Unemployment Rate, Clean Energy And Ecological Footprint In OECD Countries

Cheong-Fatt Ng
Universiti Tunku Abdul Rahman
Kwang-Jing Yii
Swinburne University of Technology
Lin-Sea Lau
Universiti Tunku Abdul Rahman
You-How Go (goyouhow@gmail.com)
Universiti Tunku Abdul Rahman, Kampar Campus https://orcid.org/0000-0003-1529-8885

Research Article

Keywords: Ecological footprint, Unemployment rate, Clean energy, Environmental Phillips curve, OECD.

Posted Date: October 19th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-907182/v1

Version of Record: A version of this preprint was published at Environmental Science and Pollution Research on January 9th, 2022. See the published version at https://doi.org/10.1007/s11356-021-17966-6.

Abstract

OECD countries have encountered the challenges of improving the environmental sustainability while maintaining economic growth by not impairing employment. Designing green policies with the consideration of clean energy is claimed to resolve the mentioned challenges. This study attempts to reexamine the environmental Kuznets curve (EKC) hypothesis by using ecological footprint as an indicator of environmental degradation. Besides, our study aims to test the validity of environmental Phillips curve and role of clean energy on ecological footprint. Our data cover a panel of 36 OECD countries from 1995-2015. We adopt the second generation panel unit root and cointegration test to account for the presence of cross section dependence (CSD). Moreover, the long-run relationship is estimated using Common Correlated Effect Mean Group (CCEMG) and Augmented Mean Group (AMG) that are robust to CSD. Our results are able to provide valuable insights for environmental policy recommendations in OECD countries.

1. Introduction

For more than four decades, there has been a continuous rise in human beings' demand on the environment. The consumption on nature has exceeded what the Earth can replenish (World Wildlife Fund, 2021). Recently, ecological footprint has been widely used as an indicator to measure the impact of people's actions on the Mother Earth. The concept of "ecological footprint" was first introduced by William Rees-a Canadian ecologist in 1996. According to Rees (2000), "ecological footprint" can be defined as the productive land and sea areas required to generate resources that a population demands and to absorb the wastes that this group of people produce, regardless of the location of the land and sea. In particular, the "ecological footprint" covers six components, namely the cropland, the grazing land, forest land, built-up land, fishing grounds and carbon footprint (Yilanci, Gorus, & Aydin, 2019). The idea of "ecological footprint" was then popularised by a non-profit organisation, i.e. The Global Footprint Network (GFN) in which "ecological footprint" has been adopted as a measurement for sustainability. In recent years, "ecological footprint" concept has received much attention from the businesses and policymakers worldwide. For instance, many countries including those from Organization for Economic Cooperation and Development (OECD) such as Japan, Switzerland and the United States have started to consider or adopt the concept as part of their efforts in achieving sustainable development (Britannica, 2021). Since 1970s, the world has been experiencing "ecological overshoot" in which the global ecological footprint has outweighed the global biocapacity. As a result, there has been severe exhaustion in farm and animal biological resources including agricultural lands and fisheries. Thus, mitigation efforts are essential in overcoming the problem of "ecological overshoot". Without effective solution measures, the world will be facing the risk of ecological collapse (McBain, Lenzen, Wackernagel, & Albrecht, 2017).

In the past decades, OECD countries have achieved a favourable progress in reducing environmental degradation. For example, greenhouse gas emissions due to industrialization have been decreased and the size of forests as well as natural protected areas have been enhanced (Organization for Economic Cooperation and Development, 2021). In the meantime, OECD countries have also experienced an upward trend in the use of renewable energy. In 2019, for instance, the use of renewables grows 16.0%, 9.2 % and 5.9% in OECD Europe, OECD Americas and OECD Asia/Oceania, respectively (International Energy Agency, 2020). Despite these positive developments, environmental challenges continue to loom over OECD countries with issues such as extinction of plant and animal species as well as climate change. It is because the environmental deterioration caused by the growth in population and GDP has increased faster than the efficiency gains as a result of environmental mitigation efforts. As GDP or production rises in OECD countries, environmental degradation worsens. In other words, high employment level in the economy is associated with poor environmental quality (Kashem & Rahman, 2020). Due to increased employment and production, the OECD countries have been greatly impacted by environmental pollution both directly (in terms of increased costs in public healthcare) and indirectly (via reduced labour productivity) (Organization for Economic Cooperation and Development, 2021). Thus, appropriate environmental and economic policies are required urgently to produce a “win-win” situation for the economy and the environment.

