Environmental Science and Pollution Research (2020) 27:7244–7255
https://doi.org/10.1007/s11356-019-07387-x

RESEARCH ARTICLE

# Examining foreign direct investment and environmental pollution linkage in Asia

Muhammad Azam Khan[1] · Ilhan Ozturk[2]

Received: 27 June 2019 / Accepted: 11 December 2019 / Published online: 27 December 2019


**Abstract**
This study investigated the causal linkage between environmental pollution by carbon dioxide ($CO_2$) emissions and net foreign direct investment (FDI), along with some other variables, namely economic growth by real per capita income and trade openness, using balanced annual data of 17 countries from Asia for the period from 1980 to 2014. Panel cointegration tests confirm the long-run association among the variables. After checking the panel data for stationarity properties, the method panel fully modified ordinary least squares (FMOLS) is implemented. The FMOLS estimates on $CO_2$ emission model reveal that inward FDI has a significantly positive impact on environmental pollution, supporting the pollution haven hypothesis (PHH). Likewise, FDI model results imply that $CO_2$ emissions represent environmental pollution; economic growth and trade openness are the pivotal determinants of FDI. Panel causality results suggest bidirectional linkages between $CO_2$ emissions and inward FDI. Empirical findings suggest that economic policy reforms are required to channelise foreign capital inflows to a more environmentally healthy direction. The governments of Asian countries should chalk out policies on FDI inflows and the environment in order to achieve sustainable economic growth and development.

**Keywords** $CO_2$ emissions · Inward FDI · Trade openness · Balanced panel data · Asia

## Introduction

The broad objective of every state is to formulate sound economic policies for improving social welfare and achieve sustainable economic growth and development. Inefficient utilisation of available scarce resources and growing environmental pollution, as well as the enormous smog and thick haze problems, have been observed and all these are the results of fast economic growth. Therefore, developing countries in particular need to decide: “first economic growth, or environmental protection”? Alleviating life-threatening poverty within a generation and stimulating shared prosperity must be accomplished on sustainable basis over time and for all generations. To protect the continuing future of our globe, we need environmental, fiscal and social sustainability (World Bank 2013). The World Bank (2015) acknowledges that economic growth has to be both wide-ranging and ecologically rigorous to decrease poverty and create collective prosperity for current inhabitants and to meet the requirements of future generations. Evidently, during the past 20 years, growth has lifted lots of individuals out of poverty and has improved the income levels of lots of people, but often economic growth has come at the cost of environmental degradation and poorer public.

Three sustainable development pillars, namely economic growth, environmental stewardship and social inclusion, carry throughout all sectors of development, and stress that social condition should be improved, while economic development must be sustainable which would not be at the expense of future generations. Azam (2016a) finds that environmental degradation measured by carbon emissions has a significant adverse effect on economic growth for 11 Asian countries. This study suggests that environmental pollution should be regulated. Loungani and Razin (2001) note that inward direct foreign investment (FDI) was evidenced to be

Responsible editor: Eyup Dogan

✉ Ilhan Ozturk
ilhanozturk@cag.edu.tr

Muhammad Azam Khan
drazam75@yahoo.com

[1] Department of Economics, Faculty of Business and Economics, Abdul Wali Khan University Mardan, Mardan, Pakistan

[2] Cag University, Adana-Mersin yolu uzeri, Yenice, 33800 Mersin, Turkey

buoyant during financial crises, as in East Asian countries during the global financial crises of 1997–1998, when such an investment was extremely stable. Several prior studies empirically proved that FDI inflows play an important role in industrial development of advanced and developing economies (Bartels and de Crombrugghe 2009), and bring many benefits (i.e. job creation, enhanced capital flows, regional development, technology transfer, managerial skill, smaller resource gap between domestic savings and investment requirements; transfer of skills and technology) and thereby contribute to factor productivity and growth in recipient countries (De Mello 1997; Borensztein et al. 1998; OECD 2002; UNCTAD 2006). OECD (2002) further maintains that the evidence of the social effects of FDI inflows favours the belief that external investment may help diminish poverty and improve societal welfare. OECD (2002), p. 20) mentions that "Empirical studies have found little support for the assertion that policy makers' efforts to attract FDI may lead to 'pollution havens' or a 'race to the bottom'". Foreign investors usually undertake investment in a host country based on certain theories including market size hypothesis (see Agarwal 1980; Edwards 1990); eclectic paradigm (OLI) of Dunning (1988, 1993); and classic theory of international capital movement (Mundell 1957; Blais 1975).

Along with bringing benefit to a host country's economy however, FDI inflows also expand pollution produced by unregulated industrial activities. French (1998) reports that usually investors, seeking around the globe for the highest return on their investment, often look for those places or countries provided with abundant natural resources but handicapped by ineffective or weak and lenient environmental laws. Several inhabitants and communities are affected as the environment that benefits them is spoiled or destroyed. Liang (2006) explicates that external investment and trade in China have instigated inordinate concerns as the effluence and pollution levels in the country rise with the growth of the economy. Pao and Tsai noted that "Economic development today is global. Many companies are taking part in the global distribution of investment, and many countries encourage the use of foreign investment to promote their economic growth". However, the environmental problems hidden behind this situation should not be overlooked (Pao and Tsai 2011, p. 685). In a study, Omri et al. (2014) mention that inward FDI is also considered one of the main elements that may lead to deteriorating environmental quality. Czinkota et al. (2014) state that there are visible disputes about the positive and negative impacts of FDI with the host government caught in a love–hate association. Vinh (2015) claims that undeniably inward FDI inflows have drawn great attention from recipient countries, where some researchers are of the view they provide economic benefits, while some others are of the view that inward FDI is just profit-targeting, not concerned with treating polluted water, contaminated gases, industrial waste, etc., all of which could cause the big threat of environmental dilapidation.

Since the 1970s, developmental and environmental economists have talked about the pollution haven hypothesis (PHH). The PHH claims that variances in the strictness of environmental regulations between the North (developed countries) and the South (developing countries) will give the latter a 'comparative advantage' in pollution-intensive production. The developed economies may hence gradually specialise in 'clean' output and depend on the developing economies for the provision of pollution-intensive production (Cole 2004).[1] According to the PHH, weak or ineffective environmental laws and regulations in a recipient country could enhance incoming FDI by profit-driven companies willing to avoid pricey/expensive regulatory agreements in the country of origin (Dean et al. 2009; Hoffmann et al. 2005; Zakarya et al. 2015).

