Investigating the existence of asymmetric Environment Kuznets Curve and Pollution-Haven Hypothesis in China: Fresh evidence from QARDL and Quantile Granger Causality

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1 **Investigating the existence of asymmetric Environment Kuznets Curve and Pollution-**
2 **Haven Hypothesis in China: Fresh evidence from QARDL and Quantile Granger Causality**
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Investigating the existence of asymmetric Environment Kuznets Curve and Pollution-Haven Hypothesis in China: Fresh evidence from QARDL and Quantile Granger Causality

Graphical Abstract

Abstract

This study aims to analyze the asymmetric long-run relationship between economic growth (EG), Foreign Direct Investment (FDI) and carbon emissions (CO₂) within the context of the Environment Kuznets curve (EKC) and the pollution haven hypothesis (PHH) in China. Employing the quarterly data from 1982Q1 to 2018Q4, we have used novel techniques to meet the stated objectives of our study, named Quantile ARDL and quantile Granger causality. The significant implication of this method is that it provides locational asymmetry. We find strong evidence of the EKC and PHH for China based on the empirical results of linear and nonlinear ARDL models. Similarly, findings of quantile Granger causality validate the bidirectional relationship among all variables in upper and lower quantiles. Moreover, the results of the Wald test confirm the asymmetric long-run relationship between FDI and carbon emissions (CO₂). This study will be conducive for the policymakers to combat environmental contamination concerning economic growth and FDI inflow in China.

Keywords: Environment Kuznets Curve, Pollution Haven Hypothesis, Quantile ARDL

1. Introduction:

Several changes are made in global policy after the emergence of WTO. The purpose was to reduce the divergence between rich and poor countries by removing the tariff and non-tariff barriers Murthy and Gambhir (2018). The effect of international trade on the environment has been discussed broadly since 1970. This debate became more severe in 1990, after trade openness by various organizations (NAFTA, UNCED, and WTO)¹. Thus, global pollution distribution has emerged as an important policy question in the environmental economics literature (Gill et al., 2018a). Currently, China is the second-biggest economy of the world, and it has encountered rapid economic development in recent years because of economic reforms (World energy outlook, 2010). China has achieved remarkable economic expansion accompanied by extensive environmental pollution. The massive ecological damage has forced China to build an environment-friendly society by introducing costly environmental policies (Wang et al., 2018). China fast economic growth (EG) has made it a heated topic in the whole world. The economists and researchers are interested in knowing whether the environment in China will worsen or improve if the economy follows the increase in per capita income. The Per capita GDP of China has improved from US\$ 227 in 1978 to US\$8109 in 2015, along with massive emission of environmental pollution (27%) (Mundial, 2007). In this domain, the critical empirical foundation is the Environment Kuznets curve (EKC) hypothesis, introduced by Grossman and Krueger (1991). EKC hypothesis suggests that environmental degradation increases at early phases of economic growth, and it turns to decrease as income reaches a certain threshold level.

¹ NAFTA is the North American Free Trade Agreement.

UNCED is the United Nations Conference on Environment and Development also known as "Earth Summit".

WTO refers to World Trade Organization.

Another critical hypothesis related to environmental deterioration is the Pollution Haven Hypothesis (PHH). The PHH explains that the developed countries migrate their dirty industries to the developing countries (Gill et al., 2018a) and raise their pollution intensity. China has become the most appealing target for FDI since after trade opens up policy. During the 1990s, China was the next primary recipient of FDI after the USA and the principal beneficiary of FDI in the developing countries (He, 2006). After 2000 China became the most compelling FDI receiver nation for precious assets, cheap labour price, and lax environmental regulations.

On the other hand, carbon emissions are increasing rapidly in China. China has also become the largest producer of regional fossil fuel CO₂ emissions since 2006, as displayed in Table 1. China is now confronting enormous pressure from the international society to control carbon emissions. So China has become a haven for dirty industries of advanced countries, leading to the Pollution Haven Hypothesis in China (Sun et al., 2017). Figure 1 shows the behaviour of time series variables over time.