In view of the above, this study intends to examine the association between economic growth, unemployment, clean energy and ecological footprint in OECD countries by answering the following questions: i) Is there an inverted U-shaped EKC in the context of ecological footprint in OECD countries? ii) By considering ecological footprint, does an environmental Philips Curve (i.e. a negative linkage between unemployment and pollution) exist in OECD countries? iii) How does clean energy (including nuclear energy and hydro energy) affect ecological footprint in OECD countries? To our best knowledge, the above questions have not been explored and answered by any of the past studies. Our study is the first attempt to investigate the impact of GDP, unemployment and clean energy on ecological footprint particularly in OECD countries. Our study contributes to the existing literature in several important ways. First, different from most of the past environmental literature which have focused merely on one pollution indicator (such as carbon dioxide and sulfur dioxide), this study employs a more comprehensive indicator i.e., ecological footprint as the measurement for environmental pollution. Apparently, ecological footprint is a more appropriate indicator for environmental degradation than a single pollutant as it covers a wide range of resource stocks including soil and forests. Second, none of the existing study has analyzed the determinants for ecological footprints in OECD countries. The main reason for considering OECD is that most of the members in this bloc are high income countries with minority of them being upper-middle income (e.g. Turkey and Chile). Ecological footprint per capita for high income nations is five times as great of what low income countries experience (Solarin, 2019). Additionally, as most countries share the characteristics of advanced status with very similar economic traits, drawing inferences from the findings of this study for policy recommendations would be possible. Third, our study is unique in the sense that robust estimators (i.e. Common Correlated Effect Mean Group (CCEMG) and Augmented Mean Group (AMG)) which account for the issue of cross section dependence (CSD) in the panel data are employed to investigate the relationship between income level, unemployment, clean energy and ecological footprint in OECD countries. With the utilization of these advanced econometric techniques, more reliable results can be obtained as compared to past studies which do not take the matter of CSD into consideration.

Section 2 presents a thorough review on the past studies in regards to ecological footprint and its determinants. It is then followed by Sect. 3 which focuses on the econometric model, data sources and research methodologies. Next, Sect. 4 describes the results obtained. Lastly, the conclusion and policy recommendations are demonstrated in Sect. 5.

[1]If the ecosystem collapses, its structure and function would diminish and its size and extent would tend to shrink. Most importantly, a collapse in the ecological system may cause more than 50 percent loss in the global GDP (World Economic Forum, 2021).

2. Literature Review

Ecological footprint is a multi-dimensional indicator of environmental quality that measures how much the regenerative biological capacity of land and sea areas to maintain a given human demand on food, services, transportation, goods and housing (Wiedmann et al., 2006). Apart from this, the available literature on ecological footprint from the economic perspective is constantly increasing. We present recent studies on ecological footprint in the following sub-sections.

2.1 The environmental Kuznets curve (EKC) hypothesis with ecological footprint

The EKC hypothesis is used extensively to investigate the environmental aspect of economic growth. A majority of current studies is found to consider measures of pollution as proxies for environmental quality. Generally, carbon dioxide (CO_2) emission is chosen as one of the most popular pollutants to proxy for environmental degradation in testing the EKC hypothesis (Esteve & Tamarit, 2012; Hamit-Haggar, 2012; Wang, 2012; Chow & Li, 2014; Yii & Geetha, 2017; Lau et al., 2019; Sarkodie & Ozturk, 2020; Ummalla & Goyari, 2021; Go et al., 2021a). In fact, the use of CO_2 emissions in the analysis of the EKC hypothesis could produce bias estimates due to inappropriate environmental degradation indicator adopted.

