economic indicators on pollution (CO₂ emissions) in China during the period 1995–2010 by using the fixed effects model and the method of least square generalized linear regression. They utilize the demographic intensities, urbanization, GDP, industrial production, production of services, and energy consumption as economic indicators. The main results of their study show that the demographic intensities, GDP, industrial production, and energy consumption have an impact on CO₂ emissions.

For the case of Indonesia, Jafari, Othman, and Nor (2012) use GC over the period 1971–2007 to measure the impact of GDP, consumption of energy, capital, and urbanization on CO₂ emissions. They conclude that GDP, consumption of energy, and capital affect positively the pollution as measured by CO₂ emissions.

Bloch, Rafiq, and Salim (2012) utilize the cointegration Johansen, variance decomposition, and GC by the model error correction vectors for China during the period 1977–2008. These authors use CO₂ emission as an indicator of pollution and energy consumption, labor, capital, and GDP as indicators of economic and energy activities. Their main findings suggest that GDP and energy consumption have a positive impact on the pollution.

To examine the impact of economic activity indicators on environmental degradation, Omri (2013) uses the method of least squares generalized through the period 1990–2011 in the case of countries in the MENA region. He utilizes CO₂ emissions as an indicator of pollution and labor, capital, population, financial development, and GDP as indicators of economic activities. Their results show the presence of a positive and significant impact of the GDP and negative impact of financial development and capital on CO₂ emissions.

Shahbaz, Hye, Tiwari, and Leitão (2013) employ the model error correction vectors and the GC to study the impact of GDP, energy consumption, foreign direct investment, financial development, and trade openness on environmental pollution during the period 1971–2011 in the case of Malaysia. They show that GDP, energy consumption, foreign direct investment, financial development, and trade openness have a positive effect on CO₂ emissions.

Apergis and Payne (2014) utilize a sample of the countries of Central America over the period 1980–2010 to examine the effect of GDP, consumption of renewable electricity, oil, coal, and population on CO₂ emissions. They use the Bai–Perron cointegration for panel data, the modified OLS, and the error correction vector model based on GC. Their study demonstrates the importance of the economic and energy factors to affect CO₂ emissions which explain the existence of a positive causality.

Baek and Pride (2014) develop a survey to a sample of countries in the major nuclear production during the period 1990–2011. Econometrically, these authors use the vector autoregression cointegrated model and Johansen cointegration. They use CO₂ emissions as a pollution indicator. For economic indicators, they use GDP and the production of nuclear electricity. Their results show that economic indicators affect positively the pollution of these countries.

Farhani, Chaibi, and Rault (2014) use GC by the model error correction vectors for the case of Tunisia (1971–2008). They utilize CO₂ emissions, GDP, energy consumption, and trade openness to investigate the impact indicators of economic activity on pollution. Their empirical findings prove the presence of a positive causality between CO₂ emissions and economic indicators.

Alam et al. (2014) utilize the generalized method of moments (GMM) to analyze the impact of economic indicators (population density, energy resources, energy consumption, and financial development) on pollution (CO₂ emissions) over the period 1975–2013 in Malaysia. They conclude that energy consumption and financial development increase CO₂ emissions.

Rafindadi, Yusof, Zaman, Kyophilavong, and Akhmat (2014) employ the regression by the ordinary least square on panel data and the fixed effects model on panel data regression by the least squares method of two courses to study the causal relationship between pollution and economic activity indicators in the Asia-Pacific countries for the period 1975–2012. In their study, pollution is measured by CO₂ emissions and economic indicators are measured by GDP, the production of water, the added value of natural resources, and energy consumption. They find the existence of a positive and significant relationship between CO₂ emissions and GDP. Also, they conclude that energy consumption affects positively pollution.

Charfeddine and Ben khediri (2015) use the unit root tests with multiple structural breaks and regime-switching cointegration techniques considering for one and two unknown regime shifts to examine the nexus between CO₂ emissions, electricity consumption, economic growth, financial development, trade openness, and urbanization for the United Arab Emirates during the period 1975–2011. The empirical findings of their study prove the existence of environmental Kuznets curve (EKC). Additionally, Charfeddine and Ben khediri (2015) show an inverted U-shaped relationship between financial development and carbon dioxide emissions. Also, they find that electricity consumption, urbanization, and trade openness contribute to improve environmental quality.

Table 1 shows a summary of the empirical studies about the impact of energy consumption and economic growth on carbon dioxide emissions. In general, we can show that energy consumption and economic growth have a positive and significant impact on carbon dioxide emissions.

3. Overview of Asian economies

According to the report of the World Bank in 2014, the Asian countries will register a growth rate of 7.1% this year, which remains almost the same as in 2013. As a result, this region remains the most dynamic in the world, despite a slowdown compared to the average growth rate of 8% for 2009–2013. Growth will settle slightly in China from 7.7% in 2013 to 7.6% this year. Apart from China, the region's developing countries will also experience a slight decline in growth, which will amount to 5% against 5.2% last year.

Table 1. Summary of previous studies about the impact of energy use and economic growth on carbon dioxide emissions

