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# The energy mix-environmental aspects of income and economic freedom in Hong Kong: cointegration and frequency domain causality evidence

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**ABSTRACT**

Since the inception of the quantification or qualification of global economic freedom, there has been increasing drive and competition towards for better financial freedom among the global economies. However, balancing the drive towards environmental sustainability and economic freedom, especially from the context of the Global Goals, has remained relatively ignored. Thus, this study tries to reveal the nature of the relationship, that is, a U- or inverted U-shaped hypothesis between economic freedom and environmental degradation in the case of Hong Kong Special Administrative Region of the People's Republic of China (HKSAR). As the result of the investigation implied, economic freedom and environmental degradation exhibit a U-shaped relationship against the validity of the environmental Kuznets curve in the relationship between environmental degradation and income. The implication is that economic freedom poses more danger to the environment than income growth, especially when both experiences exponential increase. In any case, Hong Kong's two principal energy sources (coal and oil) constitute a significant source of environmental damage. Moreover, there is Granger-causality evidence with frequency inference in favour of causality between carbon emission and all the explanatory variables except for the fossil oil consumption.

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**KEYWORD**
Economic freedom; environmental quality; energy utilization; frequency-domain causality; Hong Kong

## Highlight

- The environmental sustainability aspect of Hong Kong is examined.
- The economic freedom-carbon emission relationship is U-shaped.
- The income-carbon emission relationship is inverted U-shaped (EKC hypothesis).
- Coal and oil energy consumption significantly hinders the carbon mitigation drive.
- Robustness evidence with frequency domain causality approach.

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## 1. Introduction

In the last few decades, countries' economic freedom has been qualitatively and quantitatively measured by applying several indicators of the aspects of the economy (Fraser Institute 2020; Heritage 2020a). In the last 25 years, according to The Heritage Foundation report, Hong Kong Special Administrative Region of the People's Republic of China has been the world's topmost country in terms of economic freedom (Heritage 2020b). Although the country lost this position, as indicated in the 2021 report, due to the recent internal unrest bothering around its autonomous status, the investigation period in the current study (1995–2018) is well-situated for the objective of the study. Then, if the period of dominance of Hong Kong as the world leader in economic freedom is anything to standby, it is expected that the country's economic prosperity would not have been void of setbacks that are associated with environmental aspects. Given the evidence that environment-related issue is sometimes associated with economic aspects and subsequently, the likelihood of the environmental Kuznets curve hypothesis (Grossman and Krueger 1995; Stern 2004; Shahbaz and Sinha 2019; Adedoyin, Alola, and Bekun 2020), making similar inference for economic freedom is an expected subject of interest. Hong Kong, with a Gross Domestic Product of 311.57 billion (in 2015 United States Dollars) and a population of about 7.5 million people, has experienced significant growth in total primary energy supply (of over 50% increase), electricity final consumption (of about 100% increase) and total carbon dioxide emission (of about 25% increase) compared to its 1990 energy and emission status (International Energy Agency 2020).

However, the comprehensively perceived nature of economic freedom is, until now, yet to be linked with environmental sustainability. Being one of the rare studies that present the nexus of economic freedom and environmental quality, thus the current study contributes to the body of knowledge by expanding the concept in Saint Akadiri, Alola, and Usman (2021) and Alola and Nwulu (2021). Additionally, this study reveals the evidence for or against the EKC hypothesis in the framework of economic freedom-environment degradation nexus in place of income-environmental degradation (conventional EKC hypothesis) nexus. This is because economic freedom offers a more comprehensive economic perspective compared to income. Importantly, the case of Hong Kong Special Administrative Region of the People's Republic of China (HKSAR) is considered for the study because (1) no previous study has demonstrated the nexus trade-off and/or the EKC hypothesis for the country and (2) Hong Kong has consistently maintained the top spot of the economic freedom index ranking of the last decade. Lastly, the aforementioned result is further compared with the validity of the conventional EKC hypothesis for the country in addition to illustrating the environmental impact of coal and oil. Considering the resilience of the country's energy sector (Aldieri, Gatto, and Vinci 2021), the aforementioned energy sources are the country's two main energy consumption profiles.

In line with the study objective, the review of related literature is presented in Section 2, while the dataset description and empirical method is outlined in Section 3. In Sections 4 and 5, we discuss the result of the study and outline the conclusion with policy insight.

## 2. Literature review

As defined from the dimension of individualism, Economic freedom measures the capacity of an individual to take ownership of property or asset in the absence of force, fraud or illegality, and that such acquisition is shielded from any form of intrusion by anyone. Moreover, Gwartney and Lawson (1997) further mentioned that such mentioned acquisitions are made available for others to use for personal motive, use as a medium of exchange, or sometimes donated inform of gift to others, but without constituting a danger or obstruction to the rights of others. Similarly, O'Driscoll, Feulner, and O'Grady (2003) defined economic freedom as a condition in which individuals are free to work, produce, spend, and invest as they wish. Economic freedom is often viewed as an important element for enhancing incentives, efficient resource use and improving productivity (Carlsson and Lundstrom 2001). More recently, the aforementioned definition of economic freedom in the form of the fundamental right of a human to control and dominate own property or labour has been empirically illustrated in association with socioeconomic and environmental aspects (Alola and Nwulu 2021; Saint Akadiri, Alola, and Usman 2021).

A vast body of literature using the Kuznets curve has explored the impact of economic growth on the environment, and some of them have concluded that economic growth in most countries is at the expense of environmental quality (Nathiel, Yalciner, and Bekun 2021; Sarkodie and Strezov 2019; Raggad 2018), while others have argued that economic growth comes with improved technology, change in economic activities and higher environmental awareness all of which lead to an improved environmental quality (Deacon and Norman 2004; Muhammad 2019).

Additionally, other studies have focused on the nexus of economic freedom and the trend of economic growth. Heckleman (2000) also examined the relationship between economic freedom and economic growth for a cross-section of 147 nations and established that the average level of freedom and many other underlying components of freedom precedes growth. Hussain and Haque (2016) used the economic freedom index from two panel data-sets computed by the Heritage foundation and concluded that the index has a positive impact on the growth rate of per capita GDP. Additionally, Brkić, Gradojević, and Ignjatijević (2020), using the Heritage foundation dataset, examined the impact of economic freedom alongside other economic factors on economic growth using 43 developed and developing European countries over 20 years and established that economic freedom index, not its levels are related to economic growth. Although most studies have established a level of a positive association between freedom of economic aspects and economic growth, there is still an on-going debate as to if economic freedom is good or bad for the environment, whether it increases or decreases environmental progress within a country as it pursues economic growth.

Utilizing an unbalanced dataset for 75 countries during 1975–1995, Carlsson and Lundstrom (2001) examined the level of environmental effect arising from using $CO_2$ emission as an environmental indicator. The study found that increased economic freedom in small government size decreases $CO_2$ emissions but increases emissions when the government size is large. Additionally, for 22 OECD and 87 non-OECD countries, Joshi and Beck (2018) found a conflicting relationship between economic freedom and $CO_2$ emissions depending on the type of government and the state of development. However, for the most part, the government that extends economic freedoms by increasing the scale of their economy-encouraging the expansion of businesses will generate more emissions. Furthermore, Graafland (2019) examined the role of small government and freedom from government regulations on the corporate environmental responsibility for 41 countries and 5023 companies for 2005–2014. The study posits that small government size and freedom from government regulations decrease corporate environmental responsibility by discouraging corporate environmental responsibility of companies. Also, findings from 4338 small-medium-sized enterprises from 12 European countries revealed that economic freedom and corporate environmental performance interact with each other Graafland and Gerlagh (2019).