[INSERT FIGURE 1 HERE]

[INSER TABLE 1 HERE]

Though in the previous two decades, the EKC has been rigorously examined, the empirical findings seem to be questionable as some studies exhibit the inverted U-shaped EKC (see, e.g., Al-Mulali et al., 2015b; Apergis et al., 2018; Cheng et al., 2017; Destek & Sarkodie, 2019; Salman et al., 2019; Zhu et al., 2016a), some suggest the N-shaped (see, e.g., Allard et al., 2018; Hao et al., 2018) and inverted N-shaped (see, e.g., Liu & Lin, 2019; Özokcu & Özdemir, 2017). Similarly, there are inconclusive results about the existence of PHH in China because some studies provide evidence of PHH (see, e.g., Acharyya, 2009; He, 2011; He & Yao, 2017; Sun et al., 2017; Xiao, 2015) while, some studies do not support the PHH in China (see, e.g., Sarkodie & Strezov, 2019;

Xiao, 2015; Zhang & Zhou, 2016). The reason is that existing literature varies a lot in terms of sample and methodologies.

The related literature in China in terms of the sample can be categorized into three groups, research on time series data (see, e.g., Jalil & Feridun, 2011; Jalil & Mahmud, 2009; Sun et al., 2017; Xiao, 2015; Zhang & Zhou, 2016). They have focused on Chinese aggregate data to estimate the EKC. The second strand of literature comprises panel data of China with other countries (see, e.g., Govindaraju & Tang, 2013; Pao & Tsai, 2010, 2011; Sarkodie & Strezov, 2018a; Zakarya et al., 2015). They have compared the china with other countries. While, (see, e.g., Cheng et al., 2017; He, 2011; He & Yao, 2017; Liu & Lin, 2019; Wang et al., 2017; Wang et al., 2019) have treated with the panel of Chinese provinces or cities.

Existent literature has also used different methodologies. Mostly the studies with aggregate data have used the Autoregressive distributed lagged (ARDL) model (see, e.g., Hakimi & Hamdi, 2016; Jalil & Mahmud, 2009). While Jalil and Feridun (2011) have combined the ARDL with bounds testing procedure, Shahbaz et al. (2015) have also employed the ARDL bound test. Acharyya (2009) and Wang et al. (2011) have also applied the cointegration regression analysis. Some researchers have also combined the cointegration analysis along with ARDL. Al-Mulali et al. (2015a) and Xu (2018) have employed VECM and ARDL. Hakimi and Hamdi (2016) used a vector error correction mechanism (VECM) and cointegration analysis. Cole et al. (2011) have used the fixed effect panel data model, Neequaye and Oladi (2015) have used the Instrumented FE model, Tamazian and Rao (2010) have used the generalised method of moments (GMM), Özokcu and Özdemir (2017) have used panel data techniques with Driscoll-Kraay Standard Errors while some studies have applied the spatial econometrics analysis. Hao et al. (2018) and Liu and Lin (2019) have implemented the spatial panel models SLM, SEM, SDM, Cheng et al. (2017) have used

Dynamic spatial panel model. Wang et al. (2017) and Zhang and Zhou (2016) have used the (STIRPAT) model. For more details, see Table 2.

The critical review on the nexus between EG and CO₂ emissions reveal that linear models have been applied extensively. While Po and Huang (2008) argue that linear models cannot explain the long-term relationship between time series variables due to short-term fluctuations and structural change. Similarly, Anoruo (2011) explains that linear models can only capture linear relationships while most time series variables exhibit nonlinear behaviour. Dutta et al. (2019) also claim that linear models show conflicting results while observing a volatile series, which could be due to the nonlinear behaviour of the variables. Kahneman and Tversky (2013) emphasise the importance of asymmetric modelling. Behmiri and Manera (2015) and Kumar (2017) discuss that the nonlinear structure of economic and financial time series can be due to economic situations. Besides, they comment that economic and financial variables generally exhibit nonlinear behaviour due to economic instability and crisis; hence, nonlinear models are required to capture the volatility of time series data.

