Using Bootstrap Fourier Granger Causality Test in Quantiles to Re-examine Pollution Haven/Halo Hypotheses in China and G3 Countries

Received: 9 June 2022; Accepted: 18 December 2023.

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Abstract

We re-examine the Pollution Haven and Pollution Halo hypotheses (PHEH and PHALH) using a quantile-based Bootstrap Fourier Granger causality test, a method adept at identifying non-linear structural breaks. Our study encompasses data from China and the G3 countries (Japan, the UK, and the USA) spanning the period from 1980 to 2020. Our empirical findings reveal that data from the USA corroborates the PHEH, suggesting a trend where increased foreign direct investment (FDI) aligns with higher environmental degradation. In contrast, data from China affirms the PHALH, indicating that FDI contributes to improved environmental standards. However, data from Japan and the UK do not conclusively support either hypothesis. These results have significant implications for governmental policy formulation in China and the G3 countries, particularly in shaping FDI policies that align with environmental sustainability goals.

Keywords: Pollution Haven/Pollution Halo Hypotheses; Bootstrap Fourier Granger Causality; Quantile; FDI; CO2 Emissions; China; G3 Countries; Environment

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I. Introduction

Governments worldwide have increasingly focused on determining ways to combat global warming and climate change. Previous studies have highlighted carbon dioxide (CO2) pollution as one of the causes of environmental degradation. Researchers and policymakers are investigating measures to reduce CO2 emissions causing environmental degradation (see Doğan, 2018). Accordingly, the impact on environmental quality from economic development (GDP), energy use, and foreign direct investment (FDI) has been previously studied. Most of the developing countries have formulated strategies and implemented policies to attract FDI in order to sustain and maintain economic development. Furthermore, CO2 emissions increases linked to FDI have been assessed by academic research institutes. Traditional scholars have posited that FDI further intensifies environmental degradation. Song et al. (2021) revealed the two-sided effects of FDI: FDI is a key player in economic growth and a major contributor to CO2 emissions for some countries. Yilanci et al. (2020) further documented that FDI may support the association between environmental degradation and economic performance through two different ways: 1) Pollution may increase as FDI and economic growth increase. 2) A more efficient and environmentally friendly production technology may be employed owing to the FDI, thereby lowering pollution. In this study, we investigate the effects of inward FDI on air pollution in China and G3 countries (Japan, UK, USA), which are popular destinations for global FDI.

The current paper is organized in the following sections: Section II briefly describes previous studies. Section III reports on data collection and research methodology, and Section IV presents our empirical findings followed by some policy implications. Finally, Section V concludes this study.

II. Literature Review

Previous studies present two hypotheses regarding links between inward FDI and air pollution, one is the Pollution Haven hypotheses and the other is the Pollution Halo hypothesis. These two hypotheses present conflicting potential effects of inward FDI on the environment of host countries. The Pollution Haven hypotheses (PHEH) predicts the following: MNCs shift energy-intensive technologies to low-income countries owing to 1) relaxed laws and less regulation of greenhouse gases and 2) low-cost labor and fossil fuel availability. Inward FDI increases environmental degradation and raises greenhouse gas production, affecting sustainable economic growth (Seker et al. 2015; Zhang and Zhou 2016; Ahmad et al. 2021; Xu 2021). The Pollution Halo hypothesis (PHALH), in contrast, states inward FDI enhances sustainable economic growth and improves environmental quality through the application of clean and energy-efficient technologies and management skills in sectors such as waste recycling (Zarsky, 1999; Antweiler et al. 2001; Eskeland and Harrison, 2003; Levinson and Taylor, 2008; Zeng and Eastin, 2012; Zhu et al. 2016; and Jun et al. 2018). In addition, Demena and Afesorgbor (2020) and Golub et al. (2011) noted that in developing countries, foreign companies are more likely use and transfer green technologies to the host countries compared with domestic companies. Eskeland and Harrison (2003) reported US companies use more clean and energy-efficient technologies compared to local companies within developing countries. Recently Terzi and Pata (2020) applied the Toda-Yamamoto augmented Granger causality method to analyze the relationship between FDI inflows and CO2 emissions by employing annual data from 1974 to 2011, testing the pollution haven hypothesis in Turkey. Results showed FDI inflows and CO2 emissions have a short-run univariate causal relationship, with positive causality moving from CO2 emissions to inward FDI inflows. The single-direction effect of CO2 emissions on FDI inflows supports the Pollution Haven hypothesis in Turkey.