Data statistics demonstrate that global FDI flows have increased by 38% to USD 1.76 trillion: their maximum level since the worldwide economic and financial crisis of 2008–2009. The most important factor of this huge increase in global FDI flows was cross-border mergers and acquisitions' FDI to USD 721 billion, from USD 432 billion in 2014, though greenfield investment flows remained at a high level at USD 766 billion (UNCTAD, 2016). According to the UNEP (2016) report, the environmental effects are responsible for nearly one quarter of deaths of children under the age of 5. A conscientious effort needs to place environment at the heart of the struggles to get better human health. The high percentage of deaths is due to the environment problem that appears in Southeast Asia and in the Western Pacific (respectively recorded 28% and 27% of the total burden). The high proportion of expires attributable to the environment problem is estimated to be 23%, 22%, 11%, 15% and 15% in Sub-Saharan Africa, Eastern Mediterranean region, the OECD and non-OECD countries of the Americas region and in Europe respectively. The report also adds that estimates from the World Health Organization (WHO) reveal that 250,000 more deaths could happen each year between 2030 and 2050, predominantly from diarrhoea, malaria, malnutrition and heat stress, as a consequence of climate change.

Figure 1 reveals that China is the world's largest $CO_2$ emission producer with 9123 million tonnes followed by the USA, India, Russia, Japan, Germany, South Korea, Iran, Saudi Arabia, Indonesia and Canada; 5350, 2271, 1490, 1191, 760, 662, 631, 622, 531 and 527 million tonnes, respectively.

Numerous studies have been carried out examining the linkage between inward FDI and the environment for different country(s) using univariate and multivariate frameworks and different time periods.[2] However, the empirical evidence from

[1] The PHH refers to "the migration or displacement of 'dirty' industries from the developed regions to the developing regions". (Cole 2004, p. 71).

[2] Studied some other variables including energy consumption, financial development, urbanisation, population and institutional factors.

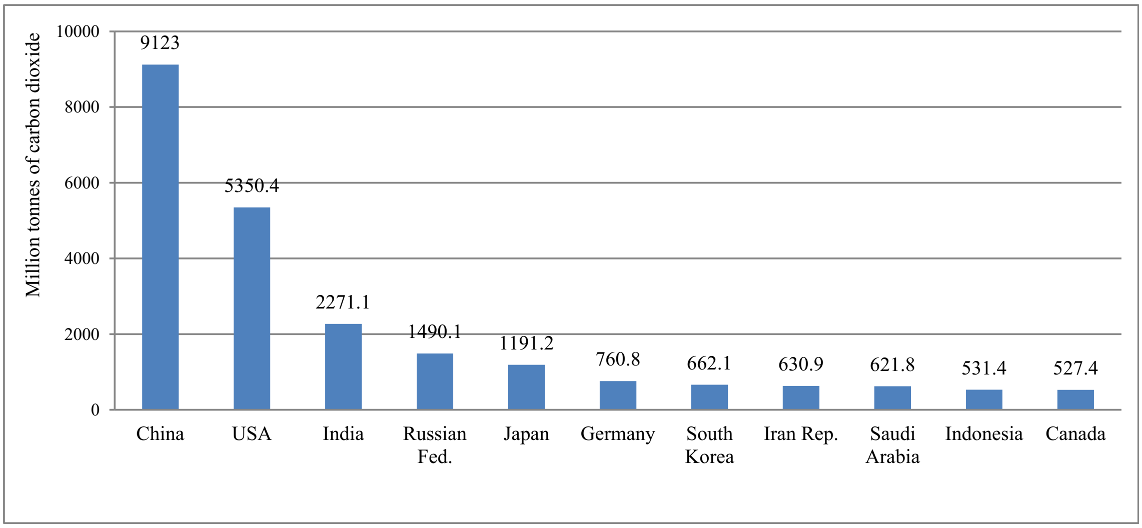


**Fig. 1** Worldwide largest $CO_2$ emission producers in 2016 based on their share of global $CO_2$ emissions (BP Statistical Review of World Energy 2017)

the existing burgeoning literature is yet elusive. Some prior studies described evidence in favour of the PHH (Baek and Koo 2008; He 2006; McDermott 2009; Pao and Tsai 2011; Peng et al. 2016; Vinh 2015), while some studies failed to discover any significant link between inward FDI and environmental degradation or pollution (Eskeland and Harrison 2003; Shaari et al. 2014). Therefore, it is difficult to draw any type of generality of the association between direct foreign investment and pollution, which can be applied by the policymakers. Thus, further holistic empirical research is required to verify the association between inward FDI and environmental effluence by $CO_2$ emissions.

The motivation of this study is based on the significance of FDI inflows on one hand, environmental problems on the other. Thus, the main objective of the present study is to survey the causal or reciprocal correlation between investment by inward FDI and environmental pollution by $CO_2$ emissions, though some other variables namely economic growth (real GDP per capita) and trade openness have also been included in the regression model of the study. This study covers 17 countries from Asia over the period ranging from 1980 to 2014. Apparently, erstwhile studies are often restricted by measurement techniques which condense the consistency of information on attraction of desirable level of inward FDI and environmental policies. Therefore, this study seeks to reduce the gap in the literature by further extending the multivariate framework, but using a unique set of variables—inward FDI, $CO_2$ emissions, economic growth and trade openness.

This empirical study makes four main contributions: first, this empirical study provides a more in-depth portrayal of the interrelationship between $CO_2$ emission and inward FDI. Both the fully modified OLS and traditional panel data estimation methods (i.e. fixed effects) are used, where the FMOLS technique developed by Pedroni (1999, 2001) has the advantage to control for the likely endogeneity of the regressors and autocorrelation (Baltagi and Kao 2000; Ramirez 2006; Diallo 2015). Moreover, the stacked panel Granger causality test was implemented to survey the direction of causality. Second, use of a different portfolio of variables (i.e. openness to trade, $CO_2$ emissions, inward FDI and growth) compared with the previous studies, where it may solve the problem of omitted variable bias that erstwhile empirical studies confronted. Third, balanced panel data over the period from 1980 to 2014 are used, and this study covers 17 Asian countries, some of which were overlooked earlier by the prior studies. The fourth contribution is that panel causality results suggest bidirectional link between $CO_2$ emissions and net direct foreign investment inflows, in contrast with some prior empirical findings. To the best of the author's knowledge, this is the pioneering study on the area under study, where the findings of this study are likely to provide more accurate and worthwhile information to management authorities in formulating prudent environmental and economic growth policies for Asian countries. According to the total emissions country rank, these selected Asian countries' rankings are as follows: China first, followed by India, Japan, Iran, South Korea, Indonesia and Australia.

The remaining structure of the study is as follows: Section 2 deals with literature review on the FDI–pollution nexus. Section 3 discusses data, model and estimation strategy. Section 4 interprets the empirical results. Section 5 deals with concluding remarks.