For 194 countries, Hartwell and Coursey (2015) found that economic freedom has environmental rewards and that smaller government, increased property rights and economic growth are important factors for the improvement of the environment. Similarly, for 23 European countries, Rapsikevicius et al. (2021) found that higher economic freedom leads to higher environmental progress during 2005–2018 with economic freedom progress increasing more rapidly than environmental performance.

Furthermore, for 111 countries, Wood and Herzog (2014) found an inverse relationship between economic freedom and $CO_2$ emissions for 2000 and 2010 when the economy is in the short run. Saint Akadiri, Alola, and Usman (2021) found that economic freedom triggers carbon mitigation in the short run, while the opposite holds in the long run, affirming a U-shaped relation in the short run and an inverted U-shaped relationship in the long run for BRICS economy over 1995–2018.

## 3. Variables and method

In driving home the objective of this study for the novel case of Hong Kong (Hong Kong Special Administrative Region of the People's Republic of China (HKSAR)), the dataset comprises the emissions of carbon dioxide (measured of in million tonnes of $CO_2$ and denoted here as CEM), the Gross Domestic Product per capita (measured in USD 2010 constant and denoted here as GDP), the index of economic freedom (is denoted here as EFI, is an index for the aspects of economic freedom),[1] coal energy (is measured in a million tonnes oil equivalent, denoted here as COAL), natural gas energy (is measured in a million tonnes oil equivalent and denoted here as NGAS), and oil energy (is measured in a million tonnes oil equivalent and denoted here as OIL). Except for the EFI, the balanced dataset was retrieved from the database of BP (British Petroleum 2020). Additionally, we employed the natural logarithm of the series except for the EFI series, and the dataset covers 1995–2018. The measurement of EFI is based on twelve (12) quantitative and qualitative factors categorised under Rule of Law, Government Size, Regulatory Efficiency, and Open Markets.

Furthermore, the common statistics and the evidence of correlation among the employed variables are presented in Table 1. In the illustration, the EFI deviates from the mean more than other variables, while the standard deviation of the natural gas consumption is the lowest. Also, all the series are normally distributed except the natural gas consumption (NGAS), which is then dropped in the succeeding estimation. There is significant evidence of a correlation between the dependent and the explanatory variables (lower part of Table 1), and a correlation between CEM and GDPC, EFI, COAL, and OIL at a 1% statistical level. However, no statistically significant correlation is observed between CEM and NGAS.

### *3.1. Empirical methods*

The link between economic expansion or income and environment (later affirmed as the Environmental Kuznets curve) has been widely illustrated in the extant literature since the emergence of the pioneering and related studies (Grossman and Krueger 1991, 1995; Stern 2004). Recently, the literature has been flooded with the investigation of the EKC validity for several economies (Bekun et al. 2021; Onifade et al. 2021a, 2021b; -Gyamfi et al. 2022). In this case, economic freedom,

**Table 1.** Statistical Properties of the explored variables.

| Variables | CEM | GDPC | EFI | COAL | NGAS | OIL |
|---|---|---|---|---|---|---|
| *Common statistics* | | | | | | |
| Mean | 4.307609 | 10.25951 | 89.47500 | 1.800644 | 0.836492 | 2.679554 |
| Median | 4.376362 | 10.31136 | 89.70000 | 1.901815 | 0.885069 | 2.743499 |
| Maximum | 4.600168 | 10.56371 | 90.50000 | 2.097402 | 1.128350 | 3.099310 |
| Minimum | 3.892714 | 9.963713 | 88.00000 | 1.256470 | 0.399865 | 2.221294 |
| Std. Dev. | 0.244838 | 0.211042 | 0.648242 | 0.238524 | 0.173226 | 0.277989 |
| Skewness | −0.667861 | −0.080859 | −0.732839 | −1.044275 | −1.106054 | −0.364676 |
| Kurtosis | 1.938524 | 1.437946 | 2.516708 | 2.867799 | 3.844935 | 1.863358 |
| Jarque-Bera | 2.910886 | 2.466166 | 2.381781 | 4.379514 | 5.607334 | 1.823908 |
| Probability | 0.233297 | 0.291393 | 0.303950 | 0.111944 | 0.060587 | 0.401738 |
| Observations | 24 | 24 | 24 | 24 | 24 | 24 |
| *Correlation matrix* | | | | | | |
| CEM | 1.000 | | | | | |
| GDPC | 0.930* | 1.000 | | | | |
| EFI | 0.456** | 0.354*** | 1.000 | | | |
| COAL | 0.862* | 0.714* | 0.438** | 1.000 | | |
| NGAS | 0.311 | 0.391** | −0.171 | −0.047 | 1.000 | |
| OIL | 0.985* | 0.949* | 0.443** | 0.775* | 0.354*** | 1.000 |

Note: CEM, GDPC, EFI, COAL, NGAS, and OIL are the emissions of carbon dioxide, Gross Domestic Product per capita, economic freedom indicator, coal consumption, natural gas consumption, and oil consumption. In addition, *, **, and *** are the respective statistical significance at 1%, 5%, and 10%.

which comprehensively measures the economic aspects in terms of progressiveness of the people within the concept of 12 qualitative and quantitative indicators, is examined alongside environmental quality.

Indicatively, the nexus of EFI and quality of the environment, i.e., carbon emission, is compared with the nexus of economic growth (GDPC) and environmental quality within the framework of EKC in two models as

$$\mathrm{CEM} = \mathrm{f}(\mathrm{EFI},\ \mathrm{EFIsq},\ \mathrm{COAL},\ \mathrm{OIL}) \tag{1a}$$

$$\mathrm{CEM} = \mathrm{f}(\mathrm{GDPC},\ \mathrm{GDPCsq},\ \mathrm{COAL},\ \mathrm{OIL}) \tag{1b}$$

Considering the small number of observations and the desire to explore short- and long-term nexus from the aforementioned models (Equations 1a and 1b), the study explores the choice of the Autoregressive Distributed Lag (ARDL). Additionally, as an essential procedure, the unit root evidence was investigated and returned with desirable results, thus providing a suitable ground for using the ARDL approach. The likelihood of a U- or inverted U-shaped hypothesis is illustrated for the distinct cases of EFI-environmental quality (from Equation 1a) and income – environmental quality (from Equation 1b) nexus. Without providing the step-wise method of the ARDL empirical technique of Pesaran, Shin, and Smith (2001), the results of the estimation and the evidence of diagnostic are available in the lower part of Table 2. Moreover, the periodograms illustrated in Figures A1–A5 and the Johansen and Juselius (1990) cointegration evidence in Table A1 of the Appendix further provided a priori evidence, justifying the estimation of the models (Equations) 1a and 1b.