Based on previous literature, we found most studies use traditional linear approaches that overlook variations across stages while also missing structural shifts triggered by national policies. The single exception is Albulescu et al. (2019) who use a quantile approach for the 14 American countries in their study. Our focus is on the characteristics of causal links, in contrast to previous studies. Furthermore, the current research focuses on sub-sample characteristics employing a nonlinear perspective. A quantile causal test approach better accounts for temporal changes in economics. The Granger approach (Granger, 1969) lacks the ability to detect tail causal relations as well as missing nonlinear causalities. In contrast a quantiles causality test overcomes these weaknesses and shows how such changes impact the FDI-CO_2 emission nexus. Previous studies focus most on using traditional definitions of Granger causality, while the current study employs the more suitable approach of quantile causality. Previous research has not taken this unique approach, thus forming the current work's contribution. Previous literature reports a range of results when testing these two opposing hypotheses. The current research aims to better quantify the link between FDI and environmental degradation by using the more advanced Quantile Granger causality test.

The Bootstrap Fourier Granger causality approach examines quantiles in assessing any association of inward FDI and environmental quality. Accordingly, we determine the effects of inward FDI in the quantile of CO2 emission and assess within which quantiles PHEH or PHALH hold true.

III. Data and Methodology

1. Data

Annual data for CO2 emissions was collected, including inward FDI and GDP for both China and G3 countries (Japan, the UK and the USA), from 1980 to 2020. Inward FDI and GDP data was retrieved from the Wind website of China. CO_2 emission data was retrieved from the *BP Statistic Review of World Energy* (June, 2021). Tables 1-1, 1-2 and 1-3 summarize the data series. Jarque-Bera statistics indicates that most of the variables in China and G3 countries are normally distributed except for CO_2 emissions for China, FDI for China, Japan, the UK and the USA, and GDP for China and Japan and all these variables are non-normally distributed. Time series plots for those three variables are shown in Figure 1 for CO2 emissions, Figure 2 for FDI, and Figure 3 for GDP. Figure 1 clearly shows CO2 emissions are downward except for China and Japan, which trend upwards during the research period. We see CO2 emissions on an upward trend in the USA during 1980-2009 and a downward trend after 2009. Other nations', such as the UK, CO2 emissions show downward trends at the earlier period of 1980. Regarding FDI (see Figure 2) and GDP (see Figure 3), G3 countries and China show an upward trend for both inward FDI and GDP. Interestingly, we found CO2 emissions, FDI, and GDP all exhibit an upward trend during our research time period.

2. Bootstrap Granger Causality in Quantile with Fourier Function

The current study tests the Pollution Haven/Pollution Halo Hypothesis and the EKC curve for both China and G3 countries. To do so, we follow most of the previous studies to form the functional formula for our study as follows:

$$CO_2 = f(FDI, GDP, GDP^2) \quad (1)$$

If we find the coefficient of the FDI is positive, we can say the Pollution Haven hypotheses is supported, otherwise (negative) the Pollution Halo hypotheses is supported. On the other hand, if the coefficient of GDP is positive and the coefficient of GDP^2 is negative, the EKC curve is supported (see Base and Kalayci, 2021). In the current study, we use the Bootstrap Granger causality test in quantile with Fourier function proposed by Chen et al., (2021) to test Pollution haven/Pollution halo hypotheses for both China and G3 countries. Considering structural interruptions in the Granger causality's deterministic equations, rather than employing dummy variables, the Fourier expansion is used. As shown by Gallant (1981) and Gallant and Souza (1991), reduced numbers of low-frequency components within a Fourier approximation capture an undetermined number of gradual and sharp structural breaks. Following this logic, we generate the following Quantile equation:

$$CO2_t(\tau) = C_{10} + \gamma_1(\tau)\sin(\frac{2\pi k^* t}{T}) + \gamma_2(\tau)\cos\left(\frac{2\pi k^* t}{T}\right) + \sum_{i=1}^{p-1}\theta_{11i}(\tau)CO2_{t-i} +$$

$$\sum_{i=1}^{p+d}\delta_{12i}(\tau)FDI_{t-i} + + \sum_{i=1}^{p+d}\delta_{13i}(\tau)GDP_{t-i} + \sum_{i=1}^{p+d}\delta_{14i}(\tau)GDP^2{}_{t-i} + \varepsilon_{1t}$$