## Literature review

The reciprocal relationship among environmental pollution and FDI along with some other variables has been intensively studied by several prior studies, but the empirical outcomes are yet elusive and vague (Xing and Kolstad

2002; Omri et al. 2014; Farhani and Ozturk 2015; Keho 2015; Ahmed et al. 2017; Salahuddin et al. 2018). He (2006) also mentions that most of the prior studies did not directly deal with the FDI–pollution nexus; however, their investigation is based on the causality from environmental regulation stringency to firm's competitiveness as entry point. The existing empirical literature reveals that analyses of the FDI–environment nexus in less developed economies have received little attention (Baek and Koo 2008). For example, Xing and Kolstad (2002) explore the impact of the US inward FDI on environmental quality in 22 countries including 15 advanced and 7 poor countries during 1985–1990; they observe that poor countries tend to apply lenient environmental regulations as a tactic to enhance dirty industries from advanced countries. Cole (2004) estimated emissions of 10 air and water pollutants, controlling for openness to trade, structural change and 'dirty' using thorough data on North–South trade flows for pollution intensive-products to evaluate the PHH. The study finds support of pollution haven impacts, though such impacts do not seem to be pervasive and seem to be somewhat small compared with the roles played by the other regressors. He (2006) finds that the overall effect of inward FDI on industrial $SO_2$ emissions is very small, using panel data of China's 29 provinces. However, the estimated model provides substantial supportive evidences for the PHH. Solarin et al. (2017) also confirmed the PHH for Ghana.

Baek and Koo (2008) observe inward FDI to have a destructive impact on environmental quality in both the short and long run in China (period 1980–2002) and India (period 1978–2000), which thereby strongly supports the PHH. The empirical evidence of Pao and Tsai (2011) seems to support the PHH and both the halo and scale effects for BRIC during 1980–2007 (except for Russia 1992–2007). Zhang (2011) finds that China's FDI among financial development indicators shows the least effect on the change of $CO_2$ emissions in China over the period of 1980–2009. The empirical findings of Liargovas and Skandalis (2012) using panel data regression indicate that trade liberalisation contributes encouragingly in the long run to the incoming FDI in 36 developing economies over the period of 1990–2008. The empirical results of Lee (2013) suggest that FDI has played a pivotal role in economic growth for the G20 economies from 1971 to 2009, while it limits its effect on an increase in $CO_2$ emissions in the sample countries. Lee and Brahmasrene (2013) find that the panel cointegration and fixed effect techniques show that economic growth has a high significantly positive effect on $CO_2$ emissions, while FDI causes a high significantly negative effect on $CO_2$ emissions using a panel dataset of European Union countries during 1988–2009. Omri et al. (2014) provide evidence of bidirectional causality between direct foreign investment and growth, and direct foreign investment and $CO_2$ emissions for 54 countries during 1990–2011.

The long-run estimates of Shahbaz et al. (2015) using the FMOLS suggest FDI enlarges environmental degradation in 99 (low, middle and high income) countries over the period of 1975–2012 and thereby support the existence of the PHH. Furthermore, the two-way causality between $CO_2$ emissions and FDI was detected in a global panel. Vinh (2015) studied the bidirectional link between FDI and environment in Vietnam using sectoral data from 1993 to 2012. The empirical finding of the study deeply supports PHH for Vietnam. Yang and Wang (2016) investigate the FDI–pollution nexus based on China's province-level panel data during 2005–2014. They expound that though the empirical results are very complex when it comes to dissimilar geographic regions and environment indicators, overall, the study observes some solid evidence that FDI inflows and pollution causally interact with each other. In five provinces of China, namely Guizhou, Neimenggu, Beijing, Henan and Shanxi during 1985–2012, a study by Peng et al. (2016) finds that inward FDI contributes significantly to carbon emissions, while there is an opposite causation direction in the case of Neimenggu province. Moreover, in the case of East China, FDI has a significantly positive influence on $CO_2$ emissions, while GDP exhibits a negative effect. Abdouli and Hammami (2017) explore the effect of economic growth, inward FDI, trade openness and energy use on environmental degradation in 17 MENA countries from 1990 to 2012. Panel regression results reveal that FDI significantly increases environmental degradation, i.e. PHH exists. Moreover, the empirical results indicate that trade openness and energy use variables significantly contribute to $CO_2$ emissions in the region. In a recent study, Bah and Azam (2017) find that FDI inflows cause environmental pollution by $CO_2$ emissions in South Africa during 1971–2012. Shahbaz et al. (2019) results suggest the existence of N-shaped relationship between inward FDI and $CO_2$ emissions in Middle Eastern and North African countries during1990–2015.

Some other studies find no or mixed empirical results, for example Rezza (2013) observes that the environmental strictness of a recipient country and its execution has no influence on the FDI inflows in the Norwegian manufacturing sector during 1999–2005. The fully modified OLS estimates of Shaari et al. (2014) find that in the long run FDI inflows do not have any impact on $CO_2$ emission for 15 developing countries between 1992 and 2012. They advise that an increase in inward FDI does not affect $CO_2$ emission, but an increase in economic growth can build up $CO_2$ emission. Moreover, the Granger causality analysis based on vector error correction model (VECM) suggests that in the short run, there FDI and economic growth has no influence on $CO_2$ emissions. Keho (2015) observes evidence supporting that FDI inflow increases $CO_2$ emissions in some members of the Economic Community of West African States during 1970–2010, while it decreases them in others, though no indication of significant influence of inward FDI on carbon emissions is also observed. However, empirical results on economic growth by GDP indicate that an increase in growth eventually increases $CO_2$ emissions in most ECOWAS countries. These empirical findings indicate mixed results across countries during the period under study. Mixed results obtained by Boontem (2016), reexamining the PHH for global level, separate groups of ASEAN countries and at country level of Thailand from 2008 to 2013. The results show that low levels of pollution control enforcements considerably enhance FDI to ASEAN countries and the East Asia Pacific region, while no statistically significant result was detected in the cases of Europe, Central Asia and Latin America. However, in the case of Thailand, foreign investors from home countries think that low levels of pollution control enforcements in Thailand substantially enhance their investment decision. Tasri and Karimi (2019) find that there is no PHH in the advanced countries during 2007–2014. Some more selected prior empirical studies on the relationship between incoming FDI and environmental pollution are given in Table 1.

The aforementioned empirical studies indicate that the interrelationship between $CO_2$ emission and inward FDI in the context of a large panel of Asian countries has been overlooked. Therefore, a fresh empirical study is required to examine the relationship between $CO_2$ emission and FDI for a panel of 17 Asian countries, which is the broad objective of this study.

## Data, model and estimation strategy

### Data description

This study based on secondary annual cross-section balanced data on a panel of 17 countries from Asia over the period of 1980–2014.[3] The sample size is 595 ($n = 35$ (years) × 17 (countries)). The study uses variables, namely net foreign direct investment inflows ($IN_{it}$), environmental pollution by $CO_2$ emissions ($CO_{2it}$), economic growth ($Y_{it}$) and trade openness ($XP_{it}$). Data on all selected variables have been obtained from the World Development Indicators (2018) (http://datacatalog.worldbank.org/). A brief summary of the descriptive statistics and correlation matrix on selected variables is reported in Table 2.