Different from the existing literature, we consider the potential nonlinear association between EG, FDI and CO₂ emissions and apply the Quantile autoregressive distributed lag (QARDL) model proposed by Cho et al. (2015). This study aims to analyse the asymmetric long-run relationship between EG, FDI and CO₂. Within the context of the EKC and PHH in China. To meet the stated objectives of our study, we have used a novel technique employing the quarterly data from 1982Q1 to 2018Q4. This approach has some benefits as compared to alternate methods. Firstly it offers a more flexible econometric structure to test the strength of long term association across quantiles by testing cointegration between I(0) and I(1) variables. Thus it reduces the constraint of the Johansen cointegration test, which requires all the time series in the system I(1) (Lahiani et al.,

2018). Secondly, it also relaxes the condition of normality and provides a robust conclusion. Thirdly, it allows estimating the cointegration between the CO₂ emissions and decisive factors for the whole distribution rather than the conventional measures that emphasise the mean value. The traditional measures may not be as explanatory as QARDL (Zhu et al., 2016b). Moreover, the QARDL provides locational asymmetry. It allows analysing the asymmetric short and long term impact of EG and FDI on CO₂ emissions. So the QARDL is an excellent choice to precisely model the nonlinear and asymmetric connections between EG, FDI and CO₂ emissions.

The rest of the paper is arranged as follows: section two explores the brief literature; section three describes the methodology and data source; section four is dedicated to Empirical results and discussion. Finally, section 5 concludes the paper and offers some policy implications.

2. Literature Review

The literature on the environment is extensive, and it can be mapped out from the pioneering work of Baumol (1971) and Crocker (1966). Our study is closely linked with two divisions of literature: one is the association between economic growth and environment deprivation EKC (see, e.g., Destek & Sarkodie, 2019; Salman et al., 2019; Sarkodie & Strezov, 2018b) and the other is the PHH (see, e.g., Sun et al., 2017; Xiao, 2015).

2.1 The Environment Kuznets Curve Hypothesis (EKC):

A compelling argument in the economics literature is the association between EG and environmental deterioration named EKC. It was the first to raise a voice against “too poor too green”, which suggests that the developing nations cannot control the environmental issues appropriately because of insufficient resources. Only rich countries can protect their environment because they can plant clean technologies to control environmental problems. Gill et al. (2018a)

and Grossman and Krueger (1991) exhibit that economic growth is useful to reduce environmental destruction. Further, they demonstrate that gains from trade could not be as dangerous for the climate as anticipated. Extensive research has been carried out on the environment – growth nexus after the Grossman and Helpman (1993) and Grossman and Krueger (1991), but the results are complex. These studies have found that economic growth is helpful to overcome environmental problems (Ozturk & Acaravci, 2010; Sari & Soytas, 2007; Zhang et al., 2018). Brajer et al. (2011) has used the three comprehensive indexes of pollution along with individual pollution measures and concluded that EKC depends on the form of environment indicator. Though the results show some support to inverted U-shaped EKC, the study has found some strong conflicting effects. Azomahou et al. (2006) have employed a panel of 100 countries; their findings also do not support the conventional EKC instead confirm an upward slope relation between income and per capita pollution. Similarly, some studies have found no affirmation for the existence of conventional EKC (Al-Mulali et al., 2015a; Ngarambe et al., 2018; Ozturk & Acaravci, 2010; Pao & Tsai, 2011; Xu, 2018; Zhu et al., 2016a)

However, extensive empirical literature determines the evidence of the EKC hypothesis. Stern and Common (2001) used a more comprehensive sample. They found the inverted U-shaped association between per capita sulfur emanations and per capita income within a sample of high-income states. Similarly, Ozturk and Al-Mulali (2015) have used the panel data of Cambodia and found the existence of EKC. Kharbach and Chfadi (2017) have also determined the reversed U-shaped association between GDP and CO₂ emissions in the transportation division of Morocco. Galeotti et al. (2006) and Vollebergh and Kemfert (2005) have also stated the existence of EKC by employing diverse countries data and by using the CO₂ emissions as environment indicator. Moreover, following studies have also estimated the traditional EKC (Al-Mulali et al., 2015b;

Ang, 2007; Apergis et al., 2018; Cheng et al., 2017; Destek & Sarkodie, 2019; Neequaye & Oladi, 2015; Salman et al., 2019; Sarkodie & Strezov, 2018a; Shahbaz et al., 2015; Wang et al., 2017). Allard et al. (2018) and Hao et al. (2018) have examined an N-shaped EKC. While Liu and Lin (2019) and Özokcu and Özdemir (2017) demonstrate the reversed N-shaped association between environment and per capita income.