(2)

Where $CO2_t$is $CO2_t$emissions, $FDI_t$is inward Foreign investment, and GDP is gross domestic product. A Granger causality test of FDI to CO2 emissions (Pollution haven/Pollution halo hypotheses*)*, across different quantile levels, is evaluated under the null hypothesis of $\delta_{12i}(\tau_1) = \delta_{12i}(\tau_2) = \cdots = \delta_{12i}(\tau_p) = 0$ in Equaton (1). k* is the optimal frequency estimated. Due to our sample size of 41 years, we set up a maximum lag p =2, choosing optimal lags (p*) based on Akaike Information Criterion (AIC). Setting the τ= 0.2, 0.4, 0.6, and 0.8. The null hypothesis of no Granger causality is $R\beta(\tau) = 0$ in the following Wald statistic:

$$\text{Wald} = \left(R\beta(\tau)\right)'[R(Z'Z)^{-1}(\mathrm{D} * S)]R')^{-1}](R\beta(\tau)) \quad (3)$$

Where R is an indicator matrix of the parameters and $\beta(\tau)$ is the column stack of D, and S is the variance–covariance matrix for an unrestricted model, and $\otimes$ is the Kronecker product. Hatemi-J and Uddin (2012) have shown ARCH effects can cause data to exhibit non-normal distributed Wald statistics, causing a large deviation from its asymptotic distribution. To counter this issue, the Bootstrapping simulation technique from Hatemi-J and Uddin (2012) is used for 10000 iterations in constructing the critical values at 10%, 5%, and 1%. Critical values of restricted F statistics were also generated to test the null hypotheses of absence of sin(.) and cosine(.) terms in the equation (1), also employing a Bootstrapping procedure.

IV. Empirical Results and Policy Implications

Many macroeconomic and financial time series data exhibit non-stationary properties, and non-stationary variables create spurious results (Granger and Newbold, 1979). Therefore, a unit root test prior to model estimation is essential. Following existing literature, we first applied conventional unit root tests such as augmented Dickey–Fuller (ADF), Phillips–Perron (PP), and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) to examine the null hypothesis of unit root for the variables studied. Thereafter, we used the bootstrap Fourier Granger causality test in quantiles.

(1) Empirical Results of Unit Root Tests

Table 2 reports the unit root test results. We incorporated ADF, PP, and KPSS tests in our study. All the three tests confirmed that the variables CO2 emissions, inward FDI, and GDP were non-stationary at its level but became stationary at the first difference for China-G3 countries, except for inward FDI and GDP being stationary at its level for China and the US, respectively. Because inward FDI and GDP were stationary for China and the US, respectively, we used level variables for both China and the US and different variables for both Japan and the UK to estimate the links between inward FDI and CO2 emissions (environmental quality) using bootstrap Fourier Granger causality test in quantiles.

(2) Empirical Results of the Bootstrap Fourier Granger Causality Test in Quantiles

Before our estimation and testing, we tested for structural breaks using the Wald test proposed by Cheng et al. (2021). Using a bootstrapping procedure with 10,000 replications, we tested the null hypothesis of $\gamma_1 = \gamma_2 = 0$ in Equation (2) and computed the critical values of restricted F statistics. Results in Table 3 indicate that only China exhibited significant breaks at the 5% level and that the rest of G3 countries did not present any significant (smooth) breaks. Table 3 demonstrates the optimal lag length equal to 1 for both Japan and the UK and for both China and the USA, the lag lengths are equal to 2). Because we only observed structural (smooth) breaks (the optimal frequency k* equal to 0,1) for China, we used Bootstrap Fourier Granger causality test in quantiles only for China. For the rest of the G3 countries, we used Bootstrap Fourier Granger causality test in quantiles to investigate the PHEH/PHALH. Considering our sample size of 41 years, we set $\tau = 0.2$, 0.4, 0.6, and 0.8. Table 5 reports these empirical results. We observed that FDI affected CO2 emissions China, with a negative sign at the 0.6 quantile; and the USA, with a positive sign at the 0.2 quantile. For both Japan, and the UK, no links were observed between FDI and CO2 emissions. Table 5 further summarizes these results. Only the USA data supports the PHEH; China supports the PHALH; Japan, and the UK support neither.