### Model specification

The prime objective of the present study is to empirically investigate the causal relationship among foreign direct investment inflow, environmental pollution ($CO_2$ emissions), economic growth and trade openness. The relationship among these selected variables can be expressed in the following functional form:

$$\begin{aligned} CO_{2it} &= f(IN_{it} Y_{it} XP_{it}) \\ IN_{it} &= f(IN_{it} Y_{it} XP_{it}) \end{aligned} \quad (1)$$

The model used in this study is based on Baek and Koo (2008); Cole (2004); He (2006); Lee and Brahmasrene (2013); Shahbaz et al. (2015).

More expressly, Eq. (1) can be rewritten in the following symbolic form:

$$CO_{2it} = \alpha_{0i} + \alpha_{1i} IN_{it} + \alpha_{2i} Y_{it} + \alpha_{3i} XP_{it+} \varepsilon_{1it} \quad (2)$$

$$IN_{it} = \beta_{0i} + \beta_{1i} CO_{2it} + \beta_{2i} Y_{it} + \beta_{3i} XP_{it+} \varepsilon_{2it} \quad (3)$$

Granger causality multivariate regression model of this study can symbolically be expressed as follows:

$$\begin{aligned} CO_{2it} = \alpha_{1,i} &+ \sum_{i=1}^{p} \alpha_{2,i} CO_{2,i,t-1} + \sum_{i=1}^{p} \alpha_{3,i} IN_{i,t-1} \\ &+ \sum_{i=1}^{p} \alpha_{4,i} Y_{i,t-1} + \sum_{i=1}^{p} \alpha_{5,i} XP_{i,t-1} + \varepsilon_{1,i,t} \end{aligned} \quad (4)$$

$$\begin{aligned} IN_{i,t} = \beta_{1,i} &+ \sum_{i=1}^{q} \beta_{2,i} CO_{2,i,t-1} + \sum_{i=1}^{q} \beta_{3,i} IN_{i,t-1} \\ &+ \sum_{i=1}^{q} \beta_{4,i} Y_{i,t-1} + \sum_{i=1}^{q} \beta_{5,i} XP_{i,t-1} + \varepsilon_{2,i,t} \end{aligned} \quad (5)$$

In Eqs. (2) and (3), $i = 1,2,\ldots\ldots\ldots.N$ refers to each country in the panel ($N = 17$ in our case) and $t = 1,2,\ldots\ldots t$ refers to the time period ($T = 33$ in our case), $\alpha_i$ and $\beta_i$ are regression coefficients in Eqs. (2), (3), (4) and (5), respectively. In Eqs. (4) and (5), $p$ and $q$ stand for each variable in the optimum lag periods. $\varepsilon$ is the error value of each model equation.

Prior studies reveal that market size measured by GDP per capita, trade openness and pollution (environmental pollution) by $CO_2$ emissions (unregulated pollution due to weak rule and regulation, investors invest more) have positive impacts on FDI inflow. Likewise, erstwhile studies provide evidence of a positive link among $CO_2$ emissions, FDI inflows, economic growth and trade openness.

### Estimation strategy

After thoroughly studying prior studies' estimation techniques, the present study will use the panel FMOLS[4] and panel Granger causality test.[5] The ordinary least squares (OLS) technique does not yield effective estimates in the existence of distinctive order of integration of the variables. Due

[3] List of countries used: Australia, Bangladesh, China, Indonesia, India, Fiji, Islamic Rep. of Iran, Japan, Korea, Rep., Pakistan, Malaysia, Maldives, Sri Lanka, Nepal, the Philippines, Singapore and Thailand.

[4] See Shahbaz et al. (2015) and Azam et al. (2016) for more statistical details about the panel cointegration tests, estimating cointegration regression and causality test.

[5] See Othman and Masih (2015) and Behringer et al. (2016).

**Table 1** Specific previous studies on the linkage between foreign direct investment and $CO_2$ emissions

| Author(s) | Sample periods and country(s) | Method(s) used | Variables used | Findings |
|---|---|---|---|---|
| Hu et al. (2018) | 2003–2010 | Panel regression, fixed effect | Total factor productivity, FDI, pollution emission intensity, cost–profit ratio, energy production efficiency | The labour-based FDI has negative, and capital-based FDI has a significantly positive spillover effect |
| Yoon and Heshmati (2017) | 2009–2015 South Korea | Pooled least squares estimation | Environmental regulation, FDI, GDP, GDP per capita, dummy variable for Asia and industry | Found that FDI increases $CO_2$ emissions |
| Behera and Dash (2017) | 17 South and Southeast Asian countries 1980–2012 | FMOLS and DOLS | $CO_2$ emission, FDI, primary energy use and urbanization | Overall variables surge $CO_2$ emission |
| Ali et al. (2017) | 1971–2012 Malaysia | ARDL | $CO_2$ emissions, energy use, GDP per capita, FDI, trade and financial development | Found significant correlation between FDI and $CO_2$ emissions |
| Peng et al. (2016) | 1985–2012 China | SUR, OLS and panel VAR | $CO_2$ emissions, FDI and GDP | FDI contributes significantly to $CO_2$ emissions in five provinces, while results are opposite in some other provinces (mixed results) |
| Keho (2015) | 1970–2010 12 ECOWAS countries | ARDL | $CO_2$ emissions, FDI, population, real GDP per capita | FDI increases $CO_2$ emissions in some countries while it decreases them in others (mixed results) |
| Tang and Tan (2015) | 1976–2009 Vietnam | Johansen cointegration test and VECM Granger causality | $CO_2$ emissions, energy use, FDI and GDP | FDI inflows reduce $CO_2$ |
| Ren et al. (2014) | 2000–2010 China | GMM | $CO_2$ emissions, per capita industrial output, FDI and trade openness | Found that FDI and trade openness raise $CO_2$ emissions |
| Shaari et al. (2014) | 1992–2012 15 developing countries | FMOLS | $CO_2$ emissions, FDI and GDP | Found that an increase in FDI does not affect $CO_2$ emissions |
| Pao and Tsai (2011) | 1980–2007 BRIC | ECM and VECM | $CO_2$ emissions, FDI and GDP | Found that FDI increases $CO_2$ emissions |
| Baek and Koo (2008) | China (1980–2002) and India (1978–2000) | VEC | $SO_2$ emissions, FDI and GDP | FDI in both countries has a negative impact on environmental quality |
| Liang (2006) | 1996–2003 China | OLS, IV and fixed effects | $SO_2$ emission, FDI, per capita GDP and industrial output | Found a negative relationship between FDI and $SO_2$ emission (air pollution) |