2.2 The Pollution Haven Hypothesis (PHH) and environment:

The PHH unfolds that due to stringent environmental policies, the developed countries migrate their dirty industries to the developing countries. They take benefit of the fragile environmental laws of developing nations and raise their pollution. This phenomenon is observed under the comparative cost theory when developed nations concentrate on the manufacturing and export of clean products, and the developing countries emphasise the production and export of dirty goods; thus, developing states grow into the pollution heaven for the dirty industries of developed nations (Gill et al., 2018b). The empirical research has exposed that different environmental regulations have different implications. Xu (1999) has observed that exports of environmentally sensitive goods (ESGs) remain unchanged by introducing stringent environmental regulations. While in some circumstances, rigorous environmental regulations can reduce competitiveness. Low and Yeats (1992) have explored that developing economies gain a comparative advantage in the manufacturing of ESGs more than the industrialized countries because of weak environmental regulations.

Another critical factor that affects the environment is foreign direct investment (FDI). The previous empirical evidence about the effect of FDI on the environment are inconclusive (Zhang & Zhou, 2016). Some studies found the positive impact of FDI on the climate of the host country. Their view is FDI promotes cleaner technology and improvement in energy efficacy, so it helps to

improve the host country's environment (Sun et al., 2017). Eskeland and Harrison (2002) have
 examined the FDI framework in four developing states: Cote d'Ivoire, Mexico, Morocco, and
 Venezuela and found that though international firms are located in high air pollution regions of
 developing countries, they produce less pollution than foreign firms use more energy effective
 technology and apply cleaner energy sources as compared to their peer. Al-Mulali and Tang (2013)
 also conclude that FDI helps to reduce CO₂ emissions in the GCC countries. Thus PHH does not
 confirm. Likewise, Zhang and Zhou (2016) have used the Chinese provincial-level data and
 deduced that FDI brings a reduction in CO₂ emissions in China. Tamazian et al. (2009) have
 analysed that trade openness and financial development tend to decrease the environmental
 degradation in BRICS counties. Moreover, Wang et al. (2019) have found no evidence of PHH in
 the domestic trade of China.

Likewise, Javorcik and Wei (2004) have found some weak evidence of PHH on 24 Transition
 Economies. They have identified that the absence of some essential features (such as bureaucratic
 corruption) in the host country leads to ambiguous results. Cole and Elliott (2005) have
 investigated that it is not only the lax environment regulations that cause PHH, but factor
 endowment is also essential to determine PHH. High capital abundant countries are more likely to
 experience PHH.

While the studies which found the negative impact of FDI on host countries claim that trade
 openness aggravates the market competition. It forces some of the developing countries to limit
 their environmental regulations to invite FDI, so the environmental condition of the host country
 declines due to FDI inflows. Sun et al. (2017) and Hitam and Borhan (2012) have found that FDI
 is a cause of climate worsening in Malaysia. Hoffmann et al. (2005) have employed the data of
 112 nations and found the adverse effect of FDI on the environment of low-income countries

because low-income countries are less proficient at executing and scrutinising the environmental regulations. They conclude that the existence of PHH depends on the level of growth of the host country. Similarly, Lee (2013) has examined that FDI increases the economic growth in G20 countries but the increase in CO₂ emissions limit its decisive role. Al-mulali (2012) have also concluded that FDI contributes to increase CO₂ emissions in Middle East countries.

[INSERT TABLE 2 HERE]

3. Empirical Methodology and Data

3.1 Methodology:

We are closely following the methodology of Lahiani et al. (2018) and Shahbaz et al. (2018). The EKC hypothesis suggested by Grossman and Krueger (1991) in its general form can be written as follows:

$$CO_2 = f(y, y^2, V)$$

Here CO₂ is environment indicator, y is GDP, and V refers to other explanatory variables that may affect the environmental deterioration. We have also included foreign trade in our model to avoid omitted variable bias (Halicioglu, 2009). The FDI variable is also incorporated to evaluate the effect of FDI on environmental pollution as proposed by PHH (Walter & Ugelow, 1979). We estimate the following regression equation in the logarithmic form:

$$\ln CO_2^t = \alpha_0 + \alpha_1 \ln GDP_t + \alpha_2 \ln GDP_t^2 + \alpha_3 \ln FDI_t + \alpha_4 \ln Trade_t + \varepsilon_t$$

where t refers to the period, CO₂ is per capita carbon emission, GDP is per capita gross domestic product, FDI is foreign direct investment, Trade is the sum of imports and exports, and ε_t is the

standard error term. If $\alpha_1 < 0$ and $\alpha_2 > 0$ it represents the U-shaped association between CO_2 and GDP, if $\alpha_1 > 0$ and $\alpha_2 < 0$ it follows an inverted U-shaped curve. Thus, EKC holds.