Authors	Sample and period	Methodology	Results
Perman and Stern (2003)	74 countries (1960–1990)	Cointegration test	GDP and square GDP have a positive and significant impact on CO ₂ emissions
Markandya, Golub, and Pedroso-Galinato (2006)	12 Western European countries (1850–2001)	Unit root test, cointegration test	Inverted U-shaped relationship between income and pollution
Richmond and Kauffman (2006)	20 developed countries (1973–1997)	Cointegration test	Energy consumption and per capita GDP have a positive impact on CO ₂ emissions
Managi (2006)	48 states (1970–1997)	EKC hypothesis	Inverted U-shaped relationship between GDP per capita and environmental pollution
Fan, Liu, Wu, and Wei (2006)	Developing countries (1975–2003)	STIRPAT model	Urbanization has a positive impact on CO ₂ emissions
Soytas, Sari, and Ewing (2007)	USA (1960–2004)	GC; Variance decomposition	EC and GDP have a positive impact on CO ₂ emissions
Ang (2008)	Malaysia (1971–1999)	Panel cointegration test and Vector error correction; GC	A positive impact of energy consumption on CO ₂ emissions
Halicioglu (2009)	Turkey (1960–2005)	Panel cointegration test; GC	Economic growth has a more significant impact on the CO ₂ emissions CO ₂ emissions are determined by energy consumption, GDP per capita
Lean and Smyth (2009)	ASEAN countries (1980–1960)	Vector error correction; GC	A positive and significant relation between EC and CO ₂ emissions
Apergis and Payne (2009)	Six central American countries (1971–2004)	EKC hypothesis	Energy consumption has a positive and statistically significant impact on CO ₂ emissions
Jalil and Mahmud (2009)	China (1975–2005)	Panel cointegration test; GC; ARDL	Trade openness has a positive but statistically insignificant impact on CO ₂ emissions
Narayan and Narayan (2010)	43 developing countries (1980–2004)	Panel cointegration test; EKC hypothesis	A CO ₂ emission has fallen with a rise in economic growth
Apergis and Payne (2010)	11 countries of the commonwealth independent states (1992–2004)	Vector error correction model; Panel cointegration test	Energy consumption has a positive and statistically significant impact on CO ₂ emissions U-shape pattern associated with the EKC hypothesis
Sharif Hossain (2011)	Newly industrialize countries (NIC) (1971–2007)	Unit root tests; Cointegration tests; GC	Energy consumption and per capita GDP have a positive effect on CO ₂ emissions Urbanization has a negative effect on CO ₂ emissions
Sharma (2011)	69 countries (1985–2005)	Dynamic panel data model	Urbanization does have a negative and statistically significant impact on CO ₂ emissions for the global panel Urbanization has a negative but insignificant impact on CO ₂ emissions in the low-income, middle-income, and high-income panels
Saboori and Sulaiman (2011)	Iran (1971–2007)	Cointegration approach; ARDL	EKC hypothesis assumes an inverted U-shaped relationship between income and environmental degradation Energy consumption has a positive and significant impact on CO ₂ emissions
Narayan and Popp (2012)	93 developing countries (1980–2006)	GC	Economic growth has a positive and significant impact on CO ₂ emissions Energy consumption has a positive and significant impact on GDP per capita
Arouri, Ben Youssef, M'henni, and Rault (2012)	12 MENA (1981–2005)	Unit root tests and Cointegration techniques	Energy consumption has a positive significant impact on CO ₂ emissions Economic growth has a positive impact on CO ₂ emissions
Sadorsky (2014)	Emerging economies (1971–2009)	STIRPAT model	Urbanization is positive but statistically insignificant on CO ₂ emissions

Notes: EC refers to energy consumption, GDP: economic growth, CO₂: carbon dioxide emissions, URB: urbanization, TR: trade openness; and EKC refers to environmental Kuznets curve. STIRPAT: stochastic impacts by regression on population, affluence, and technology. ARDL: autoregressive distributed lag. Vector error correction mode (VECM).

The major economies of Southeast Asia, such as Indonesia and Thailand, will face tightening of global financial conditions and an increase in household debt. In Malaysia, growth will accelerate slightly to 4.9% in 2014. Exports will increase, but the increase in the debt service and the fiscal consolidation underway will weigh on domestic demand. In the Philippines, where growth could decline to 6.6%, accelerating reconstruction spending would offset the decline in consumption following the natural disasters in 2013. The economies of smaller size should experience sustained growth, and face risks of overheating that may require further tightening of monetary policy.

Structural reforms are essential to reduce vulnerabilities and ensure long-term sustainable growth. China has undertaken a series of reforms in finance, market access, mobility of labor, and taxation in order to increase the efficiency of growth and boost demand interior. Over time, these measures will sustain the economy on a more stable basis, inclusive and sustainable. Some initiatives already announced by the government, such as tax reform and reducing barriers to private investment, could also boost short-term growth. If they are successful, reforms in China could have tremendous positive effects on trading partners that supply agricultural products, consumer goods, and modern services. However, a disorderly adjustment of the Chinese economy would have a negative impact on regional and global growth, particularly in countries dependent on natural resource exports.

In this section, we present the Asian economies under study in terms of CO₂ emissions, GDP per capita, energy consumption, and financial development.

Figure 1. CO₂ emissions, energy consumption, economic growth, and financial development in China.

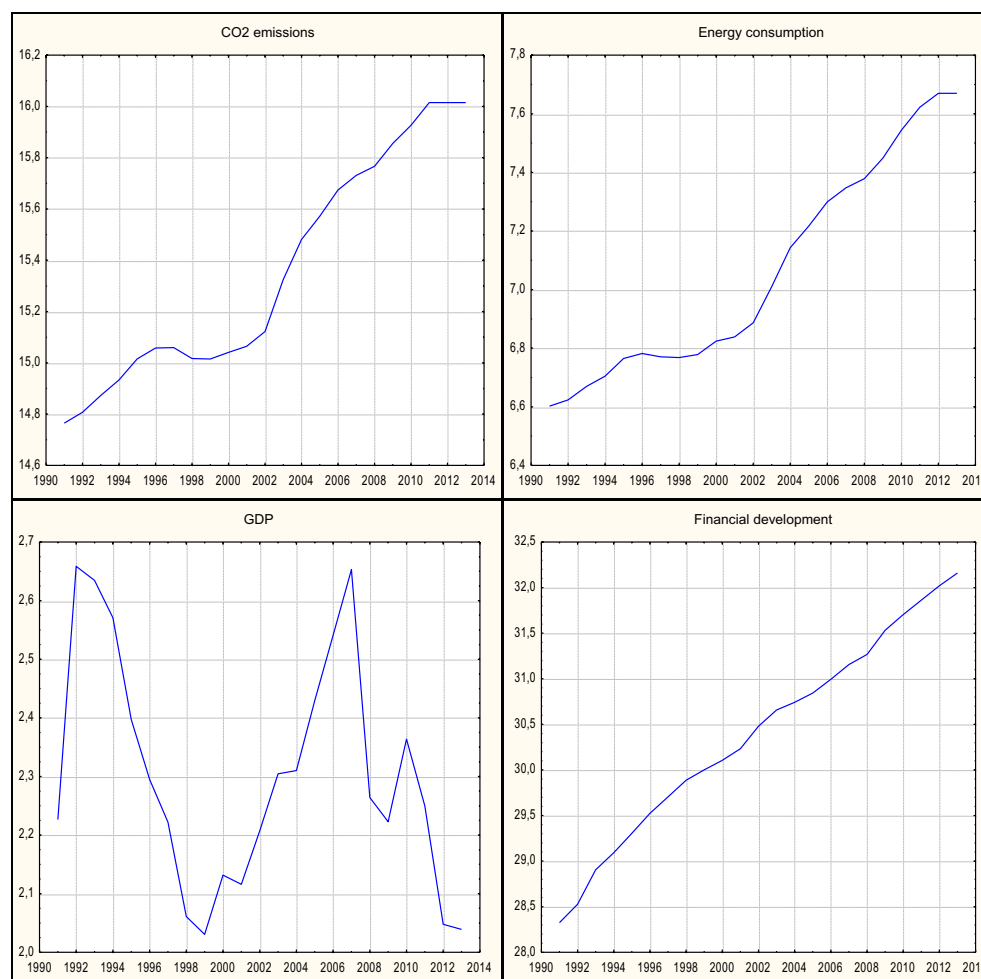
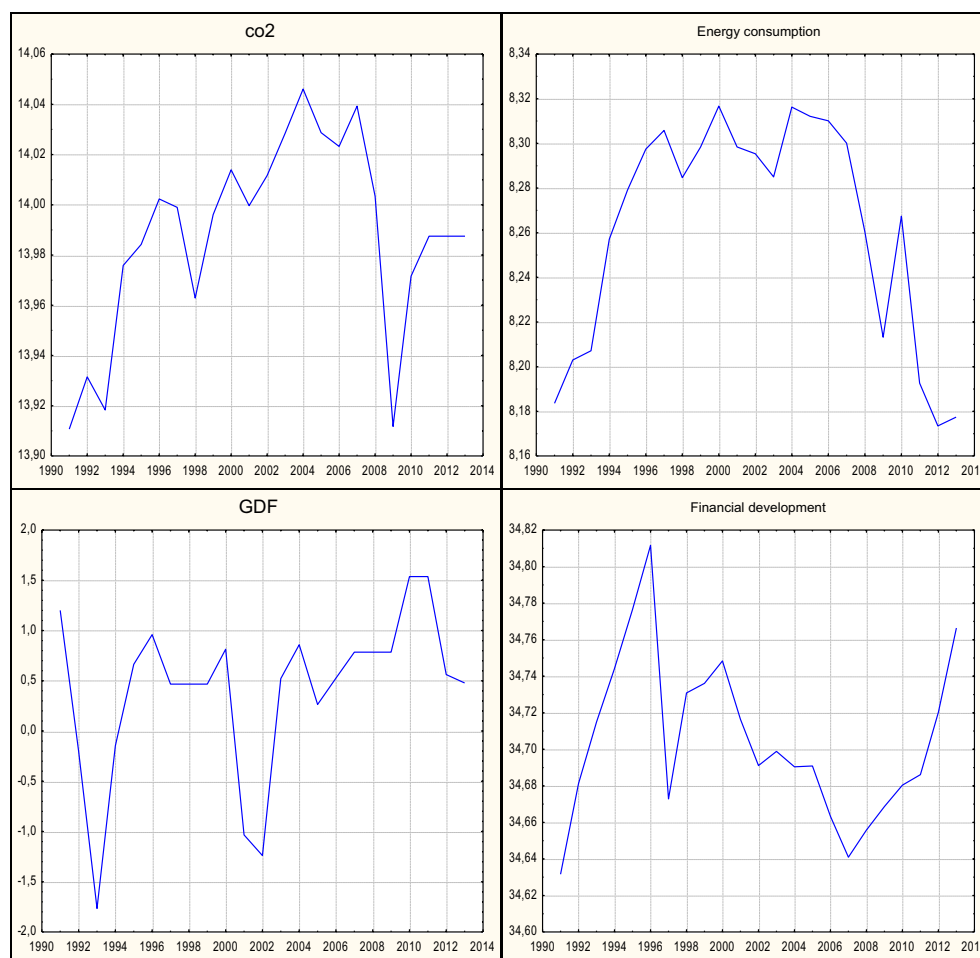