Assembled by authors

*VEC* vector error correction, OLS ordinary least squares, *$SO_2$* sulphur dioxide, *IV* instrumental variable, *GMM* generalised method of moments, *VAR* vector autoregression, *ARDL* autodistributive lag model

to this visible problem in OLS, panel FMOLS developed by Pedroni (2001) would be implemented to compute the values of long-run estimates. The panel FMOLS estimator usually generates stable estimates in small samples and does not undergo large size distortions in the existence of endogeneity and heterogeneous dynamics. Regarding the advantage of FMOLS estimator, Ramirez (2006) documented that "In addition, it proceeds to estimate the pooled production (productivity) function via a 'group-mean; panel FMOLS estimator developed by Pedroni [1999, 2001] which not only generates consistent estimates of the parameters in relatively small samples, but also controls for potential endogeneity of the regressors and serial correlation." (p. 6).[6] Therefore, based on the distinct features of FMOLS, we apply this approach to deal with potential endogeneity and serial correlation biases in data used in this study. For instance, environmental quality may be one of the driving factors to enhance foreign direct investment to the recipient country(s); hence, the government of the host countries[7] has various efforts to improve environmental quality by controlling pollution, $CO_2$ emissions and carbon sequestration by carbon tax, plantation and so on. On the other hand, inward FDI is likely to deteriorate environmental quality in many ways. We implement the FMOLS estimator to address the potential endogeneity between carbon emission and FDI inflow. In addition, we incorporated real GDP per capita which represents economic growth and trade openness as control variables, while macro time series data is often characterised with unit-root issue, which causes a serial

[6] Azam (2019a, b) also used the panel FMOLS estimator based on its advantages.

[7] See for more detail Khwaja et al. (2012); Jin et al. (2016); and World Bank (2017).

**Table 2** Descriptive statistics and correlation matrix

| Statistics/ variables | $IN_{it}$ | $CO_{2it}$ | $Y_{it}$ | $XP_{it}$ |
|---|---|---|---|---|
| Mean | 7.8895 | 3.9790 | 6882.105 | 41.7700 |
| Median | 0.7178 | 1.5719 | 1763.799 | 25.4986 |
| Maximum | 290.9284 | 19.11876 | 37,573.37 | 230.2690 |
| Minimum | − 25.0931 | 0.0284 | 178.8503 | 3.39625 |
| Std. Dev. | 27.2005 | 4.76182 | 10,603.44 | 44.5324 |
| Skewness | 7.14463 | 1.42844 | 1.722448 | 2.26029 |
| $IN_{it}$ | 1.0000 | | | |
| $CO_{2it}$ | 0.1918 | 1.0000 | | |
| $Y_{it}$ | 0.1145 | 0.8399 | 1.0000 | |
| $XP_{it}$ | 0.0492 | 0.2885 | 0.2363 | 1.0000 |
| Observations | 578 | 578 | 578 | 578 |

correlation problem in error series. Thus, we apply FMOLS approach to eliminate potential existence of a serial correlation problem. In addition, for more robust results, the traditional panel estimation techniques, namely fixed effect would also be employed based on the Hausman test.

## Empirical results

### Panel unit root tests

Prior to empirical evaluation of the panel data, it is necessary to have an understanding of the integrating properties of the data series. This study therefore, employed the widely used three-panel unit root tests for this purpose, i.e. Fisher-ADF and Fisher-PP tests by Maddala and Wu (1999) and Choi (2001); Im et al. (2003) (IPS); and Levin, Lin and Chu (LLC) (2002). Results of IPS, LLC and ADF panel unit tests are given in Table 3. It is evident from Table 2 that most of the selected variables, namely FDI inflows, $CO_2$ emissions, growth and openness to trade, are found non-stationary in its level and became stationary after its first difference with individual constant and trend in a panel. These panel unit root results suggest that all selected variables used in the study are integrated at $I(1)$ in each panel.

### Panel cointegration results

Pedroni (1999, 2004) developed tests that are implemented for long-run investigation and the results are displayed in Table 4. Table 4 demonstrates that there is strong indication to reject the null hypothesis of no cointegration in each panel. So, it can be safely concluded that all selected variables ($IN_{it} = f(CO_{2it}$, $Y_{it}$, $XP_{it}$) and $CO_{2it} = f(IN_{it}, Y_{it}, XP_{it})$) are cointegrated over

**Table 3.** Panel unit root analysis

| Tests | Variables | Level | | First difference | |
|---|---|---|---|---|---|
| | | Constant | Constant + trend | Constant | Constant + trend |
| Levin, Lin and Chu (LLC) | $IN_{it}$ | 9.18496 (1.000) | 0.96747 (0.8333) | − 5.23630 (0.000) | − 1.36540 (0.0861) |
| | $CO_{2it}$ | 4.68379 (1.000) | − 0.67250 (0.2506) | − 16.2707 (0.000) | − 14.2114 (0.000) |
| | $Y_{it}$ | 17.4779 (1.000) | 5.66554 (1.000) | − 7.45528 (0.000) | − 13.6240 (0.000) |
| | $XP_{it}$ | 0.41084 (0.6594) | 1.29048 (0.9016) | − 20.5417 (0.000) | − 18.7395 (0.000) |
| Im, Pesaran and Shin W-stat (IPS) | $IN_{it}$ | 8.31331 (1.000) | − 1.99271 (0.0231) | − 12.5234 (0.000) | − 14.2948 (0.000) |
| | $CO_{2it}$ | 7.43976 (1.0000 | − 2.52201 (0.0058) | − 17.1950 (0.000) | − 15.2465 (0.000) |
| | $Y_{it}$ | 17.3910 (1.000) | 6.04363 (1.000) | − 10.6359 (0.000) | − 14.1405 (0.000) |
| | $XP_{it}$ | 1.04388 (0.8517) | 1.24884 (0.8941) | − 19.3926 (0.000) | − 17.4485 (0.000) |
| Fisher Chi-square (ADF) | $IN_{it}$ | 11.7803 (0.9921) | 77.0850 (0.0000) | 257.926 (0.000) | 260.264 (0.000) |
| | $CO_{2it}$ | 9.29805 (1.000) | 58.4927 (0.0056) | 303.614 (0.000) | 250.127 (0.000) |
| | $Y_{it}$ | 5.381469 (1.000) | 24.4975 (0.8846) | 199.028 (0.000) | 226.607 (0.000) |
| | $XP_{it}$ | 27.2378 (0.7880) | 32.6381 (0.5343) | 338.122 (0.000) | 287.695 (0.000) |

Values in () denote probability value. Akaike's Information Criteria (AIC) is used for lag length

**Table 4** Pedroni panel cointegration test results

| Model | Series: $CO_{2it} = f(IN_{it}, Y_{it}, XP_{it})$ | | Series: $IN_{it} = f(CO_{2it}, Y_{it}, XP_{it})$ | |
|---|---|---|---|---|
| | Statistic | P value | Statistic | P value |
| Panel v–statistic | 3.189834 | 0.0007 | 0.090038 | 0.4641 |
| Panel rho–statistic | − 2.116229 | 0.0172 | − 7.183829 | 0.0000 |
| Panel PP–statistic | − 4.941098 | 0.0000 | − 14.57188 | 0.0000 |
| Panel ADF–statistic | − 4.456122 | 0.0000 | − 10.73739 | 0.0000 |
| Group rho–statistic | 0.893720 | 0.8143 | − 1.856952 | 0.0317 |
| Group PP–statistic | − 2.560204 | 0.0052 | − 11.31128 | 0.0000 |
| Group ADF–statistic | − 3.586461 | 0.0002 | − 8.570795 | 0.0000 |

Deterministic intercept and trend are included in the cointegration equations

the period ranging from 1980 to 2014. Further, the results of Johansen Fisher panel cointegration test are presented in Table 5, which additionally support for the presence of cointegration among a selected set of variables by refusing the null hypothesis of no cointegration in each panel at 5% level of significance.