Regarding GDP (GDP^2) links to CO2 emissions, we do not report Bootstrap Granger causality test results here due to space and our focus on testing PHEH and PHALH. Results are summarized in Table 5. Only China has a positive sign for GDP and a negative sign for GDP^2, supporting the Environmental Kuznets Curve (EKC). This result is not consistent with those found in Bese and Kalayci's (2021) study that EKC does not hold across the three developed countries of Denmark, the United Kingdom, and Spain. Interestingly, China supports the PHALH, implying that inward FDI further reduces CO2 emissions in China. China is well-known as the 'world's factory' for the past several decades. We believe that our findings might be reliable due to the use of a more advanced econometric technique (bootstrap quantile approach) and the use of the current time period of 1980–2020. In fact, we have witnessed an accelerated economic growth in China over the several decades since the open-door policy began in 1978. The government and people in China have enjoyed economic growth over this period. However, concerns over environmental quality need to be addressed through efficient energy use, upgraded industry with high technology and low CO_2 emissions, establishment of environmental management system, and the replacement of coal consumption with natural gas, wind power, and nuclear energy. Ton et al. (2021) reported a variable impact on eco-efficiency across stages of economic development from FDI. The less economic development, the more negative the impact of FDI on eco-efficiency (supporting the PHEH). However, rapid economic growth increases environmental awareness. For instance, when the economic level passed a certain threshold (approximately 79, 000 RMB; Tong et al. 2021), FDI contributed to improvements in eco-efficiency scores, indicating a positive pollution halo effect. Our results are consistent with this finding.

Our empirical results are not consistent with Albulescu et al. (2019) who studied 14 American countries. They supported the PHEH at a low quantile of CO_2 emissions for full sample and lower-income countries. Empirical results are also not consistent with the following studies, supporting the PHEH: the study by Omri et al. (2014) for 54 European and Central Asian countries; Zhou et al., (2018) for Chinese urban areas; Shahbaz et al. (2018) for France; Shahbaz et al. (2019) for the US; Nasir et al. (2019) for ASEAN-5 countries; Wang et al. (2020) for 29 regions in China; Abdo (2020) for 12 Arab countries; Bildirici and Gokmenoglu (2020) for 9 Middle-East countries; Caglar (2020) for India; Mguyen (2020) for Vietnam in the short and long run; Repkine and Min (2020) for China and Singhania, and Saini (2021) for 21 developed countries. Furthermore, our results are not consistent with those supporting the PHEH in the study by He (2011), Sun et al. (2017), Zhang and Zhang (2018), Zhou et al. (2018), Yu and Xu (2019), Xu et al. (2019) for China, Caglar (2020), and Pata and Kumar (2021). Results are consistent with Caglar (2020) for Italy supporting neither hypothesis and Terzi and Pata (2020) for Turkey supporting the Pollution Heaven hypothesis. Furthermore, our empirical results are not consistent with those found in the study by Marques and Caetanor (2020) for 21 countries. The authors indicated that high-income countries' data supported the PHALH and that middle-income countries' data support the PHEH. Yilanci et al. (2021) supported the PHALH among the BRICS countries studied. Abid and Sekrafi (2021) studied 31 developed countries and 100 developing countries in their study. The authors observed that the developed countries' data supported the PHALH and that developing countries' data supported the PHEH. Our empirical result for the USA case is also consistent with that fund in Ahmed et al., (2022) in the Asia-Pacific region supporting PHH. Finally, Adeel-Farooq et al. (2021) determined that the pollution effects of FDI are related to the FDI origin. The authors observed that FDI from developed countries supported the PHALH while FDI from developing countries supported the PHEH. We believe that our results are more reliable due to the more advanced econometric technique used in our study. These findings provide implications for government policymakers, especially for developing countries vigorously attracting FDI.