**Table 2.** The ARDL findings.

| GDP | S | L |
|---|---|---|
| Independent variables | Coefficient | Coefficient |
| CEM(−1) | 0.010[A] | |
| GDPC | 0.362 | 4.542[A] |
| GDPCsq | −0.020 | −0.217[A] |
| COAL | 0.267[A] | 0.240[A] |
| OIL | 0.685[A] | 0.617[A] |
| Adjustment parameter | −1.393[A] | C = −21.520[A] |
| *Diagnostic* | | |
| Wald test: F-statistic = 611.345[A] (0.000) | | |
| Serial correlation: F-statistic = 2.918 (0.103) | | |
| Heteroscedasticity: F-statistic = 0.765 (0.660) | | |
| Skewness = −0.008; Kurtosis = 2.043; Normality test = Normal | | |
| Stability test with CUSUM and CUSUMSQ = Stable | | |

Note: A, B, and C denote the statistical significance at 1%, 5%, and 10%, respectively. Where CUSUM and CUSUMSQ are cumulative sum and cumulative sum of squares, respectively. The correlation test is performed by Breusch-Godfrey LM, while the heteroscedasticity test is performed by Breusch-Pagan-Godfrey.

| EFI | S | L |
|---|---|---|
| Independent variables | Coefficient | Coefficient |
| CEM(−1) | 0.062[C] | |
| EFI | −2.374[C] | −9.190[B] |
| EFIsq | 0.013[C] | 0.051[B] |
| COAL | 0.347[A] | 0.324[A] |
| OIL | 0.716[A] | 0.669[A] |
| Adjustment parameter | −1.071[A] | C = 412.251[A] |
| *Diagnostic* | | |
| Wald test: F-statistic = 141.115[A] (0.000) | | |
| Serial correlation: F-statistic = 0.106 (0.900) | | |
| Heteroscedasticity: F-statistic = 0.649 (0.738) | | |
| Skewness = 0.291; Kurtosis = 2.341; Normality test = Normal | | |
| Stability test with CUSUM and CUSUMSQ = Stable | | |

Note: A, B, and C denote the statistical significance at 1%, 5%, and 10%, respectively. Where CUSUM and CUSUMSQ are cumulative sum and cumulative sum of squares, respectively. The correlation test is performed by Breusch-Godfrey LM, while the heteroscedasticity test is performed by Breusch-Pagan-Godfrey.

### 3.1.1. Robustness check

To provide additional information or inference from the frequency dynamics, as captured by the periodograms in Figures A1–A5 of the Appendix, the current study employs the Granger causality technique to provide the causality nexus between carbon emission and the explanatory variables (GDPc, EFI, Coal, and Oil). Through the Granger causality approaches of Granger (1969), Geweke (1982), and Hosoya (1991), the latest Breitung and Candelon (2006) approach modified the Granger causality technique that is built on the newer approaches of Toda and Yamamoto (1995), and Dolado and Lütkepohl(1996). Breitung and Candelon (2006) provide a Granger causality relationship in the frequency domain irrespective of the order of integrating the variables or even when there is no evidence of cointegration. Thus, the current study relies these advantages by employing the Wald test of the Granger causality approach of Breitung and Candelon (2006). The modification proposed by Breitung and Candelon (2006) for the frequency domain test is given as

$$x_t = c_1 + \sum_{j=1}^{p} \alpha_j x_{t-j} + \sum_{j=1}^{p} \beta_j y_{t-j+} \sum_{k=p+1}^{p+d_{\max}} \alpha_k x_{t-k} + \sum_{k=p+1}^{p+d_{\max}} \beta_k y_{t-k} + \mu_t \quad (2)$$

provided that $d_{\max} > 0$. In this case, where $x_t$ and $y_t$ are the pair of variables to be examined for mutual Granger causality evidence (such as $CO_2$ and GDPc, $CO_2$ and EFI, $CO_2$ and Coal, and $CO_2$ and Oil) over the experimental period $t$, given frequency $\omega$, and lag length $j = 1, \ldots, p$. Consequently, the null hypothesis $H_0 := M_{y \to x}(\omega) = 0$ (of no Granger causality from $y$ to $x$) involving only $\beta_j$ is now determined. In Breitung and Candelon (2006), the details and further guidance for the estimation procedures are available.

## 4. Discussion of result

The impact of economic freedom on environmental degradation ($CO_2$) in the short- and long-run is negative, implying that economic freedom improves the environment (see Table 2). İn the long run, the effect of EFI (economic freedom) on $CO_2$ is larger (9.190 units) than in the short run (2.374 units), indicating a significantly increasing impact. This result implies that the freer the people of Hong Kong economically, the better the environmental quality. It is also interesting to deduce that the economic freedom attained by people and the economy of the country will cause a more sustainable environment in the long run. However, the square of economic freedom index (EFIsq) on carbon emissions is positive in the short- and long run, i.e. a 1 unit increase in EFIsq is responsible for 0.013 and 0.051 unit million tonnes equivalent of $CO_2$ in the short and long run, respectively. This evidence implies that when the people and/or the country's economy experiences a doubled fold of economic freedom, or the economic freedom attains a certain threshold, its effect begins to hamper environmental sustainability. Notably, the environmental effect from the impact of EFI and EFIsq constitutes a U-shaped (of EFI and environmental degradation) relationship. Although Hong Kong currently demonstrates the highest economic freedom globally, this implies that the environmental quality of the country will be jeopardized when the economic freedom attribute surpasses a certain threshold. Thus, this suggests a trade-off relationship between economic freedom and environmental quality, especially at a certain attainable economic freedom, as also established in the case of Russia in Alola and Nwulu (2021).

On the other hand, the income (GDPC)-environmental degradation relationship, in this case, depicts an inverted U-shaped, i.e. EKC hypothesis (see Table 2). This is because a 1% increase in the GDPC, and the GDPsq causes a 0.362% rise and (−) 0.020% decline in carbon emissions in the short run. İn the long run, the impact of the GDPC (4.542%) and GDPCsq (−0.217%) is larger and statistically significant at 1% in the long run. İndicatively, the study supported an inverted U-shaped (EKC) hypothesis between income and environmental degradation in the short and long run for the case of Hong Kong. Unfortunately, no previous study has exactly illustrated/investigated the EKC hypothesis for the case of Hong Kong. However, the result of the EKC hypothesis in the

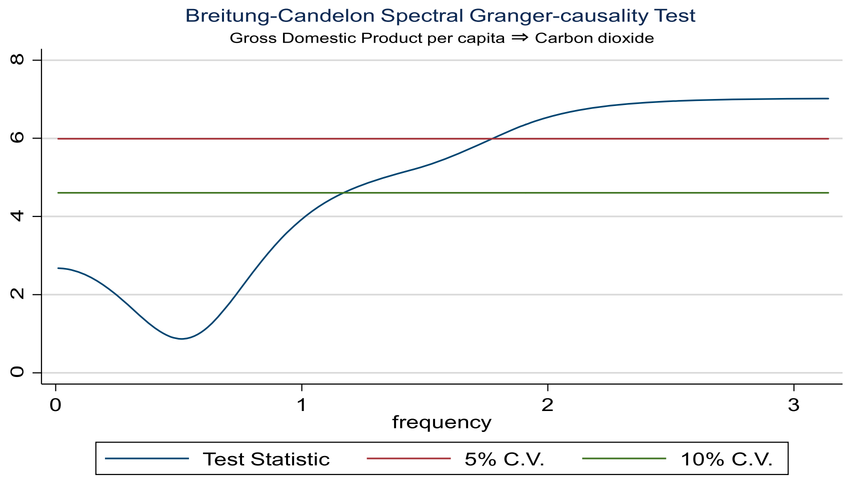


**Figure 1.** Evidence of causality from GDPc to $CO_2$.

current study is contrary to the economic freedom-environmental degradation relationship, which is an exact also result demonstrated by Alola and Nwulu (2021).