Figure 2. CO₂ emissions, energy consumption, economic growth, and financial development in Japan.



Figures 1–8 present the Asian economies under study in terms of CO₂ emissions, GDP per capita, energy consumption, and financial development. From these figures, we can remark that CO₂ emissions are characterized by an important increase over the period of study from 1991 to 2013, except in Japan, Singapore, and South Korea. For these three countries, CO₂ emissions are increasing, especially after the Asian Crisis of 1996.

Additionally, we can find that CO₂ emissions are positively correlated to the energy consumption. This result can be captured from Figures 1–8 which present the energy consumption for eight Asian countries employed in our study.

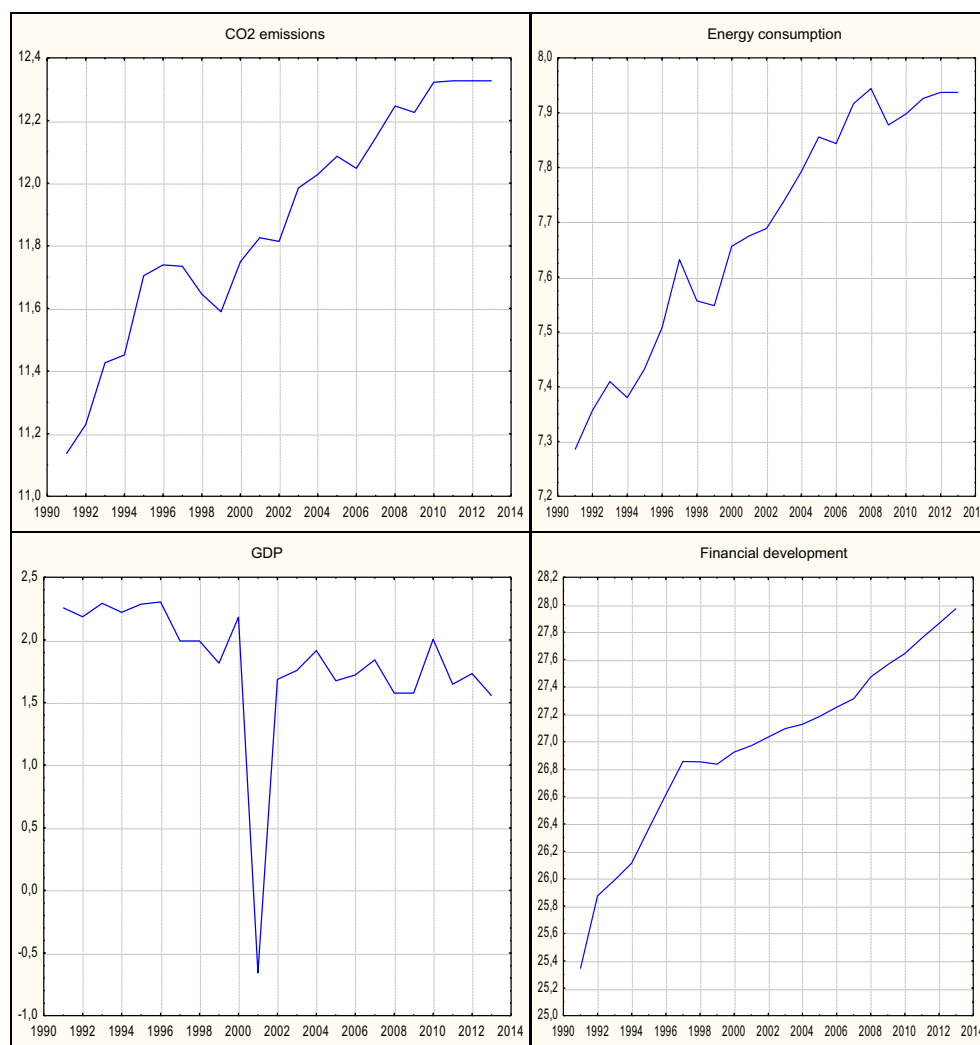
Furthermore, we can remark that the GDP of the Asian economies under study has an important peak in two periods: 1998–1999 (the Asian financial crisis) and 2000–2002 (Terrorist attacks of 2001). Also, the GDP of Asian countries is affected by the financial crisis of 2007.