While FDI positively affects economic growth, it is accompanied by ever rising CO_2 emissions in the USA. Thus, the establishment of an environmental management systems is crucial. The United States, regrettably, has become a haven for pollution-intensive activities. To counter this trend, it is imperative to develop policies that encourage foreign direct investment (FDI) in the service sector. The U.S. government should aim to mitigate the adverse environmental impacts of FDI inflows by focusing on sustainable economic growth, complemented by more stringent environmental regulations. Implementing carbon pricing mechanisms and establishing carbon credit trading markets are critical strategies for further reducing CO_2 emissions. Enhancing environmental standards is vital, both for firms involved in FDI and domestic industries, especially since there is evidence that FDI inflows and GDP growth can exacerbate CO_2 emissions. The government could consider imposing an energy tax on FDI directed towards pollution-intensive industries. Such taxation strategies not only ameliorate environmental conditions but also minimize the distortions typically associated with taxation, through the redistribution of tax revenues, as suggested by Pearce (1991).

In addition to taxation, other tools for carbon reduction include cross-border carbon taxes and the establishment of carbon credit markets. To foster the adoption of eco-friendly technologies, stringent environmental regulations are necessary. This should be complemented by enhanced inspection and monitoring of waste treatment activities in FDI enterprises as well as the export sector.

Adopting alternative strategies, such as the utilization of green and renewable energy sources (see Pata, 2021; Pata and Caglar, 2021), technical innovation, and production process upgrades (aimed at efficient energy use), and reduced load capacity factors (see Pata and Isik, 2021) can effectively reduce CO_2 emissions. Moreover, fostering social responsibility among FDI enterprises and producers of green goods is crucial. Advances in science and technology have enabled enterprises to adopt advanced technologies that reduce energy consumption and emissions, thereby bolstering environmental protection efforts.

The government of China should facilitate inward FDI in the service sector. Such a shift will create advantages for government encouragement of foreign capital inflows to high-tech industries as well as energy-saving technologies. Governmental improvement of environmental management and supervision systems related to FDI can encourage the banking sector to offer investment funding for high-tech and energy-saving technologies R&D. All these should help inward FDI transform from a quantity-oriented mode to a quality-oriented mode, thereby supporting environmental quality. Reduction of environmental damage flows from the growth of clean and energy efficient industries while balancing economic growth and sustainability.

Finally, both Japan and the UK should balance economic growth with environmental safeguards. Negative impact to the domestic environment can be avoided through clean FDI that boosts economic output. Environmental standards should be upgraded for FDI firms and domestic industries. Increasingly rigorous environmental policies can restrict inflows of investments to dirty industries in the three countries studied. Furthermore, FDI flows should be directed toward more sustainable and greener sectors of the economy. In terms of financial development, financial resources should be allocated to more eco-friendly sectors of the economy. Thus, green finance is the way forward for these three countries. Focusing on more sustainable economic growth is crucial and can be accomplished by allocating resources to eco-friendly sectors of the economy. In addition, stringent environmental regulations are required to restrict the inflows of foreign dirty industries in these three countries.

Based on our findings, we can offer policymakers the following useful recommendations: low or no emission industries and increased energy efficiencies are key to environmental damage reduction in China-G3 countries. Reducing CO2 emissions can be accomplished in three ways: 1) FDI-led technological improvements that increase energy use efficiency while reducing CO2 emissions. 2) FDI investment increases patent applications (production process investment and R&D work), thereby improving efficiency. Synergies from R&D investment increase patent applications. 3) Inflows of FDI directed toward renewables increase the technology spillover effect that further reduces CO2 emissions. Finally, a carbon-capture mechanism can help lower existing CO2 levels.

V. Conclusions

Our study rigorously explores the validity of the Pollution Haven Hypothesis (PHEH) and Pollution Halo Hypothesis (PHALH) in the context of China and the G3 countries (USA, Japan, and UK) over the period of 1980–2020. Utilizing the advanced Bootstrap Fourier Granger causality test in quantiles, we successfully captured structural breaks across quantiles in a nonlinear fashion, offering a nuanced understanding of the relationship between foreign direct investment (FDI) and environmental quality.