Furthermore, this study examined the impact of the two most utilized energy sources (Coal and oil consumption) on carbon emissions in Hong Kong. In the two examined models (from Equations 1a and 1b), the impact of coal consumption and oil consumption on carbon emissions is positive in the short and long run. However, the impact of the two energy sources on carbon emissions in the long run is significantly minimized, indicating that the energy sources cause minimal emissions of million tonnes equivalent of $CO_2$ compared to the short-run case. Additionally, in the economic freedom model, the impact of coal and oil energy utilization on carbon emissions is significantly more severe in the short and long run, thus suggesting a higher energy utilization that results in severe environmental damage when economic freedom is prioritized in the country. This evidence lauds the study of Gasmi, Recuero Virto, and Couvet (2020) that opined on the adoption of a policy that balances the energy mix, especially towards achieving sustainable growth.

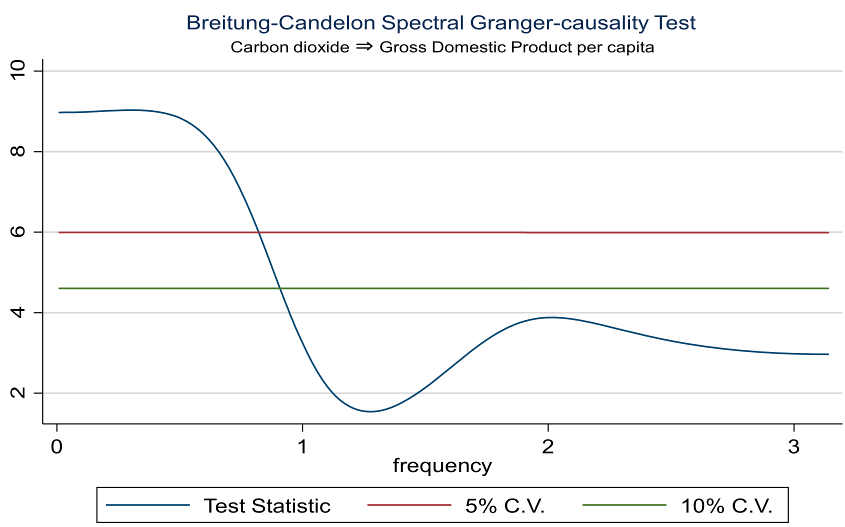


**Figure 2.** Evidence of causality from $CO_2$ to GDPc.

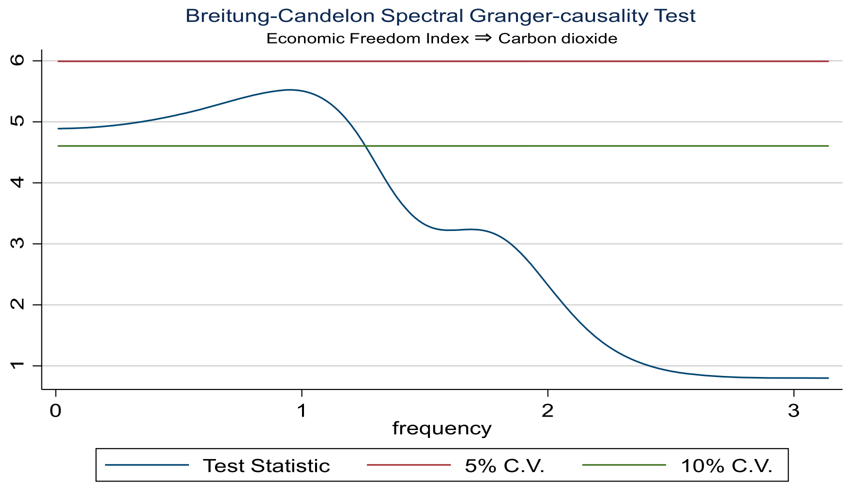


**Figure 3.** Evidence of causality from EFI from $CO_2$.

Moreover, a series of diagnostic tests, as indicated in the lower part of Table 2, further provided robust evidence in support of the estimation techniques and results. İn specific, the tests for serial correlation and the heteroskedasticity assert that the estimations are unperturbed by concerns related to serial correlation and heteroskedasticity, respectively. Additionally, as presented in the above models, there is significant evidence of a short-run relationship as suggested by the Wald test. İn addition to the evidence of skewness and peaks by the respective information from skewness and kurtosis estimations, the series are jointly distributed normally. This is per the normality test. Generally, the estimated models are statistically stable, due to the cumulative sum and the squared cumulative sum results.

### 4.1. Robustness evidence

Given the inference from the log of the periodogram for GDPc and EFI in Figure A1 and Figure A2, respectively, there is significant evidence that the periodogram peaks at almost the same frequency