Since the nonlinear and asymmetric relationship between EG, FDI and CO_2 emissions are now acknowledged, we employ the recently developed QARDL model proposed by Cho et al. (2015) to explore the association between CO_2 emissions, EG and FDI. We perform the following steps in this study. First, we find the stationarity to identify the order to integrate variables by applying unit root tests. Secondly, we investigate the long-run equilibrium relationship by using the ARDL model. Third, we extend the ARDL model to the QARDL model setting to explore further the quantile long-run equilibrium correlation between variables of interest. Then we apply the Wald test to check the constancy of our parameters of concern.

3.1.1 QARDL model: We employ the newly established QARDL model proposed by (Cho et al., 2015) to explore the nonlinear behavior of EG and FDI on CO_2 emissions that refer to the EKC and PHH in the context of China. The benchmark ARDL model, as examined in (Pesaran et al., 2001) is written as:

$$CO2_t = \alpha + \sum_{i=1}^p \varphi_i CO2_{t-i} + \sum_{i=0}^{q1} \omega_i GDP_{t-i} + \sum_{i=0}^{q2} \vartheta_i GDP_{t-i}^2 + \sum_{i=0}^{q3} \theta_i FDI_{t-i} + \sum_{i=0}^{q4} \delta_i TRADE_{t-i} + \epsilon_t \quad (1)$$

ϵ_t refers to the error term, which is defined as $CO2_t - [CO2_t / \epsilon_{t-1}]$ and ϵ_{t-1} being the lowest σ -field created by $[CO2_t, GDP_t, GDP_t^2, FDI_t, TRADE_t, CO2_{t-1}, GDP_{t-1}, \dots]$ besides p, q_1, q_2, q_3, q_4 are lag orders in the model determined Bayesian information criteria (BIC)..

297 We formalise the following QARD(p, q) model by extending the model (1) in a quantile setting,
 298 as suggested by (Cho et al., 2015).

$$\begin{aligned}
 299 \quad Q_{\Delta CO2_t} = & \alpha(\tau) + \sum_{i=1}^p \varphi_i(\tau) CO2_{t-i} + \sum_{i=0}^{q1} \omega_i(\tau) GDP_{t-i} + \sum_{i=0}^{q2} \vartheta_i(\tau) GDP_{t-i}^2 + \sum_{i=0}^{q3} \theta_i(\tau) FDI_{t-i} \\
 300 \quad & + \sum_{i=0}^{q4} \delta_i(\tau) TRADE_{t-i} \\
 301 \quad & + \epsilon_t(\tau) \tag{2}
 \end{aligned}$$

302 Here $\epsilon_t(\tau)$ indicates the error term that is described as $CO2_t - Q_{\Delta CO2_t}(\tau / \mathcal{E}_{t-1})$ and
 303 $Q_{\Delta CO2_t}(\tau / \mathcal{E}_{t-1})$ is the τ -th quantile of $CO2_t$ depends on the information set $\mathcal{E}_{t-1}$ (Kim &
 304 White, 2003) and $0 < \tau < 1$.

305 To avoid the potential autocorrelation in the error term, we generalise the QARDL model in Eq(2)
 306 as follows:

$$\begin{aligned}
 307 \quad Q_{\Delta CO2_t} = & \alpha(\tau) + \rho CO2_{t-1} + \gamma_{gdp} GDP_{t-1} + \gamma_{gdp^2} GDP_{t-1}^2 + \gamma_{fdi} FDI_{t-1} + \gamma_{trade} TRADE_{t-1} \\
 308 \quad & + \sum_{i=1}^p \varphi_i(\tau) \Delta CO2_{t-i} + \sum_{i=0}^{q1} \gamma_i(\tau) \Delta GDP_{t-i} + \sum_{i=0}^{q2} \lambda_i(\tau) \Delta GDP_{t-i}^2 \\
 309 \quad & + \sum_{i=0}^{q3} \theta_i(\tau) \Delta FDI_{t-i} + \sum_{i=0}^{q4} \pi_i(\tau) \Delta TRADE_{t-i} \\
 310 \quad & + \epsilon_t(\tau) \tag{3}
 \end{aligned}$$