These bias estimates are found in previous EKC studies in the context of different countries. For example, Qatar over the period of 1980–2011(Mrabet & Alsamara, 2017), Malaysia over the period of 1971–2016 (Bello et al., 2018) and 14 European countries over the period of 1990–2014 (Altıntaş & Kassouri, 2020). By using a broader proxy for re-evaluating the hypothesis, countries' ecological footprint provides a means by which researchers can keep abreast of a more comprehensive measure of environmental degradation. For this reason, several studies opt to validate the EKC hypothesis that explains the relationship between environmental quality and economic development by emphasizing on the role of ecological footprint as an alternative to CO_2 emissions (Caviglia-Harris et al., 2009; Al-Mulali et al., 2015; Aşıcı & Acar, 2016; Acar & Aşıcı, 2017; Charfeddine & Mrabet, 2017; Ulucak & Bilgili, 2018; Destek et al., 2018; Mikayilov et al., 2019; Yilanci & Pata, 2020; Dogan et al., 2020; Ansari et al., 2020; Danish et al, 2020; Naqvi et al., 2021; Pata & Caglar, 2021).

The EKC hypothesis with ecological footprint is initially supported by the findings of Al-Mulali et al. (2015) who demonstrate an inverted U-shaped relationship between ecological footprint and economic growth in most of the upper middle- and high-income countries over the period of 1980–2008. However, this relationship does not occur in low-income countries in which technologies are available in improving energy efficiency. Due to high costs, energy saving and renewable energy in such countries are not accessible. Then, several scholars proceed to validate this hypothesis in other countries, wherein they successfully provide clear evidence of an inverted U-shaped for the EKC hypothesis. For instance, Aşıcı and Acar (2016) attempt to investigate whether countries that grow richer tend to reduce their ecological footprint. By analyzing the production and import components of the ecological footprint for the period 2004–2008, they perform the analysis for a panel of 116 countries. Their results indicate the support for EKC hypothesis between income per capita and ecological footprint of production. In terms of imported footprint, they find that it exhibits a monotonic increasing trend with income. When the economy grows further, the countries would export the ecological cost of their consumption to other poorer economies. By studying Turkey over the period of 1961–2008, Acar and Aşıcı (2017) find an inverted U-shaped relationship between footprint production and income, suggesting that the country tends to domestically reduce its outputs from environmentally harmful production through imports.

Additionally, Charfeddine and Mrabet (2017) find that the real economic growth per capita exhibits an inverted U-shaped relationship with ecological footprint in eight oil-exporting countries for the period between 1975 and 2007. Ulucak and Bilgili (2018) apply continuously updated fully modified and continuously updated bias corrected models to reveal that the EKC hypothesis is present among all examined countries' ecological footprint regardless of income groups from 1961 to 2013. Destek et al. (2018) apply second generation panel data methodologies to take the cross-sectional dependence among countries into account. Their results demonstrate that the real income exhibits U-shaped relationship with ecological footprint in European Union countries from 1980 to 2013. By employing fully modified ordinary least squares and dynamic ordinary least squares long-run estimators for the period from 1992 to 2016, Danish et al. (2020) find that the EKC hypothesis with ecological footprint is validated in individual BRICS countries (Brazil, Russia, India, China and South Africa). Naqvi et al. (2021) reach the similar finding across a panel of 155 countries from different income groups over the period of 1990–2017.

Some studies fail to find evidence for the inverted U-shaped relationship between ecological footprint and economic development. For instance, Caviglia-Harris et al (2009) use an unbalanced panel of 146 countries over the period of 1961–2000 and find that economic growth alone could not lead to sustainable development. Moreover, Mikayilov et al. (2019) investigate the long-run impact of tourism development on ecological footprint in the case of Azerbaijan for the period of 1996–2014. By employing time-varying coefficient and conventional cointegration techniques, their results support time invariant income elasticity of environmental degradation, implying that the EKC hypothesis is not present. In a study on Brazil, Russia, India, China, South Africa and Turkey for the period of 1980–2014, Dogan et al. (2020) take the issues of heterogeneity and cross-section dependence into account. Their results do not support the EKC hypothesis. In addition, they find that energy intensity and energy structure are important determinants of environmental degradation.