The empirical results of panel FMOLS estimator are shown in Table 6. These results reveal that by taking foreign direct investment (IN) as a response variable, all estimated coefficients are statistically significant. Likewise, FMOLS results given in Table 6 indicate that by taking environmental pollution by $CO_2$ emissions as a response variable, all estimated coefficients are statistically significant with the exception of economic growth. Empirical results show that the estimation has the most significant explanatory power based on the adjusted $R^2$ values of 0.9138 and 0.4281. It means that the $R^2$ explains almost 91% and 43% of variations by the incorporated explanatory variables in the response variables respectively. It is evident from Table 6, based on the estimated $CO_2$ emission model, that FDI inflows are credibly the most significant factor that contributes to environmental pollution ($CO_2$ emissions). The estimated coefficient sign is in accordance with the study hypothesis and correctly reflects theoretical expectations. The coefficient of 0.017 is achieved for the inward FDI variable significant at the 1% level of significance. One percentage point rise in FDI inflows leads to a rise in environmental pollution by 0.017 unit percentage for each specific country.

These empirical results support the pollution haven hypothesis for 17 countries from Asia over the period of 1980–2014. In a study, Liang (2006), p. 01) noted that "Relatively lenient environmental policies in the developing countries may give them a comparative advantage in pollution intensive goods, and openness to trade and foreign direct investment might harm the host country's environment". Therefore, the empirical findings of detrimental effect of inward FDI on environmental quality of this study are in accordance with the findings by He (2006); Baek and Koo (2008); Pao and Tsai (2011); Shahbaz et al. (2015); Vinh (2015); and Peng et al. (2016), and are inconsistent to those of Liang (2006) and Lee and Brahmasrene (2013).

Table 6 further reveals that in the estimated model trade openness is undeniably also an important variable that

**Table 5** Johansen Fisher panel cointegration test results

| No.of CE(s) | Trace statistics | P value | Max Eigen statistics | P value |
|---|---|---|---|---|
| Series: $IN_{it}=f(CO_{2it},Y_{it},XP_{it})$ | | | | |
| None | 207.2 | 0.0000 | 159.2 | 0.0000 |
| At most 1 | 86.54 | 0.0000 | 84.13 | 0.0000 |
| At most 2 | 34.41 | 0.3532 | 32.09 | 0.4625 |
| At most 3 | 26.16 | 0.7564 | 26.16 | 0.7564 |
| $CO_{2it}=f(IN_{it},Y_{it},XP_{it})$ | | | | |
| None | 207.2 | 0.0000 | 159.2 | 0.0000 |
| At most 1 | 86.54 | 0.0000 | 84.13 | 0.0000 |
| At most 2 | 34.41 | 0.3532 | 32.09 | 0.4625 |
| At most 3 | 26.16 | 0.7564 | 26.16 | 0.7564 |

No intercept or trend included in the cointegration equations

**Table 6** Panel cointegration action estimates

| Equations | $CO_{2it} = f(IN_{it}, Y_{it}, XP_{it})$ | | $IN_{it} = f(CO_{2it}, Y_{it}, XP_{it})$ | |
|---|---|---|---|---|
| Method: panel fully modified least squares (FMOLS) | | | | |
| Variables | Coefficient | P value | Coefficient | P value |
| $IN_{it}$ | 0.0166* [0.0052] (3.1585) | 0.0017 | – | – |
| $CO_{2it}$ | – | – | 3.6877* [1.1272] (3.2713) | 0.0011 |
| $Y_{it}$ | 5.05E−05 [3.89E−05] (1.2970) | 0.1952 | 0.0014* [0.0005] (2.7383) | 0.0064 |
| $XP_{it}$ | 0.0065* [0.0023] (2.8017) | 0.0013 | 0.2367** [0.1363] (1.7363) | 0.0831 |
| adj. $R^2$ | 0.9138 | | 0.4281 | |

Asterisks indicate 1% (*) and 10% (**) levels of significance positively contributes to environmental pollution. The estimated coefficient of 0.006 is obtained for the trade openness variable (measured as exports of goods and services to GDP ratio) found significant at the 1% level of significance, an empirical result that goes along with the general consensus. These results imply that an increase of one percentage point in trade openness leads to enlarge environmental pollution by 0.006 unit percentage for each specific country, though the link between growth and $CO_2$ emissions (environmental pollution) found is positive but statistically insignificant. Overall, empirical results of $CO_2$ emissions model indicate that FDI, market size (economic growth) and trade openness are the important determinants of $CO_2$ emissions for 17 Asian countries.

Moreover, the empirical results of FDI model reported in Table 6 show that environmental pollution is positively related to FDI inflows, meaning in this case that high environmental pollution by $CO_2$ emissions encourages FDI inflows. It implies that because of prevailing unregulated law regarding pollution in these countries, foreign investors invest more and more, taking advantage of lenient environmental policy. Both market size (economic growth by real GDP per capita) and trade openness have positive impacts on incoming FDI and are statistically significant. These empirical results reveal that $CO_2$ emissions, economic growth and trade openness are the key determinants of net direct foreign investment for the sample countries, and also consistent with the OLI theory of Dunning (2002).

Additionally, to confirm the impact of FDI inflows with some other variables on $CO_2$ emissions, the fixed effects estimator based on the Hausman test is applied. The fixed effects estimates are reported in Table 7. The results given in Table 7 further support that FDI inflows increase environmental pollution.

After estimating the marginal effects of incoming FDI, growth and openness to trade on $CO_2$ emissions and $CO_2$ emissions, growth and trade openness on FDI inflows, this study employs the stacked panel Granger causality test to investigate the direction of causality between the selected variables for the sample countries during the period under study. The results of panel Granger causality test are presented in Table 8. The result of panel causality exhibits that there is interrelationship between $CO_2$ emissions and net foreign direct investment inflows. These empirical findings support the results of Pao and Tsai (2011), Shahbaz et al. (2015), Vinh (2015) and Tang and Tan (2015) who also observed the correlation association between inward FDI and $CO_2$ emissions. The linkage between market size and economic growth found is bidirectional. The results support the unidirectional causality running from $CO_2$ emissions to economic growth. Similarly, the causality test reveals the unidirectional causality running from trade openness to $CO_2$ emissions, while