311 The above eq(3) can be expressed to assign the ECM parameters of the QARDL model (Cho et
 312 al., 2015).

$$\begin{aligned}
313 \quad Q\Delta CO2_t &= \alpha(\tau) + \rho(\tau)(CO2_{t-i} - \beta_{gdp}(\tau)GDP_{t-1} - \beta_{gdp^2}(\tau)GDP_{t-1}^2 - \beta_{fdi}(\tau)FDI_{t-1} \\
314 \quad &\quad - \beta_{trade}(\tau)TRADE_{t-1}) \\
315 \quad &+ \sum_{i=1}^{p-1} \varphi_i(\tau)\Delta CO2_{t-i} + \sum_{i=0}^{q1-1} \gamma_i(\tau)\Delta GDP_{t-i} + \sum_{i=0}^{q2-1} \lambda_i(\tau)GDP_{t-1}^2 \\
316 \quad &+ \sum_{i=0}^{q3-1} \theta_i(\tau)\Delta FDI_{t-i} + \sum_{i=0}^{q4-1} \pi_i(\tau)\Delta TRADE_{t-i} \\
317 \quad &+ \epsilon_t(\tau) \tag{4}
\end{aligned}$$

318

319 The aggregate short period effect of the past CO₂ emissions on current CO₂ emissions are estimated
320 as $\varphi_* = \sum_{i=1}^{p-1} \varphi_i$ while the aggregate short term effect of the contemporary and previous gross
321 domestic product, the square of GDP, FDI and trade on the current level of CO₂ emissions are
322 estimated as $\gamma_* = \sum_{i=0}^{q1-1} \omega_i$, $\lambda_* = \sum_{i=0}^{q2-1} \vartheta_i$, $\theta_* = \sum_{i=0}^{q3-1} \theta_i$, $\pi_* = \sum_{i=0}^{q4-1} \delta_i$, separately. The
323 long-run cointegration parameters for GDP, GDP², FDI and Trade are calculated as
324 $\beta_{gdp}^* = -\frac{\gamma_{GDP}}{\rho}$, $\beta_{gdp^2}^* = -\frac{\gamma_{gdp^2}}{\rho}$, $\beta_{FDI}^* = -\frac{\gamma_{fdi}}{\rho}$, $\beta_{Trade}^* = -\frac{\gamma_{trade}}{\rho}$ respectively. While ρ , the speed
325 adjusting parameter is required to be negative and significant.

326 Further, we employ the Wald test to examine the short and long-run asymmetric (nonlinear) effect
327 of GDP growth and FDI on CO₂ emissions. We consider the following null hypothesis for long
328 and short-run asymmetry effect, respectively:

$$329 \quad H_0^L = \beta(0.05) = \beta(0.1) = \dots = \beta(0.95)$$

330 against the alternative hypothesis $\forall i \neq j$ or $\beta(i) \neq \beta(j)$

$$331 \quad H_0^S = \varphi(0.05) = \varphi(0.1) = \dots = \varphi(0.95)$$

against the alternative hypothesis $\forall i \neq j$ or $\varphi(i) \neq \varphi(j)$

3.2 Data

We have selected China by following the accumulation of air pollution index to explore the asymmetric behavior of EG and FDI on the CO₂ emissions to validate the existence of EKC and PHH. We have used the quarterly data from 1982Q1 to 2018Q4. The annual data from 1982 to 2018 are used and transformed into quarterly data using the quadratic match-sum principle (Lahiani et al., 2018). This method is useful to adjust cyclical fluctuations in data, and its application is also quite simple (Arain et al., 2019). All the variables are taken from World Bank (2018). Table 3 reports the definitions of the variables and data sources. Table 4 presents the descriptive statistics and results of Unit root tests.