With the application of dynamic ordinary least square and fully modified ordinary least square, Ansari et al. (2020) find that an inverted U-shaped relationship between economic growth and ecological footprint does not exist in the case of Gulf Cooperation Council countries (Bahrain, Oman, Qatar, Saudi Arabia and the United Arab Emirates) from 1991–2017. By considering time-varying causality, another study by Yilanci and Pata (2020) on China shows no evidence for the EKC hypothesis over the period of 1965–2016. Their results indicate that the short-term elasticity of economic growth is smaller than the long-term elasticity, implying that economic complexity has an increasing impact on ecological footprint over time. By taking the presence of one structural break in the annual data of China into account, Pata and Caglar (2021) find a U-shaped quadratic relationship between ecological footprint and income level from 1980–2016, revealing that the EKC hypothesis does not hold.

2.2 The environmental Phillips curve (EPC)

Another strand of the literature explores the relationship between environmental degradation and unemployment (Kashem & Rahman, 2020a; Anser et al., 2021). In an effort to provide a new concept in explaining this relationship, Kashem and Rahman (2020a) propose the EPC. They apply a panel data estimation method to validate their concept by looking into 30 industrialized countries for the sample period of 1990–2016. Based on both visual inspection and econometrics, they observe that the invented function shows an inverse relationship between pollution and unemployment. This finding confirms the existence of a negative relationship between pollution and unemployment. In line with this, the authors suggest that the use of any viable technology could curb pollution and maintain or improve the employment level of the economy.

However, Rayhan (2020) queries their justification by stating that the relationship between pollution and unemployment would become vertical when the economy achieves the full employment level of output in the long run. By responding to the query, Kashem and Rahman (2020b) state that the full employment would not exist in any countries in the reality. Their empirical study demonstrates the existing negative relationship between these two variables in most of the countries, provided that a reflection of real situation prevails in the countries. Lastly, Anser et al. (2021) conduct a study using a panel data set that consists of Brazil, Russia, India, China, South Africa and Turkey for the period spanning from 1992 to 2016. Their findings affirm the validity of the EPC by indicating that a significant trade-off exists between unemployment and environmental degradation.

2.3 The impact of clean energy on air pollution and ecological footprint

The use of clean energy is vital for environmental sustainability (Tapaninen et al., 2009). In line with this, many current studies demonstrate that pollution emerges as the key factor behind the significant growth of clean energy sources. For instance, Menyah and Wolde-Rufael (2010) find that consumption of nuclear energy could mitigate CO_2 emissions in the United States from 1960 to 2007. Cai et al. (2018) reveal a unidirectional causality running from clean energy consumption to CO_2 emissions in the United States for the period from 1965 to 2015. By using a balanced panel dataset from 1995 to 2015, Lau et al. (2019) find that electricity generated by nuclear source could lower CO_2 emissions without retarding the long-run growth in a group of 18 OECD countries. Maji (2019) performs the analysis of system generalized method of moments by using annual data of 2010–2017. Their results support the notion that increased renewable energy usage could dampen CO_2 emissions in 42 sub-Saharan countries. Anser et al. (2021) find that renewable energy consumption could reduce the growth of CO_2 emissions in Brazil, Russia, India, China, South Africa and Turkey from 1992 to 2016. Also, Destek and Aslan (2020) discover that consumption of disaggregated renewable energy (hydroelectricity, wind, solar and biomass) could reduce carbon emissions in the Group of Seven countries between 1991 and 2014. Usman et al. (2020) demonstrate that alternative and nuclear energy asymmetrically affects CO_2 emissions in the case of Pakistan for the period from1975-2018.

Using a dataset from 31 Chinese provinces for the period of 2011–2017, Zhu et al. (2020) demonstrate that technological innovations in renewable energy could alleviate concentrations of nitrogen oxides and respirable suspended particles, but not for sulfur dioxide. Ummalla and Goyari (2021) find that clean energy consumption could significantly reduce CO_2 emissions in a panel of BRICS countries for the period from 1992–2014. By using Australian annual data from 1980 to 2014, Ahmed et al. (2021) find that a high elasticity of reduction in CO_2 emission per capita is due to an increase in the long-run consumption of clean energy.