**Table 7** Fixed effects estimation

| Equations | $IN_{it}=f(CO_{2it},Y_{it},XP_{it})$ | | $CO_{2it}=f(IN_{it},Y_{it},XP_{it})$ | |
|---|---|---|---|---|
| Variables | Coefficient | *P* values | Coefficient | *P* value |
| $IN_{it}$ | - | - | 0.0158* [0.0027] (5.8358) | 0.0000 |
| $CO_{2it}$ | 3.6286* [0.6217] (5.8358) | 0.0000 | - | - |
| $Y_{it}$ | 0.0014* [0.0003] (4.9613) | 0.0000 | 6.24E−05* [1.93E−05] (3.2360) | 0.0013 |
| $XP_{it}$ | 0.1977* [0.0727] (2.71867) | 0.0068 | 0.0016* [0.0048] (0.3349) | 0.7378 |
| Constant | − 24.6435* [3.74539] (6.5796) | 0.0000 | 3.3570* [0.2141] (15.6794) | 0.0000 |
| Adj. $R^2$ | 0.4197 | | 0.917274 | |
| *F*-stat | 22.9612 | | 337.7283 | |
| Correlated random effects-Hausman test | 36.2561 (0.0000) | | 43.3915 (0.0000) | |
| Total panel (balanced) observations | 578 | | | |
| Cross-sections included | 17 | | | |

Asterisk indicates estimated coefficients are significant at 1% level. Standard errors are in parentheses and *t*-statistics in brackets bidirectional causality is found between economic growth and openness to trade. However, neutral influence exists between trade openness and incoming FDI, as no causality is observed between these variables in the sample countries during the period under study (see Table 8).

## Conclusion and policy implications

This study aims to examine the causal linkage between environmental pollution by $CO_2$ emissions, and net foreign direct investment along with some other variables—economic growth measured by real GDP per capita and trade openness for 17 Asian countries. Annual balanced panel over the period of 1980–2014 is used for empirical exploration. Appropriate panel cointegration and causality analysis methods are implemented. The results indicate that all variables are integrated at $I(1)$ corroborated by proper panel unit root tests. Panel cointegration tests confirm the long-run association among $CO_2$ emissions (environmental pollution), direct foreign investment inflows, economic growth (real per capita GDP) and trade openness. The panel fully modified ordinary least squares (FMOLS) estimates reveal that inward foreign direct investment has a significantly positive impact on environmental pollution. It implies that inward FDI is found to have a detrimental impact on environmental quality, supporting the pollution haven hypothesis in 17 Asian countries over the period of 1980–2014. The other variable trade openness in the $CO_2$ emission model is detected to have a positive and significant effect on environmental pollution. Likewise, in the FDI model, explanatory variables, namely $CO_2$ emissions, economic growth and trade openness, have a significantly positive impact on inward FDI. FDI model results imply that $CO_2$ emissions, economic growth and trade openness are the important determinants of FDI inflows. Panel causality results suggest bidirectional association between environmental pollution by $CO_2$ emissions and net FDI inflows.

These empirical findings are of specific interest to management authorities as they help build appropriate economic policies and more conducive foreign investment policies to get better environmental quality. These policies should not only ensure increase in economic growth but also must ensure sustainable economic growth and development under the premise of defending the host country's environment. Economic policy reforms are required to channelise foreign capital inflows to a more environmentally healthy direction, where the objective of multinational corporations would not only to maximise their profit but rather should sustain sustainable development of the host countries. In enhancing FDI, countries should stringently study the qualifications for foreign investors or to stimulate environmental protection through the harmonised know-how and technological transmission with international companies to circumvent environmental destruction (Pao and Tsai 2011). Thus, the governments of Asian countries should chalk out prudent policies on FDI inflows on one hand, and to keep the environment clean and green on the other hand. It is also suggested that initially, developing countries need to focus relatively more on promoting socioeconomic development first, then go for achieving sustainable economic growth and development.

**Table 8** The stacked panel Granger causality test results

| Stacked pairwise Granger causality tests | | |
|---|---|---|
| Null hypothesis | *F*-Statistic | *P* value |
| $CO_{2it} \rightarrow IN_{it}$ | 1.89235 | 0.0515 |
| $IN_{it} \rightarrow CO_{2it}$ | 1.60770 | 0.1108 |
| $Y_{it} \rightarrow IN_{it}$ | 2.47229 | 0.0094 |
| $IN_{it} \rightarrow Y_{it}$ | 2.40228 | 0.0116 |
| $XP_{it} \neq IN_{it}$ | 0.63578 | 0.7665 |
| $IN_{it} \neq XP_{it}$ | 0.95821 | 0.4743 |
| $Y_{it} \neq CO_{2it}$ | 1.01718 | 0.4253 |
| $CO_{2it} \rightarrow Y_{it}$ | 6.98510 | 2E–09 |
| $XP_{it} \rightarrow CO_{2it}$ | 3.70716 | 0.0002 |
| $CO_{2it} \neq XP_{it}$ | 1.54768 | 0.1291 |
| $XP_{it} \rightarrow Y_{it}$ | 3.23228 | 0.0008 |
| $Y_{it} \rightarrow XP_{it}$ | 3.14987 | 0.0011 |

Direction of causality (→), no causality (≠)

### Compliance with ethical standards

**Ethical statement** The manuscript has not been previously published, is not currently submitted for review to any other journal and will not be submitted elsewhere before a decision is made by this journal.

## References

Abdouli M, Hammami S (2017) Economic growth, FDI inflows and their impact on the environment: an empirical study for the MENA countries. Qual Quant 51(1):121–146

Agarwal JP (1980) Determinants of foreign direct investment: a survey. Weltwirtschaftliches Arch 116(4):739–773

Ahmed K, Bhattacharya M, Shaikh Z, Ramzan M, Ozturk I (2017) Emission intensive growth and trade in the era of the Association of Southeast Asian Nations (ASEAN) integration: an empirical investigation from ASEAN-8. J Clean Prod *154*:530–540

Ali W, Abdullah A, Azam M (2017) Re-visiting the Environmental Kuznets Curve hypothesis for Malaysia: fresh evidence from ARDL bounds testing approach. Renew Sust Energ Rev 77(2017): 990–1000

Azam M (2016) Does environmental degradation shackle economic growth? A panel data investigation on 11 Asian countries. Renew Sustain Energy Rev 65:175–182

Azam M (2019a) Energy and economic growth in developing Asian economies. J Asia Pac Econ. https://doi.org/10.1080/13547860.2019.1665328

Azam M (2019b) Relationship between energy, investment, human capital, environment and economic growth in BRICS-4. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-019-06533-9

Azam M, Khan AQ, Abdullah HB, Qureshi ME (2016) The impact of $CO_2$ emissions on economic growth: evidence from selected higher $CO_2$ emissions economies. Environ Sci Pollut Res 23(7):6376–6389

Baek J, Koo WW (2008) A dynamic approach to the FDI-environment nexus: the case of China and India. Presented at the American Agricultural Economics Association Annual Meeting, Orlando, FL, July 27–29, 2008

Bah MM, Azam M (2017) Investigating the relationship between electricity consumption and economic growth: evidence from South Africa. Renew Sust Energ Rev 80:531–537