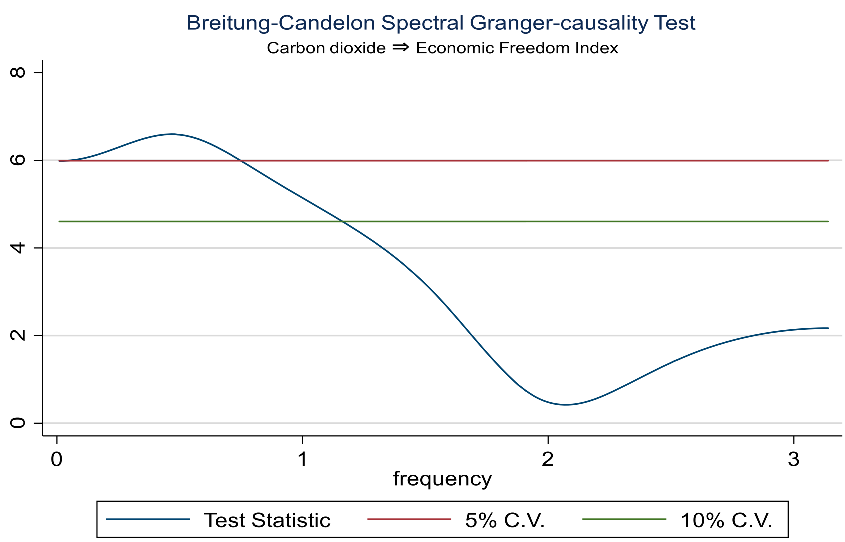


**Figure 4.** Evidence of causality from $CO_2$ to EFI.

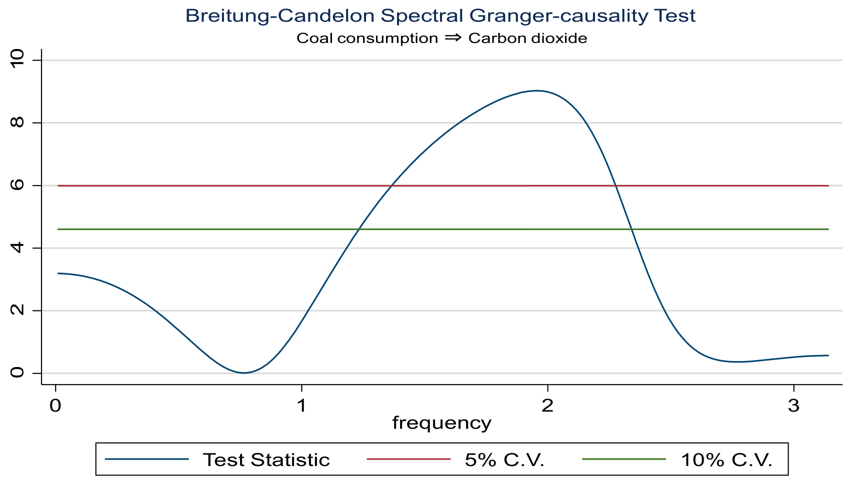


**Figure 5.** Evidence of causality from coal to $CO_2$.

of about 0.05 per year for the variables. Given that the period is a reciprocal of frequency, this corresponds to about a 20-year cycle (a similar trend experienced) in each of GDP and EFI aspects. Similarly, coal and oil energy consumption, as illustrated in Figures A4 and A5, expectedly mimics the pattern of frequency and periodical trend.

Moreover, the Breitung and Candelon (2006) Granger causality result offers additional frequency-related inference. For instance, the result provides evidence of bi-directional Granger causality from GDPc to $CO_2$ emission but only at specific frequencies. At the same time, there is evidence of Granger causality from a frequency of about 1.8 (at a 5% statistically significant level) or about a frequency of 1.2 at a 10% statistically significant level and beyond (see Figure 1), Granger causality from $CO_2$ emission to GDPc is only 5% statistically significant between the frequency of 0 and approximately 0.8 (see Figure 2). Interestingly, the evidence here shows that economic freedom Granger causes $CO_2$ emission with feedback (see Figure 3 and 4) both at the same frequency of about 1.2 at a 10% statistically significant level. This evidence further

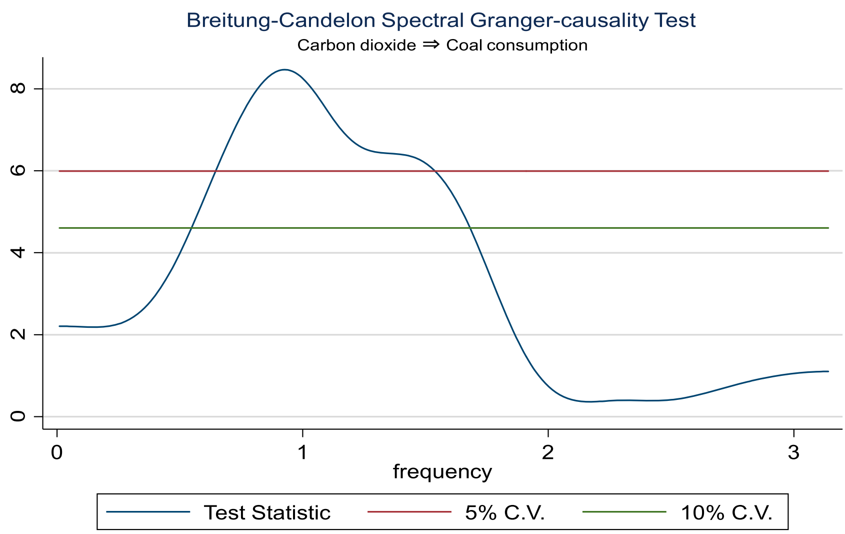


**Figure 6.** Evidence of causality from $CO_2$ to coal.

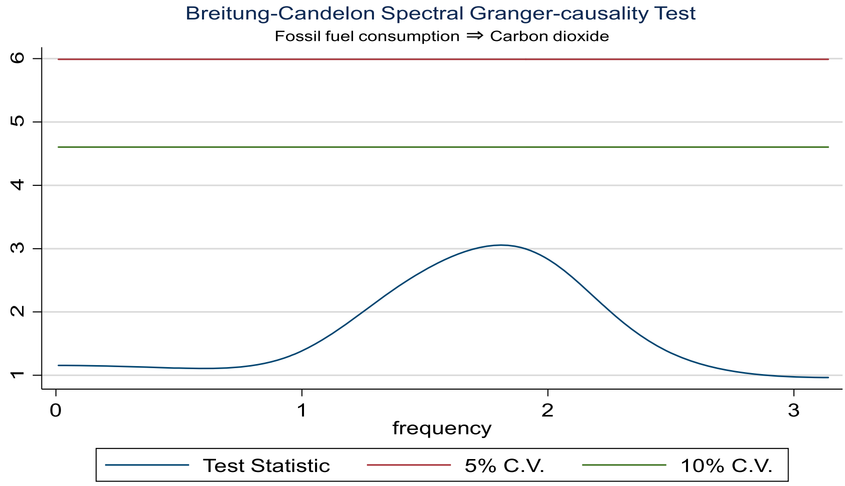


**Figure 7.** Evidence of causality from oil to $CO_2$.

corroborates the aforementioned Granger-causality evidence from GDPc to $CO_2$ emission in Figure 1. Furthermore, the Granger causality from coal energy consumption to $CO_2$ emission as illustrated in Figure 5 occurs during frequency (1.5, 2.2) at a 5% statistically significant level, while the reverse occurs at the frequency (0.5, 1.5) also at 5% statistically significant level (see Figure 6). However, no statistical evidence of frequency-related Granger causality is found between conventional energy consumption and $CO_2$ emission (Figures 7 and 8).

## 5. Conclusion with policy concern

This is a presentation of a unique perspective of environmental sustainability because the EKC hypothesis is investigated and that the EFI concept is adopted to breach an existing gap in the literature, especially for Hong Kong. The study adopted a two-model approach to illustrate the EKC hypothesis by employing the GDP per capita, economic freedom, coal energy utilization, and oil

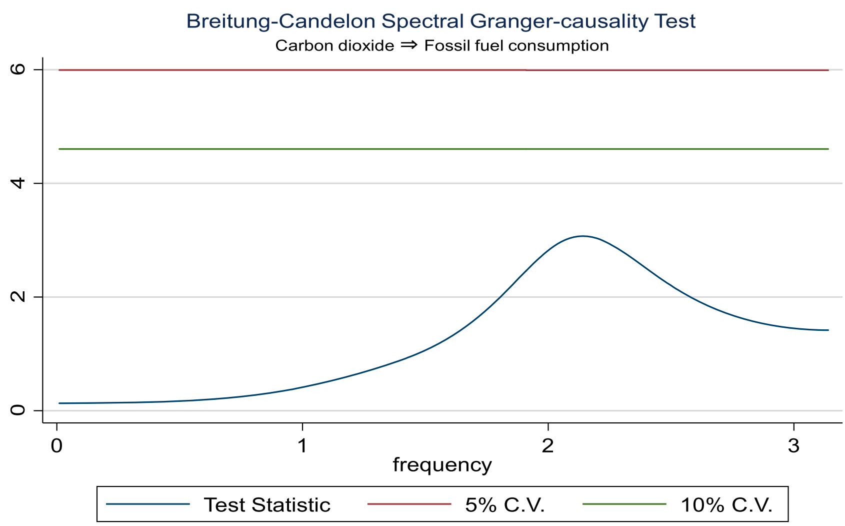


**Figure 8.** Evidence of causality from $CO_2$ to oil.

energy utilization over a period 1995–2018. Here, the investigation provides evidence of the U-shaped nexus between EFI and environmental degradation while validating the EKC hypothesis when GDP is employed as an economic-related variable in the short and long run. However, Breitung and Candelon (2006) Granger causality offers statistical evidence of causality between carbon emission and all the explanatory variables except for the fossil oil consumption. İmportantly, the study found significantly larger impacts of economic freedom, coal energy consumption, and oil energy consumption on carbon emissions in the short and long run as against the GDPC model. Thus, this study identifies useful policies for the government of Hong Kong, other governments across the globe, and intergovernmental agencies.