The empirical findings of our study are revealing. While the USA showed evidence supporting the PHEH, indicating that increased FDI is associated with higher environmental degradation, China demonstrated support for the PHALH, suggesting that FDI in China leads to improved environmental standards. Interestingly, neither hypothesis found support in Japan or the UK, indicating a more complex or potentially neutral relationship between FDI and environmental quality in these countries. These findings have significant implications for policy formulation in the China-G3 context. For the USA, where the PHEH holds, there is a clear need to reevaluate and improve environmental standards associated with FDI. This could include stricter regulations on emissions and mandatory adoption of cleaner technologies by foreign-invested firms. In China, where the PHALH is supported, it is crucial to continue encouraging FDI in sectors that promote environmental sustainability. This can be achieved through incentives for green technologies and sustainable practices. Japan and the UK, given their neutral results, should focus on maintaining a balance between economic growth from FDI and environmental sustainability.

Across all these nations, the implementation of policies promoting green energy, renewable energy use, and technological innovation in production processes is essential to effective CO_2 emission reductions. The introduction of taxes on CO_2 emissions, including cross-border carbon taxes and the establishment of carbon credit markets are crucial steps in this direction. These actions not only incentivize emission reduction but also generate funds that can be reinvested in environmental protection initiatives. Additionally, stringent environmental regulations are necessary to facilitate the transition towards eco-friendly technologies. This could include mandatory environmental impact assessments for all major FDI projects and incentives for companies that adopt environmentally friendly practices. A novel approach that governments of the China-G3 countries should consider is encouraging the development and deployment of carbon capture technologies and increasing forest coverage. This dual strategy would not only mitigate current emissions but also contribute to long-term carbon sequestration. Implementing these changes can significantly enhance environmental quality in these countries, contributing to the global effort to combat climate change. It is imperative that these nations lead by example, demonstrating how economic development and environmental sustainability can be synergistically achieved.

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Table 1-1. Summary Statistics of CO2 Emissions

	Mean	Maximum	Minimum	Std.Dev.	Skewness	Kurtosis	J-B
China	43.317	82.441	12.672	25.933	0.432067	1.506	4.961*
Japan	3.9402	5.095	2.437	0.887	-0.08432	1.514	3.724
UK	1.8277	2.9753	0.262	0.769	-0.19028	2.342	0.961
USA	18.952	22.849	11.340	2.997	-0.57034	2.534	2.529

Table 1-2. Summary Statistics of inward FDI

	Mean	Maximun	Minimum	Std.Dev.	Skewness	Kurtosis	J-B
China	3873	176948	1074	505224	1.443	3.853	15.103***
Japan	849	22578	3270	82861	0.543	1.626	5.117*
UK	6660	207527	46375	617329	0.753	2.263	4.687*
USA	25161	946583	83046	2386788	1.137	3.695	9.436**

Table 1-3. Summary Statistics of GDP

	Mean	Maximum	Minimum	Std.Dev.	Skewness	Kurtosis	J-B
China	3.51E+1	1.43E+1	1.91E+1	4.43E+1	1.2322	3.060	10.121**
Japan	4.01E+1	6.20E+1	1.11E+1	1.45E+1	-0.850	2.627	5.053*
UK	1.76E+1	3.10E+1	4.61E+1	9.00E+1	-0.005	1.520	3.648
USA	1.06E+1	2.14E+13	2.86E+1	5.49E+1	0.3197	1.887	2.743

Notes: ***, ** and * indicate significance at the 1, 5 and 10 % levels, separately.