Finally, we can observe that the financial development is continuously increasing in all the countries studied in this paper.

4. Methodology

Following the empirical literature in the previous section (Lotfalipour, Falahi, & Ashena, 2010; Lee, 2013; Omri, 2013; Omri, Daly, Rault, & Chaibi, 2015; Saboori, Sulaiman, & Mohd, 2012; Sharma, 2011; Sharif Hossain, 2011), the present paper aims to examine the impact of economic growth (the real GDP per capita (LGDP)) and energy consumption (LEC) on environmental degradation (LCO₂

Figure 3. CO₂ emissions, energy consumption, economic growth, and financial development in Malaysia.



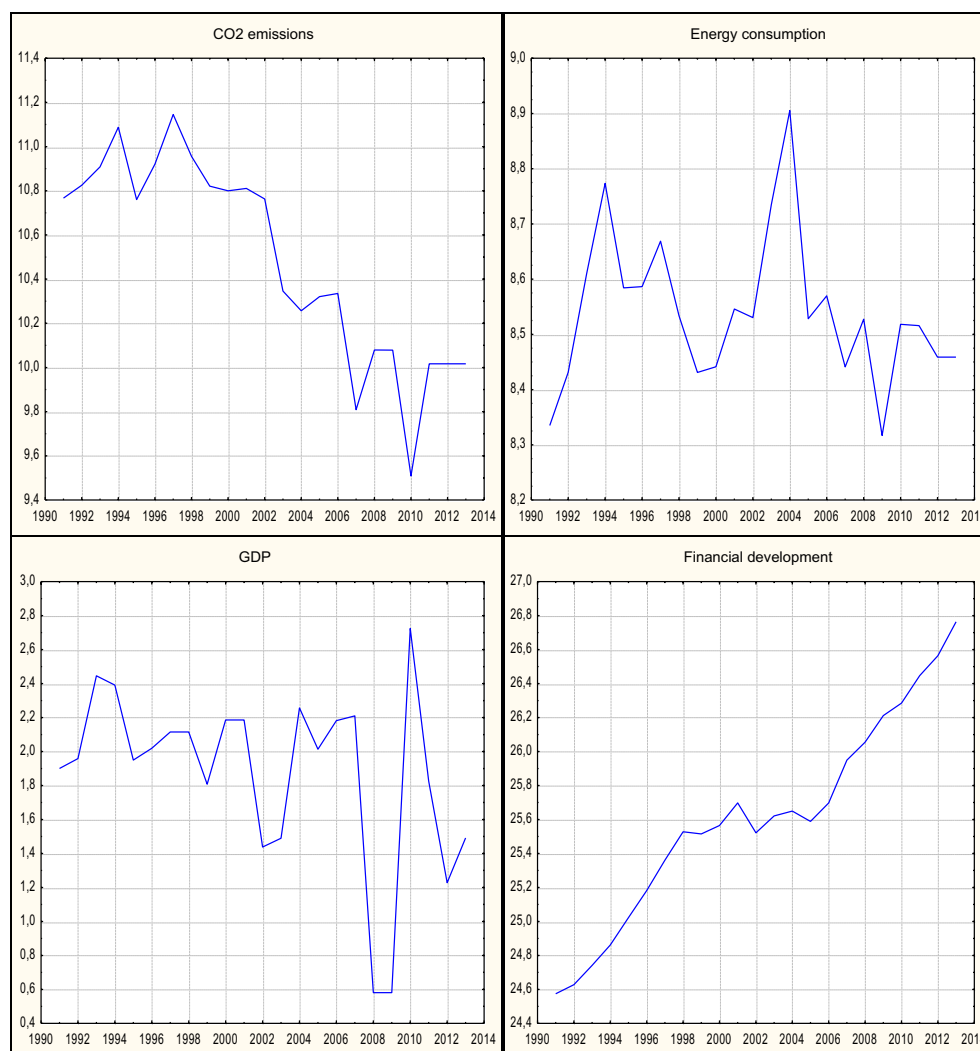
emissions) by incorporating financial development (LFD), trade openness (LT), urbanization (LU), and capital stocks (LK) in the carbon dioxide emission function. For this reason, we will test the validity of the EKC hypothesis, which is advanced by Simon Kuznets. Based on the Cobb–Douglas production function, the estimated econometric model is presented as follow:

$$LCO_{2it} = \alpha_0 + \alpha_1 LGDP_{it} + \alpha_2 LEC_{it} + \alpha_3 LFD_{it} + \alpha_4 LT_{it} + \alpha_5 LU_{it} + \alpha_6 LK_{it} + \varepsilon_{it} \quad (1)$$

where, $LGDP$ represents the growth rate of the GDP per capita, LFD represents financial development, LT represents trade openness, LCO_2 represents carbon dioxide emissions per capita, LEC represents energy consumption, LK represents capital stock, and LU represents the urbanization rate. α_0 corresponds to the constant. ε_{it} represents the error term. α_{ji} represents the estimated coefficients of all independent variables where $j = 1, \dots, 6$. The subscript $i = 1, \dots, 8$ denotes the country. The subscript $t = 1, \dots, 23$ denotes the time period. Table 2 resumes all variables used in this paper.

The panel cointegration, Fisher (1932), Pedroni (1997) and Kao (1999), tests are applied to verify the long run relationship between environmental degradations, economic growth, energy consumption, and financial development. Fully modified OLS is useful to find long run elasticity. Short run dynamic relationship is estimated by vector error correction model (VECM). For this analysis, the first step is to verify the stationarity of data and panel-based unit root tests are applied for this purpose.

Figure 4. CO₂ emissions, energy consumption, economic growth, and financial development in Singapore.



Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) tests are extended for panel data analysis, to check whether the data are stationary or not. The panel unit root tests are an extension of Augmented Dickey-Fuller test because most tests include it as a regression component. Five different types of panel unit root tests are applied. First two tests, the Levin and Lin (LL) test and Breitung t-stat test, are assumed common unit root process across cross sections. In these two tests, null hypothesis is that data are non-stationary or have a unit root and alternative hypothesis is that data are stationary or have a no unit root, while the other three tests, Im, Pesaran, and Shin W-stat test, Augmented Dickey-Fuller-Fisher Chi-square test, and Phillips-Perron-Fisher Chi-square test, assume individual unit root process across cross sections.