In view that Hong Kong has once retained the highest-ranking on the economic freedom index except for the latest report released in 2021, this study opined that the long years of such accomplishment could not be free from environmental-related short-comings. Thus, as a policy insight, an environmental hazard resulting from economic freedom could be avoided in the immediate and long term by incorporating the dimensions of environmental sustainability practices in societal and economic-wide institutions. Considering that the environmental sustainability of the country begins to deteriorate after a specific threshold, especially when an exceedingly (twice) economic freedom is allowed, a relevant co-benefit policy should be the suitable approach to thwarting the environmental short coming that comes along with economic freedom.

An obvious weakness in this study is that political factor is not specifically accounted for in the model, which could be undoing considering the country's political configuration. Thus, future studies could possibly account for the political effect in the model. Moreover, there is a sparse study on the economic freedom-environmental sustainability nexus, and this could be a new direction for researchers and policy-makers in environmental-related studies.

## Note

1. The EFI provides a measure of the general dimension economic freedom with detail information provided at https://www.heritage.org/index/about.

## Disclosure statement

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## References

Adedoyin, F. F., A. A. Alola, and F. V. Bekun. 2020. "An Assessment of Environmental Sustainability Corridor: The Role of Economic Expansion and Research and Development in EU Countries." *Science of The Total Environment* 713: 136726.

Aldieri, L., A. Gatto, and C. P. Vinci. 2021. "Evaluation of Energy Resilience and Adaptation Policies: An Energy Efficiency Analysis." *Energy Policy* 157: 112505.

Alola, A. A., and N. Nwulu. 2021. "Income vs. Economic Freedom Threshold and Energy Utilities in Russia: An Environmental Quality variableness?" *Environmental Science and Pollution Research* 28 (26): 35297–35304.

Bekun, F. V., B. A. Gyamfi, S. T. Onifade, and M. O. Agboola. 2021. "Beyond the Environmental Kuznets Curve in E7 Economies: Accounting for the Combined Impacts of Institutional Quality and Renewables." *Journal of Cleaner Production* 314: 127924.

Breitung, J., and B. Candelon. 2006. "Testing for Short- and Long-Run Causality: A Frequency-Domain Approach." *Journal of Econometrics* 132 (2): 363–378.

British Petroleaum. 2020. *BP Statistical Review of World Energy June 2019*. Accessed July 28, 2021. https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-statistical-review-of-world-energy-2019.html.

Brkić, I., N. Gradojević, and S. Ignjatijević. 2020. “The Impact of Economic Freedom on Economic Growth?” *New European Dynamic Panel Evidence. Journal of Riskand Financial Managment* 13 (2): 1–13.
Carlsson, F., and S. Lundstrom. 2001. “Political and Economic Freedom and the Environment: The Case of $CO_2$ Emissions.” In *Working Papers in Economics*, 29. Second version August 2001.
Deacon, R., and C. S. Norman. 2004. “Is the Environmental Kuznets Curve an Empirical Regularity?” In *University of California at Santa Barbara, Economics Working Paper Series qt2m44f7kr*. Department of Economics, UC Santa Barbara.
Dolado, J. J., and H. Lütkepohl. 1996. “Making Wald Tests Work for Cointegrated VAR Systems.” *Econometric Reviews* 15 (4): 369–386.
Fraser Institute. 2020. *Economic Freedom*. Accessed July 30, 2021. https://www.fraserinstitute.org/studies/economic-freedom.
Gasmi, F., L. Recuero Virto, and D. Couvet. 2020. "The Impact of Renewable Versus Non-Renewable Natural Capital on Economic Growth." *Environmental and Resource Economics* 77 (2): 271–333.
Geweke, J. 1982. “Measurement of Linear Dependence and Feedback Between Multiple Time Series.” *Journal of the American Statistical Association* 77 (378): 304–313.
Graafland, J. 2019. “Economic Freedom and Corporate Environmental Responsibility: The Role of Small Government and Freedom from Government Regulation.” *Journal of Cleaner Production* 218: 250–258.
Graafland, J., and R. Gerlagh. 2019. “Economic Freedom, Internal Motivation, and Corporate Environmental Responsibility of SMEs.” *Environmental and Resource Economics* 74: 1101–1123.
Granger, C. W. 1969. “Investigating Causal Relations by Econometric Models and Cross-Spectral Methods.” *Econometrica: Journal of the Econometric Society* 37: 424–438.
Grossman, G. M., and A. B. Krueger. 1991. *Environmental Impacts of a North American free Trade Agreement* (No. w3914). National Bureau of economic research.
Grossman, G. M., and A. B. Krueger. 1995. "Economic Growth and the Environment." *The Quarterl Journal of Economics* 110 (2): 353–377.
Gwartney, J., and R. A. Lawson. 1997. *Economic Freedom of the World 1997 Annual Report*. Accessed October 10, 2021 https://www.fraserinstitute.org/sites/default/files/EconomicFreedomoftheWorld_1997.pdf.
Gyamfi, B. A., S. T. Onifade, C. Nwani, and F. V. Bekun. 2022. “Accounting for the Combined Impacts of Natural Resources Rent, Income Level, and Energy Consumption on Environmental Quality of G7 Economies: A Panel Quantile Regression Approach.” *Environmental Science and Pollution Research* 29 (2): 2806–2818.
Hartwell, C. A., and D. L. Coursey. 2015. “Revisiting the Environmental Rewards of Economic Freedom.” *Economics and Business Letters* 4 (1): 36–50. doi:10.17811/ebl.4.1.2015.36-50.
Heckleman, J. C. 2000. “Economic Freedom and Economic Growth: A Short Run Causal Investigation.” *Journal of Applied Economics* 3 (1): 71–91.
Heritage. 2020a. *2020 Index of Economic Freedom*. Accessed July 28, 2020. https://www.heritage.org/index/about.
Heritage. 2020b. *Hong Kong Is No Longer What It Was*. Accessed November 5, 2021. https://www.heritage.org/asia/commentary/hong-kong-no-longer-what-it-was.
Hosoya, Y. 1991. “The Decomposition and Measurement of the Interdependency Between Second-Order Stationary Processes.” *Probability Theory and Related Fields* 88 (4): 429–444.
Hussain, M. E., and M. Haque. 2016. “Impact of Economic Freedom on the Growth. A Panel Data Analysis.” *Economies* 4 (2): 5. doi:10.3390/economies4020005.
International Energy Agency. 2020. Accessed November 4, 2021. https://www.iea.org/countries/hong-kong.
Johansen, S., and K. Juselius. 1990. “Maximum Likelihood Estimation and Inference on Cointegration – With Appucations to the Demand for Money.” *Oxford Bulletin of Economics and Statistics* 52 (2): 169–210.
Joshi, P., and K. Beck. 2018. “Democracy and Carbon Dioxide Emissions: Assessing the Interactions of Political and Economic Freedom and the Environmental Kuznets Curve.” *Energy Research & Social Science* 39: 46–54.
Muhammad, B. 2019. “Energy Consumption, $CO_2$ Emissions and Economic Growth in Developed, Emerging and Middle East and North Africa Countries.” *Energy* 179: 232–245.
Nathiel, S. P., K. Yalciner, and F. V. Bekun. 2021. “Assessing the Environmental Sustainability Corridor: Linking Natural Resources, Renewable Energy, Human Capital, and Ecological Footprint in BRICS.” *Resource Policy* 70: 101924.
O’Driscoll, G. P. Jr, E. J. Feulner, and M. A. O’Grady. 2003. *2003 Index of Economic Freedom*. Washington, DC: Heritage Foundation and Dow Jones and Company.
Onifade, S. T., A. A. Alola, S. Erdoğan, and H. Acet. 2021a. “Environmental Aspect of Energy Transition and Urbanization in the OPEC Member States.” *Environmental Science and Pollution Research* 28 (14): 17158–17169.
Onifade, S. T., S. Erdoğan, M. Alagöz, and F. V. Bekun. 2021b. “Renewables as a Pathway to Environmental Sustainability Targets in the era of Trade Liberalization: Empirical Evidence from Turkey and the Caspian Countries.” *Environmental Science and Pollution Research* 28 (31): 41663–41674.
Pesaran, M. H., Y. Shin, and R. J. Smith. 2001. “Bounds Testing Approaches to the Analysis of Level Relationships.” *Journal of Applied Econometrics* 16 (3): 289–326.