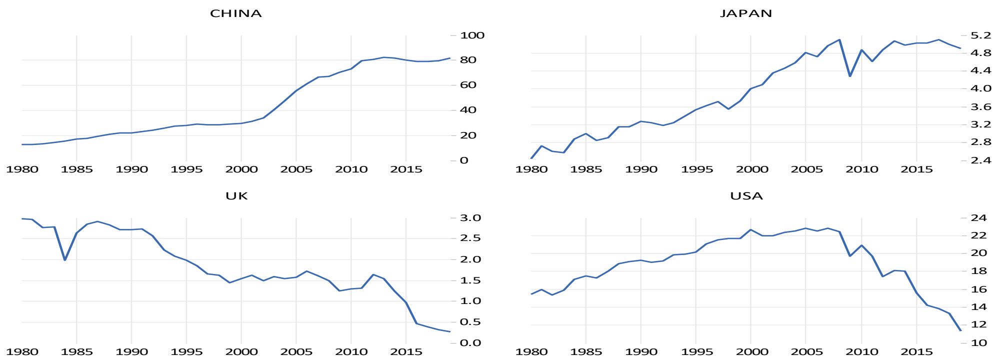

Figure 1. CO2

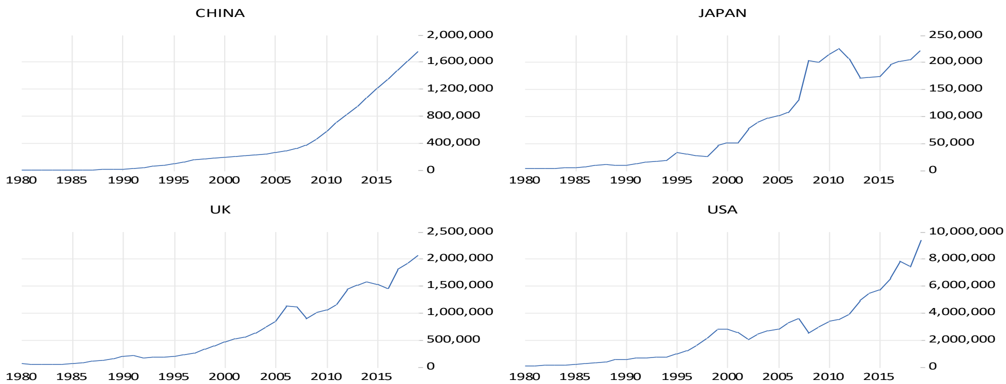

Figure 2. FDI

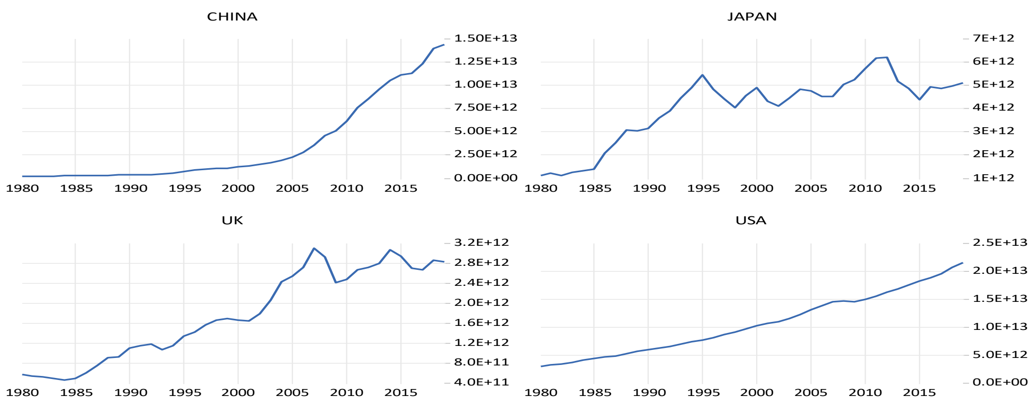

Figure 3. GDP

Table 2. Unit Root Test Results

Country	ADF	PP	KPSS	ADF	PP	KPSS
CO2		*Level*		*First*	*Difference*	
China	-0.8449	-1.0369	0.7534***	-2.8957*	-2.8124*	0.1271
Japan	-1.3597	-1.7149	0.7534***	-9.2477***	-9.3937***	0.2153

UK	1.9221	1.6926	0.6785	-4.4857***	-4.5335***	0.3128
USA	-0.4853	-0.0692	0.2005	0.1841	-4.7380***	0.6412**
FDI		*Level*		*First*	*Difference*	
China	-3.1339**	-4.0507**	0.7529***	-2.4352	-2.3270	0.5429**
Japan	-1.4216	-1.5899	0.7529***	-5.7299***	-5.7340***	0.2893
UK	-0.4597	-0.4831	0.7597***	-5.0555***	-5.0352***	0.0732
USA	-2.2247	-2.2247	0.7538***	-5.4635***	-5.4619***	0.3493*
GDP		*Level*		*First*	*Difference*	
China	0.0008	0.6341	0.7627***	-3.7243***	-3.7862***	0.2262
Japan	-2.4009	-2.7704*	0.5779**	-4.2498***	-4.2360***	0.4770**
UK	-1.2398	-1.2398	0.7211**	-4.0104***	-3.7266***	0.1771
USA	-2.806***	-6.063***	0.7762***	-4.4759***	0.0010***	0.6735**

Note: ***, ** and * indicate significance at the 1, 5 and 10 % levels, separately.