To shed more light on the clean energy usage, a further empirical investigation is performed to determine whether it is responsible for the increase or decrease of ecological footprint. Based on varied economic structures and environmental regulations across the globe, most of the studies suggest that clean energy usage can improve environmental quality. For instance, by controlling for the effects of financial development and real output, Usman et al. (2020) reveal that the share of renewables in the total primary energy supply exerts a negative pressure on ecological footprint in the long run using quarterly data from 1985 to 2014 for the United States. Meanwhile, renewable energy is positively linked to ecological footprint in the short run. In examining the determinants of ecological footprint in BRICS economies, Danish et al. (2020) find that an increase in the percentage of total renewable energy consumption could reduce ecological footprint over the period from 1992 to 2016. More recently, Sharma et al. (2021) find that the long-run usage of renewable energy could significantly reduce ecological footprint in 8 developing countries of South and Southeast Asia during the period from 1990 to 2015. Based on a sample of top 22 renewable energy countries, Ansari et al. (2021) find that consumption of renewable energy could provide a negative impact on ecological footprint in the long run. Lastly, a study by Naqvi et al. (2021) demonstrates that consumption of biomass energy could negatively contribute to ecological footprint in high- and low-income countries from1990-2017.

[2]Proposed by Kashem and Rahman (2020).

[3]It is because people in rich countries demand for more resources than citizens in the poor countries

3. Model, Data, And Estimation Procedures

3.1 Theoretical framework, model specification and data

The underlying framework used in this study is the EKC hypothesis which postulates an inverted-U shape relationship between income/economic development and environmental degradation. To realize the objectives of our study, we specify the following function:

$$EF = f(Y, Y^2, UN, CE) \qquad (1)$$

where ecological footprints (EF) is a function of income/economic development (Y), its square term to capture the inverted-U shape relationship (Y^2), unemployment rate (UN), and clean energy (CE) sources. The definition and data sources of the variables are shown in Table 1.

To allow for hypothesis testing and econometric procedures, the function in Equation (1) is transformed into the following double natural logarithm model:

$$lnEF_{it} = \beta_0 + \beta_1 lnY_{it} + \beta_2 lnY^2{}_{it} + \beta_3 lnUN_{it} + \beta_4 lnCE_{it} + \varepsilon_{it} \qquad (2)$$

where β_0 represents the intercept/constant, β_1 to β_4 are parameters to be estimated and ε indicates the residual/error term.

From Equation (2), the EKC hypothesis holds if the coefficient of Y is positive and Y^2 shows the opposite. Next, the environmental Philips curve is valid if β_3 is negative. Clean energy sources are believed to improve environmental quality and therefore β_4 is expected to be negative.

The sample used in this study consists of 36 OECD countries ranged from 1995 to 2015 with a total of 756 observations. The time period chosen depends on data availability to form a balanced panel dataset. [1]

[1] As World Bank does not provide data for alternative and nuclear energy beyond 2015, our data period ends at 2015 to maintain a balanced panel.

3.2 Methodology and estimation procedures

The issue of cross sectional dependence (CSD) has been gaining concern and attention especially in recent panel data analysis, for example Go et al. (2021b); Ng, Choong, and Lau (2020); Ali et al. (2020). The existence of CSD in panel data is attributed by the unobserved factors, shocks, and spillover effects from global financial and economic integration. Hence, the first step in the estimation procedures is the testing for the existence of CSD in the series using Pesaran (2004) CD test. From the CD test, the

existence of CSD in confirmed in the series if the null hypothesis of cross section independence is rejected.
To avoid spurious regression, the next estimation procedure is the panel unit root test to determine the order of integration of each variable. The first generation panel unit root test is not preferred in this study due to potential CSD problem in the series. Hence, this study adopts the second generation panel unit root test that accounts for CSD, namely CIPS test developed by Pesaran (2007).
After the CIPS test, we proceed to test for the existence of cointegration/long-run relationship in Equation (2). Westerlund (2007) proposed an error correction based panel cointegration test that is able to address the issue of CSD by using bootstrapping approach. This test consists of four test statistics with the null hypothesis of no cointegration. The rejection of null hypothesis indicates cointegration/long-run relationship and this allows us to examine the long-run relationship using the the Common Correlated Effect Mean Group (CCEMG) estimator introduced by Pesaran (2006) and the Augmented Mean Group (AMG) estimator proposed by Bond and Eberhardt (2009) and Eberhardt and Teal (2011). Both CCEMG and AMG are robust to CSD as they consider the correlation across panel members.