5. Data

This study is elaborated to investigate empirically the causal linkage between economic aggregates (economic growth, energy consumption, financial development, and trade) and environmental pollution in the Asian countries during the period 1991–2013. We utilize yearly panel data for a sample composed by eight Asian countries (China, India, Thailand, Japan, Malaysia, Singapore, Indonesia, and South Korea).

Figure 5. CO₂ emissions, energy consumption, economic growth, and financial development in South Korea.

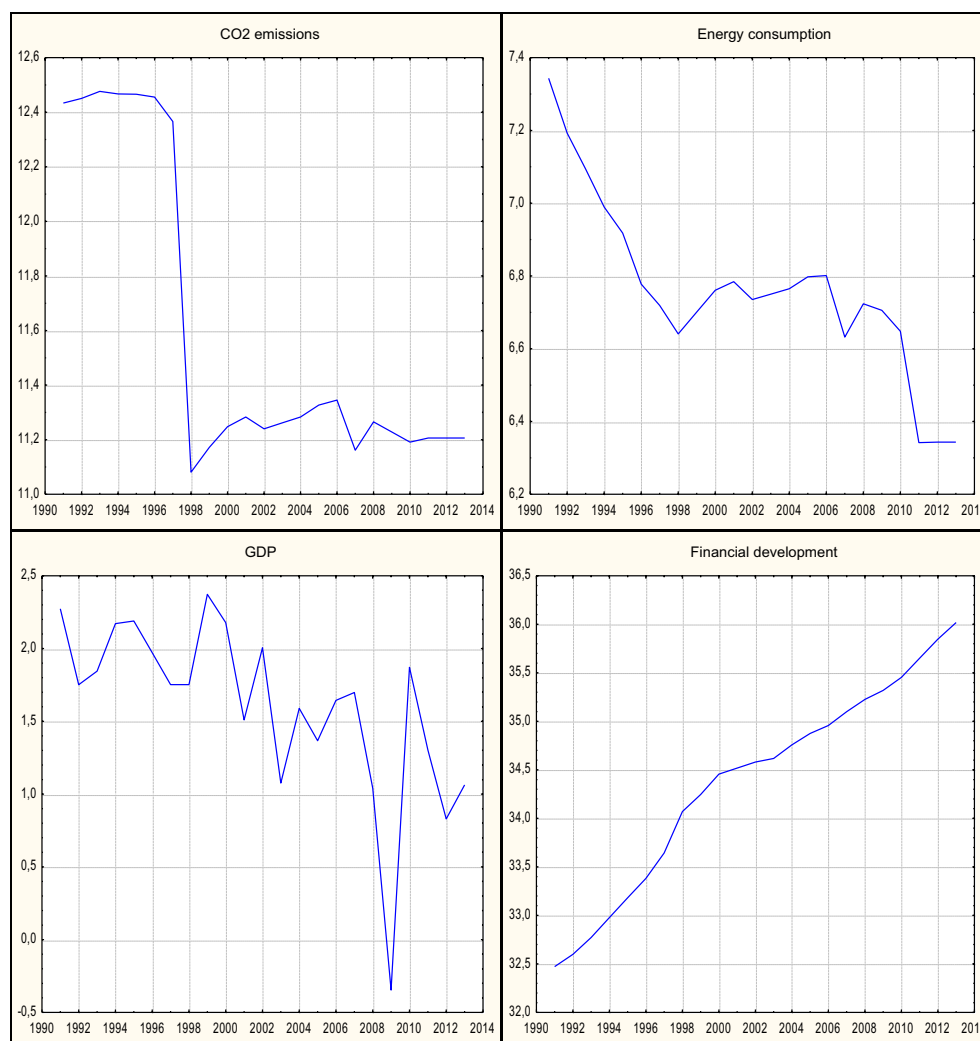


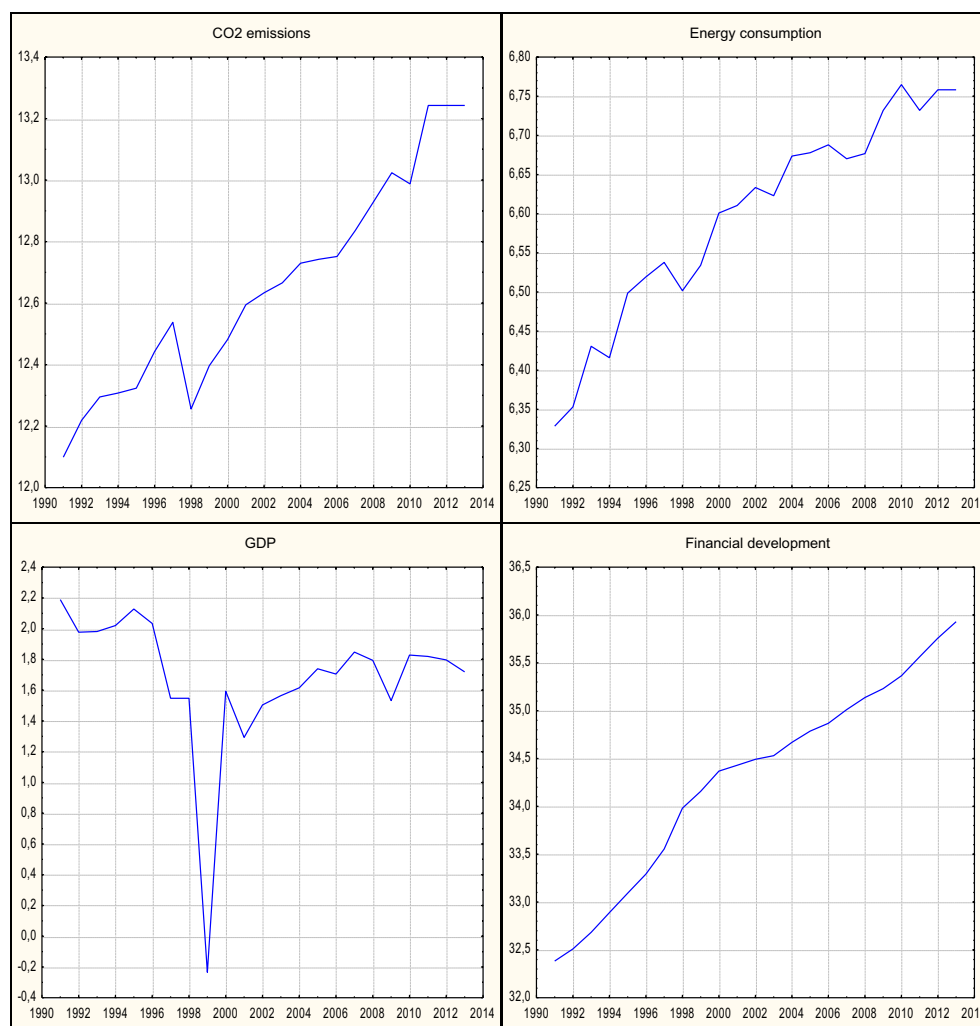
Table 3 reports the descriptive statistics of all variables used in this study. From the results summarized in this table, we can find that, on average, the highest levels of LCO₂ are equal to 16.014, of LEC equal to 8.905, of LGDP equal to 15.298, and of LFD equal to 36.018.