Raggad, B. 2018. "Carbon Dioxide Emissions, Economic Growth, Energy use, and Urbanization in Saudi Arabia: Evidence from the ARDL, Approach and Impulse Saturation Break Tests." *Environmental Science and Pollution Research* 23: 14882–14898. doi:10.1007/s11356-018-1698-7.

Rapsikevicius, J., J. Bruneckiene, M. Lukauskas, and S. Mikalonis. 2021. "The Impact of Economic Freedom on Economic and Environmental Performance: Evidence from European Countries." *Sustainability* 13: 2380. doi:10.3390/su13042380.

Saint Akadiri, S., A. A. Alola, and O. Usman. 2021. "Energy Mix Outlook and the EKC Hypothesis in BRICS Countries: A Perspective of Economic Freedom vs. Economic Growth." *Environmental Science and Pollution Research* 28 (7): 8922–8926.

Sarkodie, S. A., and V. Strezov. 2019. "A Review on Environmental Kuznets Curve Hypothesis Using Bibliometric and Meta-Analysis." *Science of the Total Environment* 649: 128–145.

Shahbaz, M., and A. Sinha. 2019. "Environmental Kuznets Curve for CO2 Emissions: A Literature Survey." *Journal of Economic Studies* 46 (1): 106–168. https://doi.org/10.1108/JES-09-2017-0249.

Stern, D. I. 2004. "The Rise and Fall of the Environmental Kuznets Curve." *World Development* 32 (8): 1419–1439.

Toda, H. Y., and T. Yamamoto. 1995. "Statistical Inference in Vector Autoregressions with Possibly Integrated Processes." *Journal of Econometrics* 66 (1-2): 225–250.

Wood, J., and I. Herzog. 2014. *Economic Freedom and Air Quality* (April 22, 2014). Fraser Institute, Vancouver, Canada, April 2014. https://ssrn.com/abstract=2539809.

## Appendix

**Table A1** . Cointegration evidence.

| | | | | |
|---|---|---|---|---|
| *A model with economic freedom (EFI)* | | | | |
| Unrestricted cointegration rank test (Trace) | | | | |
| Nounber of CE(s) | Eigenvalue | Trace Statistic | 0.05 Critical value | Probability |
| None** | 0.707 | 54.012 | 47.856 | .012 |
| At most 1 | 0.573 | 26.973 | 29.79 | .102 |
| Unrestricted cointegration rank test (maximum eigenvalue) | | | | |
| Nounber of CE(s) | Eigenvalue | Max-Eigen Statistic | 0.05 Critical value | Probability |
| None*** | 0.707 | 27.040 | 27.584 | .059 |
| At most 1 | 0.573 | 18.724 | 21.132 | .105 |
| *A model with income (GDPC)* | | | | |
| Unrestricted cointegration rank test (trace) | | | | |
| Nounber of CE(s) | Eigenvalue | Trace Statistic | 0.05 Critical value | Probability |
| None* | 0.801 | 65.155 | 47.85613 | .000 |
| At most 1 | 0.595 | 29.632 | 29.79707 | .052 |
| Unrestricted cointegration rank test (maximum eigenvalue) | | | | |
| Nounber of CE(s) | Eigenvalue | Max-Eigen Statistic | 0.05 Critical value | Probability |
| None* | 0.801 | 35.522 | 27.584 | .004 |
| At most 1 | 0.595 | 19.869 | 21.132 | .074 |

Note: The 1%, 5%, and 10% statistical significant level are respectively denoted by *, **, and ***.