Table 3. Fourier Test with CO2, FDI, GDP, and GDP^2

Country	***Frequency***	***Lags***	***F_test.***	***CV 10%.***	***CV 5%.***	***CV 1%.***
China	0.1	2	17.392**	14.259	15.2487	18.064
Japan	1.7	1	1.225	3.572	4.333	9.057

UK	0.1	1	3.393	11.714	14.360	19.324
USA	0.6	2	8.132	17.023	20.166	24.297

Note: ***, ** and * indicate significance at the 1, 5 and 10 % levels, separately.

Table 4. Bootstrap Granger Causality in Quantile (CO2 and inward FDI)

	Quantile.	***Wald test.***	***CV 10%.***	***CV 5%.***	***CV 1%.***
China					
0.2	*fdi -\->co2*	9.881	13.144	15.346	19.498
0.4	*fdi -\->co2*	5.974	10.960	12.189	15.409
0.6	*fdi -\->co2*	13.224**(-)	11.232	12.944	16.881
0.8	*fdi -\->co2*	6.606	11.786	13.868	20.032
0.2	*co2-\-> fdi*	0.764	3.717	4.7057	8.1692
0.4	*co2-\-> fdi*	0.197	2.698	3.4616	4.9152
0.6	*co2-\-> fdi*	0.206	2.372	3.0268	5.6213
0.8	*co2-\-> fdi*	0.8013	3.7918	4.8145	6.6556
Japan					
0.2	*fdi -\->co2*	1.23E-0	2.68993	3.846	8.759
0.4	*fdi -\->co2*	1.044	2.18263	3.022	6.027
0.6	*fdi -\->co2*	0.067	2.57830	3.243	6.899

0.8	*fdi* -\->*co2*	0.106	3.16089	4.742	7.807
0.2	*co2*-\-> *fdi*	0.376	2.1644	3.053	6.032
0.4	*co2*-\-> *fdi*	0.136	1.0859	1.964	4.423
0.6	*co2*-\-> *fdi*	0.360	1.806	2.901	6.979
0.8	*co2*-\-> *fdi*	1.957	4.044	5.763	12.333
UK					
0.2	*fdi* -\->*co2*	0.007	2.560	3.689	6.198
0.4	*fdi* -\->*co2*	0.052	2.177	3.275	5.668
0.6	*fdi* -\->*co2*	1.018	2.217	3.114	5.248
0.8	*fdi* -\->*co2*	0.137	3.170	4.522	7.722
0.2	*co2*-\-> *fdi*	0.0079	3.2870	4.831	8.496
0.4	*co2*-\-> *fdi*	0.0528	2.1438	3.567	6.667
0.6	*co2*-\-> *fdi*	1.0187	2.1670	3.132	5.361
0.8	*co2*-\-> *fdi*	0.1379	2.6213	4.020	6.521
USA					
0.2	*fdi* -\->*co2*	7.210**(+)	5.3445	6.6350	10.025
0.4	*fdi* -\->*co2*	1.5866	3.0436	4.0401	5.7177
0.6	*fdi* -\->*co2*	1.3973	2.3677	2.9651	5.2365

0.8	*fdi* -\->*co2*	0.2695	2.7119	3.8208	5.7037
0.2	*co2*-\-> *fdi*	0.2235	2.0203	2.8456	5.1758
0.4	*co2*-\-> *fdi*	0.2734	1.6321	2.1618	3.3111
0.6	*co2*-\-> *fdi*	0.1662	2.0318	2.6199	4.1054
0.8	*co2*-\-> *fdi*	0.2399	3.1457	3.9983	5.8978

Note: ***, ** and * indicate significance at the 1, 5 and 10 % levels, separately. We don't report results regarding CO2 emissions and GDP, GDP^2links here. Results are available upon request.

Table 5 Types of Theory

Support PHEH	Support PHALH(also support EKC)	Neither PHEH nor PHALH holds
The USA	China	Japan and the UK

Note: Pollution Haven Hypothesis (PHEH) and Pollution Halo Effect hypothesis (PHALH)