Following to the two statistics of skewness (asymmetry) and kurtosis (leptokurtic), we can conclude that all variables utilized in this paper are characterized by non-normal distribution. Then, the skewness coefficients indicate that the variable is skewed to the left (negative sign of asymmetry coefficients) and that it is far from being symmetric for all variables except three variables: LCO₂, LGDP, and LT which are skewed to the right (positive sign of asymmetry coefficients). In addition, the kurtosis coefficient shows that the leptokurtic for all variables used in this paper indicates the presence of a high peak or a fat-tailed in their volatilities (the leptokurtic coefficients are superior to 1).

Also, the positive sign of estimate coefficients of Jarque-Bera statistics indicates that we can reject the null hypothesis of normal distribution of the variables employed in this study. Besides, the high value of Jarque-Bera coefficients reflects that the series is not normally distributed at the threshold level of 1%.

The results showed by the three statistics, skewness, kurtosis, and Jarque-Bera, suggest that all variables used in this paper are not normally distributed.

Figure 6. CO₂ emissions, energy consumption, economic growth, and financial development in Indonesia.



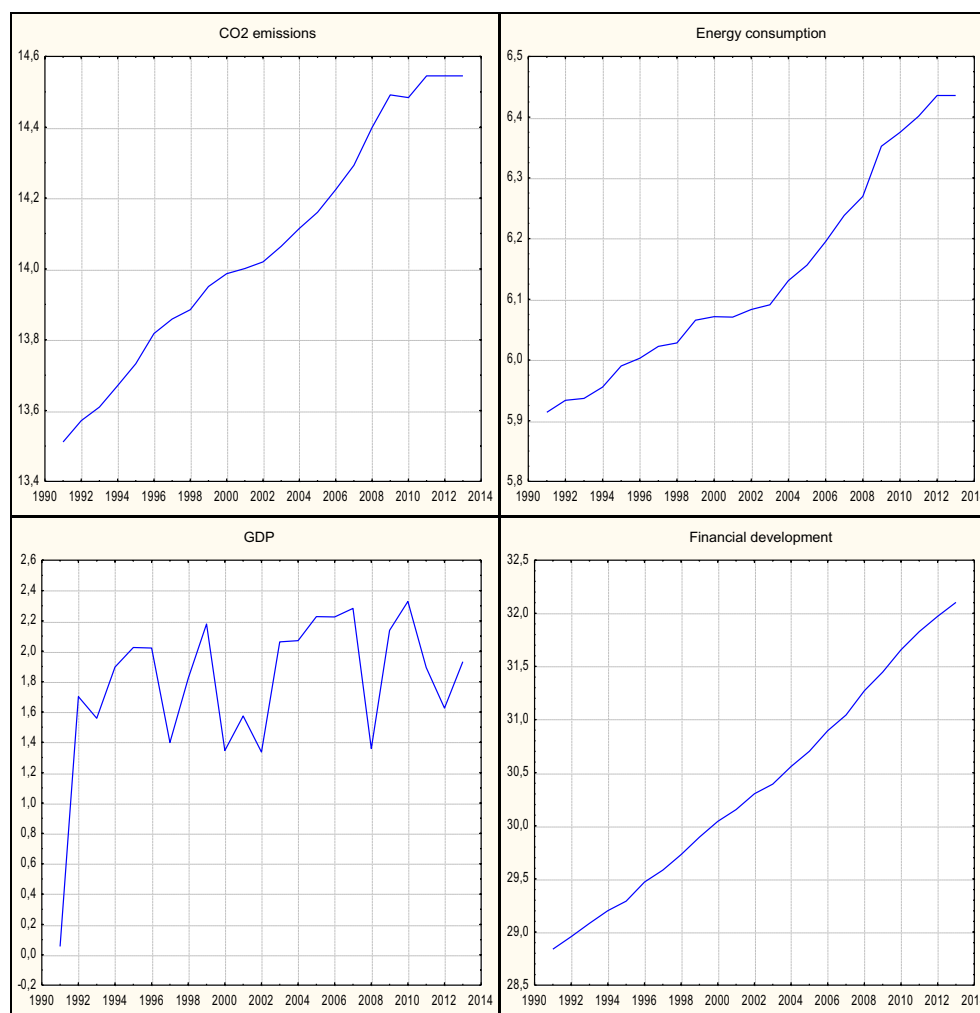
We also do a test of the unit root panel data in level and in first difference which presented in Table 4. Then, we use Levin-Lin-Chu (LLC) test, Im-Pesaran-Shin (IPS) test, Breitung test, Fisher-ADF test, and Fisher-PP test. The null hypothesis of these tests supposes that all series are non-stationary and the alternative hypothesis supposes that all series are stationary.

The acceptance or rejection of the null hypothesis is based on the value of probabilities and statistics relative to the indicated tests. These probabilities are compared to a threshold level of 10%. If these probabilities are less than 10%, then we reject the null hypothesis and if these probabilities are greater than 10%, we accept the null hypothesis. Table 4 reports the results of the stationary tests of all variables employed in this paper. From this table, we can observe that all variables are not stationary in level, but they are stationary in first difference. According to the statistics of LLC test, IPS test, Breitung test, Fisher-ADF test, and Fisher-PP test, we can conclude that all variables are integrated in order 1. Thus, we can proceed to the cointegration test which presented in Section 6.

6. Empirical findings

In this section, we specify the type of estimate for the selected model which is a regression on panel data. The choice of this type of regression is justified by the presence of the two dimensions in the data employed, the first dimension is the time (period of 23 years) and the second is individual (the sample used is composed by eight Asian countries). The empirical outcomes and explanations are reported in this section. Cointegration tests, FMOLS, and VECM are given in Tables 5–7, respectively.

Figure 7. CO₂ emissions, energy consumption, economic growth, and financial development in India.