[4]As World Bank does not provide data for alternative and nuclear energy beyond 2015, our data period ends at 2015 to maintain a balanced panel.

4. Results And Discussion

The results of Pesaran (2004) CD test and CIPS test are presented in Table 2. The CD test statistics of all variables indicate the rejection of null hypothesis of the test. Therefore, it can be concluded that CSD exists in our series. Next, the CIPS test reveals that all variables are stationary after taking first difference, except EF and CE that are stationary at level. Table 3 summarizes the results from Westerlund (2007) cointegration test. The robust p-value for all four test statistics (G_t, G_a, P_t, and P_a) proves the existence of error correction in the model. Hence, cointegration is supported and the long-run estimation is possible using CCEMG and AMG.

Table 4 outlines the long-run estimation using CCEMG and AMG. First, the results from both CCEMG and AMG do not provide evidence to support the EKC hypothesis. It can be observed that GDP and its square term (Y and Y^2) appear to be insignificant. This finding is consistent with the existing finding in the context of several countries, such as Brazil, Russia, India, China, South Africa and Turkey (Dogan et al., 2020), Azerbaijan (Mikayilov et al., 2019), Gulf Cooperation Council countries (Ansari et al., 2020) and China (Yilanci & Pata, 2020; Pata & Caglar, 2021). However, this finding opposes many past studies, for example Ng et al. (2019); Lau et al. (2019); and Ng et al. (2020) that use CO_2 emissions as the indicator for environmental degradation.

Second, the results from CCEMG and AMG further reveal that unemployment rate has a negative impact on ecological footprint. This finding is consistent with the EPC hypothesis as proposed by Kashem and Rahman (2020a) and Anser et al. (2021). The negative impact indicates an inverse relationship between ecological footprint and unemployment. According to our estimation, a 1% increase in unemployment would lead to a decrease of 0.06%-0.07% in ecological footprint. In other words, there is a trade-off between unemployment and environmental degradation. A high level of employment in the economy is associated with poor environmental quality. Therefore, OECD countries face a challenge in ensuring both sustainable economic growth and environmental quality in the future. Besides, the technological advancement could be another factor that contributes to this negative impact (Kashem & Rahman, 2020a). Industries with low technology progress tend to require more labours, resulting in inefficient resource allocation and environmental damage. This demonstrates that OECD countries have yet to develop robust green technologies that can reduce environmental pollution.

Similar to unemployment rate, the role of clean energy has a negative impact on ecological footprint. This is consistent with the findings from Lau et al. (2019) and Ng et al. (2019). Based on the estimates from CCEMG and AMG, it is expected that a 1% increase in clean energy would lead to a decrease of 0.08%-0.09% in ecological footprint. Apparently, the development of alternative energy including nuclear, hydropower, geothermal and solar power plays a significant role in improving environmental quality in the future. Though there are many concerns on nuclear energy's safety, it is undeniably one of the low carbon energy sources when used responsibly. Clean energy is believed to continually replenish resources, allowing for energy efficiency that reduces ecological footprint and helps to mitigate global warming and climate change (Sinha, Shahbaz, & Balsalobre, 2017; Apergis, Jebli, & Youssef, 2018). In contrast, Hastik et al. (2016) argue that renewable energy consumption alone might not be able to alleviate environmental challenges without creating energy-saving production techniques.

Summarizing the above findings, we conclude that the EKC hypothesis is not valid in this study. Though there is a trade-off between unemployment and environmental degradation, the development of technology, especially in clean energy sectors could be a key factor to sustainable growth and environment quality.