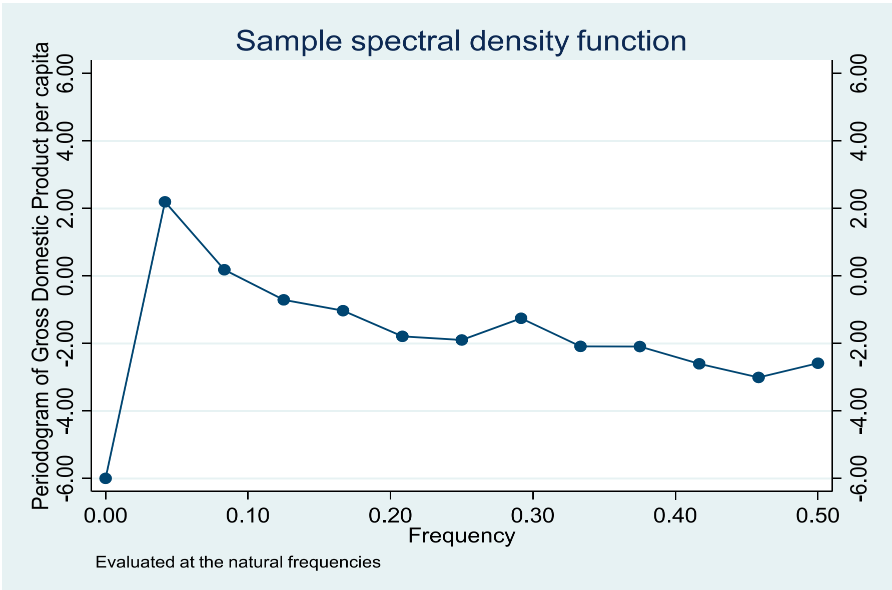


**Figure A1.** Periodogram of GDPc.

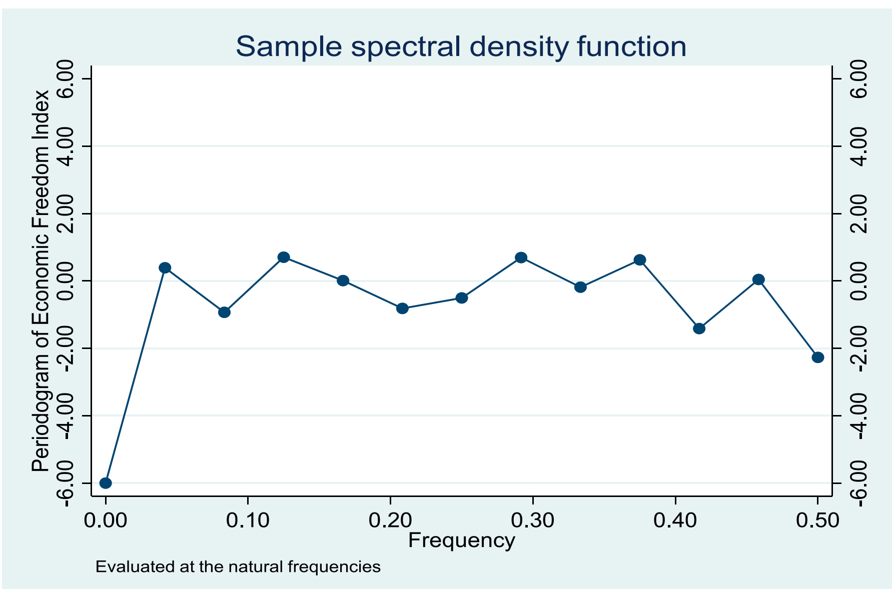


**Figure A2.** Periodogram of EFI.

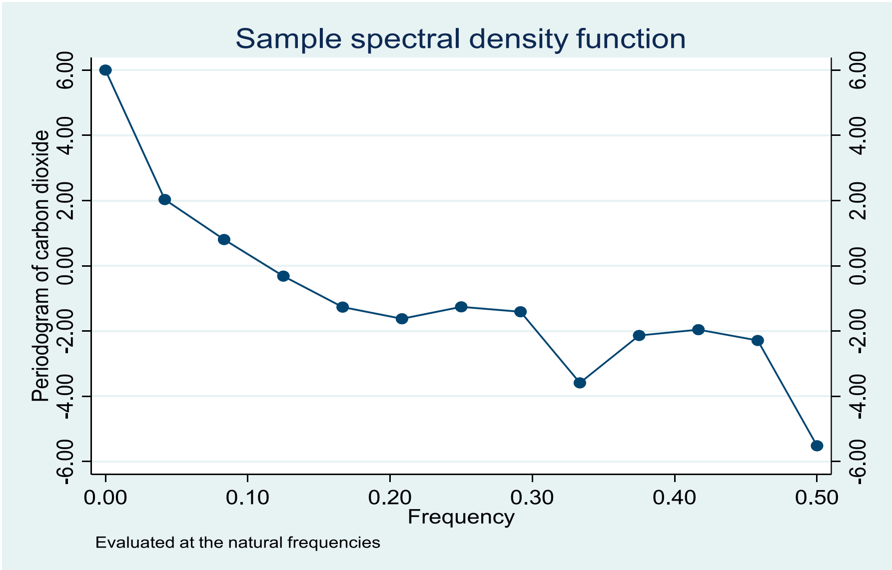


**Figure A3.** Periodogram of $CO_2$ emission.

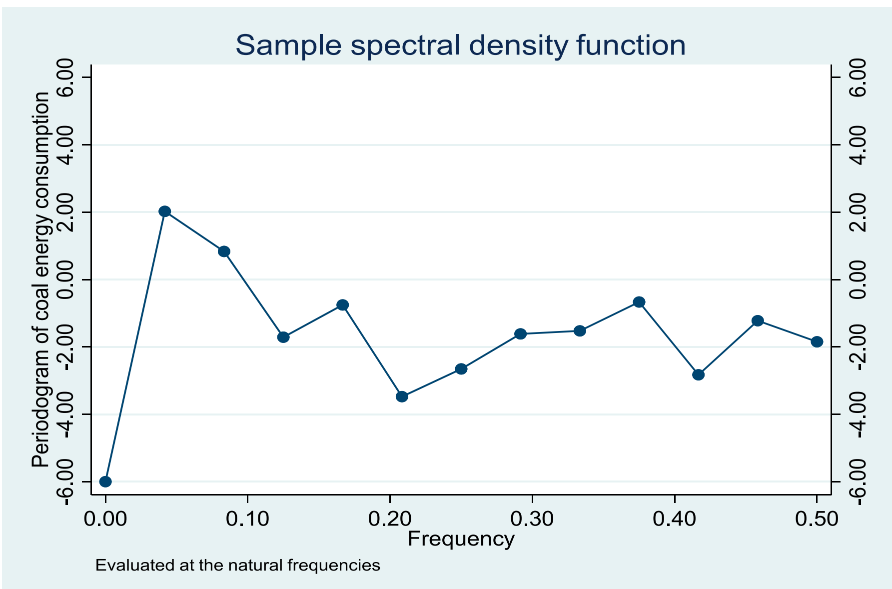


**Figure A4.** Periodogram of coal.

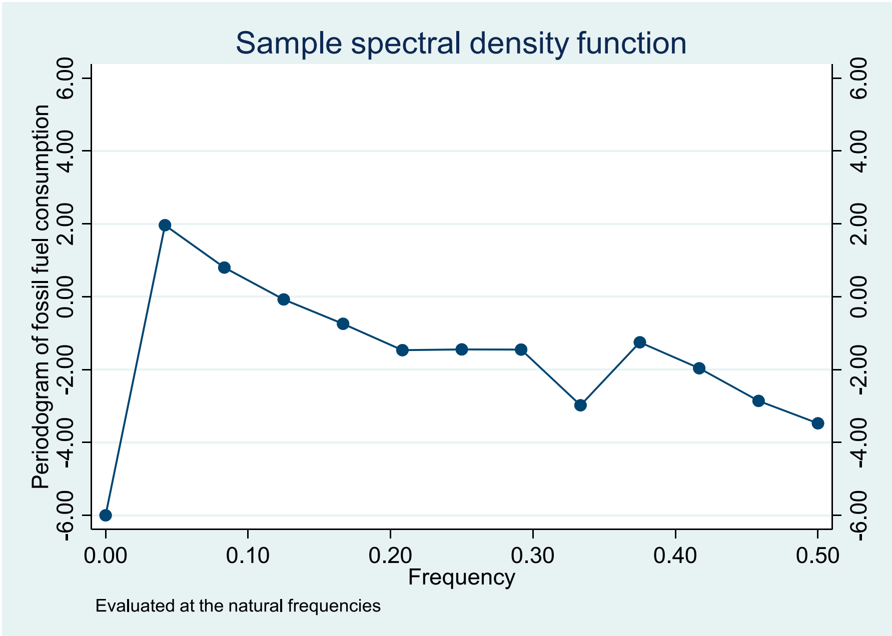


**Figure A5.** Periodogram of oil.