Before proceeding for the QARDL model, it is essential to test the order of integration of the time series variables. Thus, we perform the Augmented Dicky-Fuller and (Zivot & Andrews, 2002) (ZA) unit root tests. The advantage of the ZA test is that it allows for a structural break in the data. The test results of ADF and ZA reveal that only GDP and GDP^2 are stationary at the level I(0) while remaining all other time series (CO₂, FDI, Trade) are stationary at the first difference, indicating that they are I(1). So, we can apply the QARDL model.

[INSERT TABLE 3 HERE]

[INSERT TABLE 4 HERE]

[INSERT TABLE 5 HERE]

4. Results and discussion:

4.1 Quantile Unit root Test:

For detailed analysis, we have also performed the quantile unit root test to check the order of integration at different quantiles. Table 5 reports the results of the quantile unit root test. The results indicate that we accept the null hypothesis of unit root at a 5 % significance level for all variables except the FDI, which is stationary at Q40, Q50, Q60 and Q79. So overall, the results of the quantile unit root test are consistent with the findings of ADF and ZA tests, and we conclude that our variables are stationary at I(I).

4.2 Quantile ARDL results:

The results of linear and quantile ARDL are stated in table 6. In section A, the results of the ARDL model indicate a strong cointegration between CO₂ emissions and EG. Results specify a significant positive impact of GDP on carbon emissions. While a strong negative significant sign of GDP² indicates the existence of EKC in China. The findings align with previous literature (Dong et al., 2018a; Dong et al., 2018b; Sarkodie & Strezov, 2018a; Wang et al., 2017). They have found similar results in China. The verdicts state that environmental quality depletes in the initial phases of economic expansion, while in later phases, pollution reduces in China. Since China has achieved remarkable economic growth in a couple of past years, together, China was also the massive emitter of environmental pollution (27%) (Mundial, 2007).

[INSERT TABLE 6 HERE]

[INSERT TABLE 7 HERE]

China is now following strict environmental goals to meet with the Paris agreement. Moreover, it had already achieved its target of low carbon emissions per unit of GDP by 46 % from the 2005 level, realising its promise before 2020 (United Nations, 2018). So our findings support the EKC hypothesis in China. The significant negative sign of the speed of adjustment parameter " ρ "

confirms the consistency of the estimation of the ARDL model. The past volatility of carbon emissions has an accumulated positive and significant influence on the current values of carbon emissions. The long-run positive and significant impact of FDI on CO₂ emissions support the existence of PHH in China. The results are consistent with the findings of (He & Yao, 2017; Sun et al., 2017; Xiao, 2015). They have found similar results in China. While this phenomenon can be described by the assertion that the amount of FDI grew rapidly in China after the “Opening UP Reforms” and China is now the second-largest recipient of FDI after the USA. Despite being the largest developing country, the standard environment regulations are quite fragile in China compared to the developed world (Zheng & Sheng, 2017). After “Opening Up and Reforms” China’s CO₂ emissions have increased rapidly from 780726 Kilo Tons (KT) in 1960 to 10291926 (KT) in 2017, and China accounts for 30% of global carbon emissions (Tollefson, 2017). Moreover, the secondary industry holds a considerable proportion in foreign direct investment of China, while the industrial production and power generation divisions are the record carbon releasing zones (85 % of total CO₂ emissions) in China (Sun et al., 2017). The long-run impact of international trade on CO₂ emissions are positive and significant, signifying that trade openness causes environmental degradation. The results are aligned with the findings of Allard et al. (2018), Jalil and Feridun (2011) and Ozturk and Acaravci (2013) and also support the Grossman and Krueger (1995) argument that developing countries incline to have heavy polluting industries with a large part of pollutions.

As Linear ARDL model does not address the asymmetry short and long-run impact of GDP, FDI and trade on CO₂ emissions, while the QARDL model considers the locational asymmetry. The results of QARDL in section (B) exhibit that ECM parameter “ ρ ” is significantly negative at all quantiles (except q05, q10, q20 and q30). The long-run cointegration parameter β_{gdp} (β_{gdp^2}) is

positive (negative) and significant at all quantiles (except q05 and q10) confirms the existence of EKC in China. It also proves the asymmetry effect of economic growth on CO₂Emissions. While the long-run integration parameter β_{fdi} is positive and significant at higher quantiles (q60, q70 and q80 and q90) supports the validity of PHH in China. For short-run analysis, the accumulated influence of past variations of CO₂Emissions on their current level are positive at all quantiles with one and two time lags. The short-run accumulated effect of past and current GDP (GDP²) is positive (negative) at lower quantiles. Moreover, the accumulative impact of past and present variations of trade on CO₂ emissions are positive.