5. Conclusion

Despite the positive developments in handling environmental degradation, challenges continue in OECD countries to identify the appropriate environmental and economic policies to produce a "win-win" situation for the economy and the environment. Therefore, this study aims to examine the association between economic growth, unemployment, clean energy and ecological footprint in OECD countries. The results of CCEMG and AMG show that GDP and its square term are insignificant towards ecological footprint which do not support the EKC hypothesis. Interestingly, the existence of EPC is proven with the negative relationship between unemployment rate and environmental degradation. As suggested by Kashem and Rahman (2020a), technological advancement could be a crucial element in reducing or eliminating the trade-off between unemployment and environmental deterioration. In the future, adequate technology and manpower should be devoted toward waste management sector. This would help to improve efficiency from resource consumption to waste absorption, in line with the concept of ecological footprint. Moreover, clean energy is also negatively related to ecological footprint, indicating that the increase of clean energy usage would reduce the environmental pollution in OEDC countries.

The validity of the EPC implies that OECD countries are yet to have a robust green technology that restraint environmental degradation without impairing the countries' employment level. Therefore, government should look into the development of innovative green technology which enables sustainable production and employment opportunity with minimal pollution. The negative impact of clean energy towards ecological footprint also implies that the energy policies should be planned with the consideration of using alternative and nuclear energy while reducing the use of fossil fuels. OECD countries should upsurge investment in clean energy to replace the carbon-intensive production and power generation technology. Lastly, future research should take into account the asymmetric effects of unemployment rate and clean energy on ecological footprint. The comparative study of ecological footprint in developed and developing countries is also recommended for investigation in the future.

Declarations

Ethics approval and consent to participate:

Not applicable

Consent for publication:

Not applicable

Competing interests:

The authors declare no competing interests.

Authors Contributions

Lin-Sea Lau: Introduction; You-How Go: Literature review; Cheong-Fatt Ng: Data collection, econometric analysis, and result interpretation; and Kwang-Jing Yii: Conclusion of the paper. All authors read and approved the final manuscript.

Funding

No funding was received.

Availability of data

The data set used in this paper is from World Bank. It is available from the corresponding author on reasonable request.

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Tables

Table 1. Variables, definition and data sources

Variable	Definition	Source
EF	Ecological Footprint per person	Global Footprint Network
Y	GDP per capita (constant 2010 US$)	WDI, World Bank
Y^2	Square of GDP per capita	WDI, World Bank
UN	Unemployment rate (% of total labor force from International Labour Organization estimate)	WDI, World Bank
CE	Alternative and nuclear energy (% of total energy use). It includes hydropower and nuclear, geothermal, and solar power, among others.	WDI, World Bank

Table 2. Cross sectional dependence and CIPS test

Variable	EF	Y	Y^2	UN	CE
CD	26.75***	99.28***	99.14***	14.28***	18.34***
CIPS Test (level)	-2.900***	-1.738	-1.723	-1.589	-2.615**
CIPS Test (first difference)	-4.927***	-2.614***	-2.605***	-2.516***	-4.552***

Notes: Critical values of the CIPS test (1%) are taken from Pesaran (2007) Table 2b. *** and ** denote significant at 1% and 5%.

Table 3. Westerlund Panel Cointegration test

Statistic	Value	Z-value	p-value	Robust p-value
G_t	-3.291	-7.653	0.000	0.000
G_a	-6.496	2.877	0.998	0.000
P_t	-19.646	-7.850	0.000	0.000
P_a	-7.233	-0.918	0.179	0.020

Table 4. Results of CCEMG and AMG estimations

Dependent variable: EF	CCEMG	AMG
Independent variable	Coefficient	Coefficient
Y	8.524 (1.46) [0.145]	-3.210 (-0.51) [0.612]
Y^2	-0.367 (-1.29) [0.196]	0.209 (0.67) [0.500]
UN	-0.057* (-1.95) [0.051]	-0.067*** (-3.55) [0.000]
CE	-0.090*** (-2.79) [0.005]	-0.079*** (-2.67) [0.008]
Constant	-27.136 (-0.54) [0.590]	14.737 (0.45) [0.653]
Root Mean Square Error	0.0034	0.0041

Notes: ***, ** and * denote significance level at 1%, 5%, and 10%, respectively. Test statistics and p-values are reported in ( ) and [ ], respectively.