Pedroni, Kao, and Fisher cointegration tests are applied to verify long run relationship between variables used in this paper to examine the impact of energy consumption, economic growth, and financial development on environmental degradation. Pedroni test presents two sets of cointegration tests. First set is known as within dimension (four, statistics) and the second set is known as between dimension (three, statistics). Kao cointegration test is based on ADF t-statistic. Finally, Fisher test is based on Fisher statistic from trace test and Fisher statistic from max-eigen test. The results of cointegration are presented in Table 5. According to Pedroni test (within dimension and between dimension), we can confirm the presence of a long run relationship between all variables used in this paper, especially between environmental degradation, GDP growth, energy consumption, financial development, and trade openness. Also, the empirical findings of Kao test confirm long run relationship between variables (especially between environmental degradation, GDP growth, energy consumption, financial development, and trade openness). Moreover, the results of Fisher test corroborate the presence of a long run nexus between environmental degradation, GDP growth, energy consumption, financial development, and trade openness.

We continued our empirical analysis by the presentation of the estimation results and coefficients of the equal (1). In this equal, we examine the impact of economic growth, financial development, trade openness, energy consumptions, capital stock, and urbanization rate on environmental degradation as measured by CO₂ emissions. The estimation results of this are reported in Table 6. Then, we

Figure 8. CO₂ emissions, energy consumption, economic growth, and financial development in Thailand.

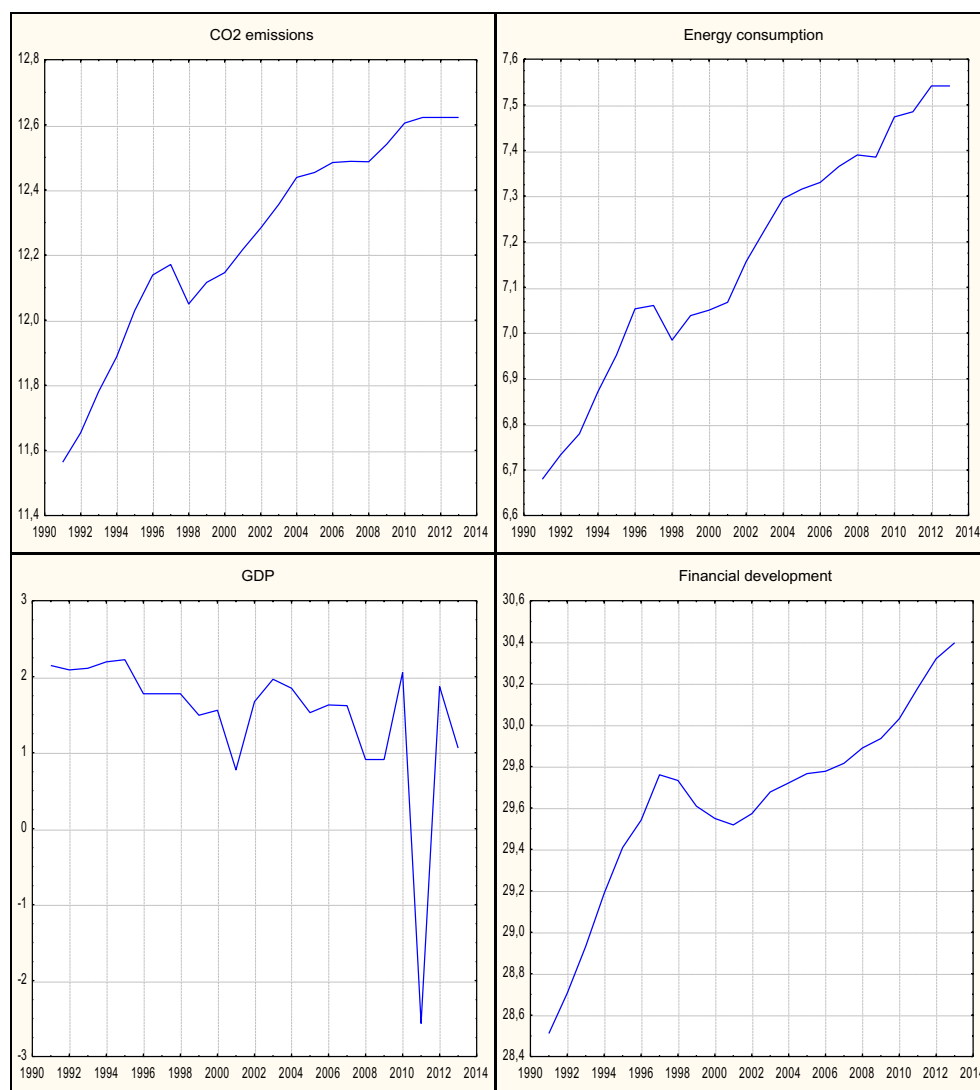


Table 2. Variables' definition

Variable	Indicator name	Source
CO ₂	CO ₂ emissions (metric tons per capita)	Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States
EC	Energy Consumption (kg of oil equivalent per capita)	International Energy Agency (IEA Statistics©OECD/IEA, http://www.iea.org/stats/index.asp)
GDP	Real GDP per capita	World Bank national accounts data, and OECD National Accounts data files
K	Capital stocks, total value (% of GDP)	Standard & Poor's, Global Stock Markets Factbook and supplemental S&P data
T	Trade (% of GDP)	World Bank national accounts data, and OECD National Accounts data files
U	Annual urban population growth (%)	World Bank Staff estimates based on United Nations, World Urbanization Prospects
FD	Domestic credit to private sector by banks (% of GDP)	International Monetary Fund, International Financial Statistics and data files, and World Bank and OECD GDP estimates

found that the coefficient of determination R^2 and adjusted R^2 is greater than 0.90 which verifies that the estimated model is characterized by a good linear fit.

Table 3. Descriptive statistics

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque–Bera	Probability	Observations
LCO ₂	12.784	12.479	16.013	9.508	1.529	0.180	2.242	15.399	0.000*	184
LEC	7.276	7.149	8.905	5.913	0.807	0.226	1.830	12.050	0.000*	184
LGDP	13.364	6.376	15.298	9.384	0.910	−4.162	7.485	312.934	0.000*	184
LFD	30.791	30.393	36.013	24.574	3.345	−0.134	1.769	14.167	0.000*	184
LT	4.292	4.073	6.085	2.767	0.898	0.350	2.166	24.098	0.000*	184
LK	3.372	3.360	3.864	2.430	0.257	−0.317	3.251	30.572	0.000*	184
LU	0.802	1.030	1.671	−1.115	0.685	−1.041	3.153	33.447	0.000*	184

Notes: This table summarizes descriptive statistics of all variables used in this paper. We used yearly panel data of eight Asian countries (China, India, Thailand, Japan, Malaysia, Singapore, Indonesia, and South Korea) from 1991 to 2013.

*Level of significance at 1%.