From Table 7, the Wald test rejects the null hypothesis of linearity for the speed of adjustment parameter, while it fails to reject the null hypothesis of parameter constancy of long-run cointegration parameters β_{gdp} , β_{gdp^2} , β_{trade} . Moreover, the test results indicate that past CO₂ emissions influence current CO₂ emissions asymmetrically at one and two periods lag only. In a nutshell, we only found a non-linearity in the PHH while our study fails to provide asymmetric behavior of EKC in China.

4.2 Quantile Granger Causality

Table 8 (Figure 2) indicate the results of the quantile Granger causality approach. We have used equally grid of 11 quantiles pattern, that is [0.05, 0.10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 0.95]. Findings show that GDP & GDP² do Granger cause CO₂ in middle quantiles while CO₂ does Granger cause GDP & GDP² in upper and lower quantiles. Therefore, results show some support to inverted U-shaped EKC in most of the quantiles. Though, China is the world top CO₂ emitter country using green technology to combat environmental pollution. Similarly, FDI does Granger cause CO₂ (and vice versa) in upper and middle quantiles, which validate the pollution

heaven hypothesis. Finally, trade does Granger cause CO₂ in middle quantiles while CO₂ does Granger cause trade in upper quantiles only.

Conclusion and policy recommendations:

This study is an effort to observe EKC and PHH in the Chinese framework as China is undergoing high economic growth and massive FDI inflow while confronting the severe issue of environmental degradation. The paper investigates the quantile long-run relationship between economic growth, CO₂ emissions and foreign direct investment based on the EKC hypothesis and PHH for China using quarterly data during 1982Q1 to 2018Q4. We have used a novel technique to meet the stated objectives of our study, named a Quantile ARDL approach. The significant implication of this method is that it provides locational asymmetry. It analyses the asymmetric short- and long-term impact of economic growth and FDI on carbon emissions. The study finds strong evidence of the EKC hypothesis for China as the results of linear ARDL and quantile ARDL models strongly suggest the existence of an inverted U-shaped relationship between economic growth and CO₂ emissions. The findings also support the evidence of PHH in China. Moreover, the QARDL results confirm the significant asymmetric effect of GDP and FDI on CO₂ emissions in China in the long run. Similarly, the findings of quantile Granger causality validate the EKC and PHH in China. Hence, being the most CO₂ emitter country globally and with quick economic progress, China uses green technology to address environmental pollution.

Although in some provinces of China, high legislative measures have been adopted for the upgrading of cleaner production. These legal measures must be enhanced, accepted, rigorously imposed and monitored in the remaining provinces to assure a further reduction in carbon emissions. The environment regulations must be restricted further and harmonised to improve their efficiency adequately. The current research has used the aggregate data on China for EKC analysis,

so inferences cannot be generalised on individual provinces. Though the research reveals that environmental quality improves at higher income levels, the inverted U-shaped EKC of China relies on the income ranks of urban citizens who readily pay for environmental protection. At the same time, the rural people with low earnings are a consistent cause of environmental aggravation. The study can be extended further to analyze province-level EKC and PHH.

Ethical Approval

Manuscript does not report on or involve the use of any animal or human data etc.

Consent to Participate

Authors have agreed for authorship, read and approved the manuscript, and given consent for submission of the manuscript.

Consent to Publish

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The data will be provided upon a reasonable request to corresponding author.

Authors Contributions

Rabia Akram: Abstract, Introduction, Literature Review, Conclusion.

Zeeshan Fareed: Data analysis, Writing results and discussion, Methodology.

Gan Xiaoli: Conceptualization, Supervision.

Bushra Zulfiqar: Supervision, Proofreading and Editing.

Farrukh Shahzad: Conceptualization, Data curation, Conclusion.

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Figures

Figure 1

Yearly time trend of CO2, GDP, FDI and Trade in China

Figure 2

Graphs of quantile Granger causality results

Supplementary Files

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