Table 4. Panel unit root test

	Levin, Lin, and Chu test		Breitung test		Im, Pesaran, and Shin test		Fisher–ADF test		Fisher–PP test	
	In level	In first difference	In level	In first difference	In level	In first difference	In level	In first difference	In level	In first difference
LCO ₂	−0.489*	−5.238*	−0.408*	−4.784*	−0.002*	−6.128*	−0.264*	−5.716*	−0.394*	−4.373*
LEC	−0.029*	−5.002*	−0.417*	−5.023*	−0.237*	−5.405*	−0.249*	−6.394*	−0.623*	−5.384*
LGDP	−0.366*	−6.590*	−0.106*	−2.764*	−0.734*	−5.484*	−0.485*	−7.843*	−0.384*	−2.019*
LFD	−0.982*	−3.584*	−0.568*	−2.273*	−0.049*	−5.297*	−0.485*	−8.386*	−0.817*	−2.372*
LT	−0.200*	−3.595*	−0.385*	−2.238*	−0.475*	−6.487*	−0.045*	−8.485*	−0.849*	−5.274*
LK	−0.172*	−2.445*	−2.734*	−3.263*	−0.102*	−3.374*	−0.458*	−9.308*	−0.734*	−2.712*
LU	−0.290*	−2.930*	−0.458*	−3.387*	−0.485*	−6.405*	−0.082*	−3.004*	−0.030*	−2.019*

Notes: In this test, the p-value is compared to 10%. If probabilities are < 10%, therefore, we reject the null hypothesis and if probabilities are > 10%, we accept the null hypothesis. With the null hypothesis, all series are non-stationary.

*Level of significance at 1%.

According to the impact of energy consumption and economic growth on environmental degradation in the case of the selected Asian countries in this paper, the results reported in Table 6 reveal that CO₂ emission rises 0.215% owing to 1% grow in total energy consumption; CO₂ emissions increase 0.027% owing to 1% grow in real GDP per capita; CO₂ emissions decrease 0.101% owing to 5% grow in financial development; CO₂ emission rises 0.022% owing to 1% grow in trade openness; CO₂ emissions increase 0.525% owing to 1% grow in capital stock; and CO₂ emissions decrease 0.006% owing to 1% grow in urbanization rate.

The results reported in Table 7 indicate short run dynamics and that there exists a bidirectional causal relationship between environmental degradation and energy consumption, environmental degradation and economic growth, environmental degradation and financial development, CO₂ emissions and trade openness, environmental degradation and capital stock, and environmental degradation and urbanization rate. Additionally, the error correction term's results show adjustment speed and it is significant at the level of 1% which also confirms that the long run relationship holds.

7. Conclusion

In this paper, we investigate the impact of energy consumption, economic growth, and financial development on environmental degradation in the case of the selected Asian countries. Empirically, to test this effect, we use a panel cointegration. Fisher (1932), Pedroni (1997), and Kao (1999) tests

Table 5. Cointegration results for effect of energy consumption and economic growth on environmental degradation

Effect of energy consumption on environmental degradation									
Pedroni test					Kao test (ADF)	Fisher test			
Within dimension	Statistics (Probability)	Weighted statistics	Between dimension	Statistics (Probability)	Statistics (Probability)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
Panel, PP-Statistic	-3.016 (0.000)*	-3.512 (0.000)*	Group, PP-Statistic	-3.052 (0.000)*	-3.020 (0.000)*	32.17	(0.009)*	44.41	(0.000)*
Panel, ADF-Statistic	-2.380 (0.000)*	-2.196 (0.000)*	Group, ADF-Statistic	-3.050 (0.000)*					
Effect of economic growth on environmental degradation									
Model Within Dimension	Statistics (Probability)	Weighted statistics	Between dimension	Statistics (probability)	Statistics (probability)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
Panel, PP-Statistic	-3.058 (0.006)*	-2.471 (0.001)*	Group, PP-Statistic	-2.986 (0.008)*	-3.076 (0.000)*	66.30	(0.000)*	55.91	(0.000)*
Panel, ADF-Statistic	-2.699 (0.000)*	-2.418 (0.001)*	Group, ADF-Statistic	-2.096 (0.002)*					

Note: Statistics in brackets are p-values.

*Level of significance at 1%.

Table 6. Fully modified OLS results for effect of energy consumption and economic growth on environmental degradation

Variable	Coefficient	Std. Error	t-statistic	Prob.
LEC	0.220	0.187	6.827	0.000*
LGDP	0.027	0.039	4.833	0.000*
LFD	-0.103	0.041	-2.540	0.020**
LT	0.022	0.129	5.311	0.000*
LK	0.539	0.106	5.213	0.000*
LU	0.006	0.070	6.255	0.000*
R ²	0.972			
Adjusted R ²	0.926			

Note: The t-values are reported below the coefficient in parenthesis.

*Level of significance at 1%.

**Level of significance at 5%.

Table 7. Panel causality results for effect of energy consumption and economic growth on CO₂ emissions

Dependent variable	Short run						Long run
	Δ LEC	Δ LGDP	Δ LFD	Δ LT	Δ LK	Δ LU	Δ LECT
Δ LCO ₂	3.027*	1.812***	2.425**	3.928*	5.001*	3.827*	3.192*

Note: ECT represents error correction term.

*Level of significance at 1%.

**Level of significance at 5%.

***Level of significance at 10%.

are applied to verify the long run relationship between environmental degradation, economic

growth, and energy consumption. Fully modified OLS is utilized to find long run elasticity. Short run dynamic relationship is estimated by vector error correction model (VECM). The period of study is from 1991 to 2013.

The main objective of our paper is to examine the impact of energy consumption and economic growth on CO₂ emissions. The empirical results of Pedroni, Kao, and Fisher cointegration tests confirm the presence of a long run relationship between variables used in this paper.

The fully modified OLS results show a positive relationship between carbon dioxide emissions (environmental degradation) and five variables: economic growth, trade openness, energy consumptions, capital stock, and urbanization rate. However, financial development has a negative impact on environmental degradation. These empirical findings indicate an evidence of bidirectional linkage between environmental degradation and energy consumption, environmental degradation and economic growth, and environmental degradation and financial development in the case of the Asian countries.

Panel causality tests through VECM elaborate that a bidirectional causal connection is found between environmental degradation and energy consumption, economic growth, and financial development. Finally, the error correction term's results confirm adjustment speed and it is significant at the level of 1% which also confirms that the long run relationship holds.

According to these empirical results, the Asian Governments need to promote financial development with their negative and significant impact on environment pollution. Also, they can promote investment on new resources in the energy sector which are beneficial in terms of CO₂ emissions, as renewable energy.

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Author details

Lamia Jamel¹

E-mail: lojamel@yahoo.fr

Abdelkader Derbali²

E-mail: derbaliabdelkader@outlook.fr

¹ Faculty of Economic Sciences and Management of Sousse, Department of Economics, Sousse University, Tunisia.

² Department of Finance, Higher Institute of Management of Sousse, Sousse University, Tunisia.

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