Baltagi BH, Kao C (2000) Nonstationary panels, cointegration in panels and dynamic panels: a survey. in Advances in econometrics 15. Edited by Baltagi, B., and Kao C., pp.7–51, Elsevier Science

Bartels FL, de Crombrugghe SA (2009) FDI policy instruments: advantages and disadvantages. United Nations Industrial Development Organization, Vienna, 2009

Behera SR, Dash DP (2017) The effect of urbanization, energy consumption, and foreign direct investment on the carbon dioxide emission in the SSEA (South and Southeast Asian) region. Renew Sust Energ Rev 70:96–106

Behringer J, Stephan S, Theobald T (2016) Macroeconomic factors behind financial instability evidence from Granger causality tests. FEPS STUDIES, Macroeconomic Policy Institute (IMK)" HansBöckler Straße 39, 40476 Düsseldorf, Germany

Blais JP (1975) A theoretical and empirical investigation of Canadian and British FDI in manufacturing in the U.S. University of Pittsburgh

Boontem K (2016) An impact of pollution control enforcements on FDI inflow. The Business and Management Review 7(3):155–168

Borensztein E, De Gregorio J, Lee JW (1998) How does foreign direct investment affect economic growth? J Int Econ 45(1):115–135

BP Statistical review of world energy (2017) Available at: https://www.bp.com/content/dam/bp-country/de_ch/PDF/bp-statistical-review-of-world-energy-2017-full-report.pdf

Choi I (2001) Unit root tests for panel data. J Int Money Financ 20(2): 249–272

Cole MA (2004) Trade, the pollution haven hypothesis and the environmental Kuznets curve: examining the linkages. Ecol Econ 48:71–81

Czinkota MR, Ronkainen IA, Moffett MH (2014) Fundamentals of international business-3rd Edition (New York: Wessex, Inc.; 3rd edition (August 29, 2014)

De Mello LR (1997) Foreign direct investment in developing countries and growth: a selective survey. J Dev Stud 34(1):1–34

Dean JM, Lovely ME, Wang H (2009) Are foreign investors attracted to weak environmental regulations? Evaluating the evidence from China. J Dev Econ 90(1):1–13

Diallo IA (2015) Exchange rate volatility and investment: a panel data cointegration approach. Expert Journal of Economics 3(2):127–135

Dunning JH (1988) The eclectic paradigm of international production: a restatement and some possible extensions. J Int Bus Stud 19(1):1–31

Dunning JH (1993) Multinational enterprises and the global economy. Addison-Wesley Publishing company

Dunning JH (2002) Determinants of foreign direct investment: globalization induced changes and the role of FDI policies. Paper present in the Economist Intelligence Unit's World Investment Prospects, 2002, London 2002

Edwards S (1990) Capital flows, foreign direct investment and debt-equity swaps in developing countries. NBER Working Paper No. 3497, October

Eskeland GS, Harrison AE (2003) Moving to greener pastures? Multinationals and the pollution haven hypothesis. J Dev Econ 70(1):1–23

Farhani S, Ozturk I (2015) Causal relationship between CO2 emissions, real GDP, energy consumption, financial development, trade openness, and urbanization in Tunisia. Environ Sci Pollut Res *22*(20):15,663–15,676

French H (1998) Capital flows and the environment. Foreign policy in focus, Washington, DC. Retrieved from http://fpif.org/capital_flows_and_the_environment/

He J (2006) Pollution haven hypothesis and environmental impacts of foreign direct investment: the case of industrial emission of sulfur dioxide (SO2) in Chinese provinces. Ecol Econ 60:228–245

Hoffmann R, Lee C-G, Ramasamy B, Yeung M (2005) FDI and pollution: a Granger causality test using panel data. J Int Dev 17:311–317

Hu J, Wang Z, Lian Y, Huang Q (2018) Environmental regulation, foreign direct investment and green technological progress—evidence from Chinese manufacturing industries. Int J Environ Res Public Health 15(221):1–14

Im KS, Pesaran MH, Shin Y (2003) Testing for unit roots in heterogeneous panels. J Econ 115(revise version of 1997's work):53–74

Jin Y, Andersson H, Zhang S (2016) Air pollution control policies in China: a retrospective and prospects. Int J Environ Res Public Health 13(12):12–19

Keho Y (2015) Is foreign direct investment good or bad for the environment? Times series evidence from ECOWAS countries. Econ Bull 35(3):1916–1927

Khwaja MA, Umer F, Shaheen N, Sherazi A, Shaheen FH (2012) Air pollution reduction and control in South Asia. Working paper Series 121, Sustainable Development Policy Institute (SDPI) Islamabad-Pakistan

Lee JW (2013) The contribution of foreign direct investment to clean energy use, carbon emissions and economic growth. Energy Policy 55:483–489

Lee JW, Brahmasrene T (2013) Investigating the influence of tourism on economic growth and carbon emissions: evidence from panel analysis of the European Union. Tour Manag 38:69–76

Levin A, Lin C, Chu C-J (2002) Unit root tests in panel data: asymptotic and finite-sample properties. J Econ 108:1–24

Liang F (2006) Does foreign direct investment harm the host country's environment? Hass School of Business, University of California, Berkeley

Liargovas PG, Skandalis KS (2012) Foreign direct investment and trade openness: the case of developing economies. Soc Indic Res 106(2): 323–331

Loungani P, Razin A (2001) How beneficial is foreign direct investment for developing countries?. Finance & Development: A quarterly magazine of the IMF, June 2001, 38 (2). http://www.imf.org/external/pubs/ft/fandd/2001/06/loungani.htm

Maddala GS, Wu S (1999) A comparative study of unit root tests with panel data and a new simple test. Oxf Bull Econ Stat 61(S1):631–652

McDermott R (2009) A panel study of the pollution-haven hypothesis. Glob Econ J 9(1):1–22

Mundell RA (1957) International trade and factor mobility. Am Econ Rev 47:321–335

OECD (2002) Foreign direct investment for development: maximising benefits, minimising costs. OECD Publications Service, France, pp 1–32

Omri A, Nguyen DK, Rault C (2014) Causal interactions between $CO_2$ emissions, FDI, and economic growth: evidence from dynamic simultaneous-equation models. Econ Model 42:382–389

Othman AN, Masih M (2015) Do profit and loss sharing (PLS) deposits also affect PLS financing? Evidence from Malaysia based on DOLS, FMOLS and system GMM techniques. Working paper, Islamic finance at INCEIF, Lorong Universiti A, 59100 Kuala Lumpur, Malaysia. Online at http://mpra.ub.uni-muenchen.de/65224/ MPRA Paper No. 65224

Pao H-T, Tsai C-M (2011) Multivariate Granger causality between $CO_2$ emissions, energy consumption, FDI (foreign direct investment) and GDP (gross domestic product): evidence from a panel of BRIC

(Brazil, Russian Federation, India, and China) countries. Energy 36: 685–693
Pedroni P (1999) Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxf Bull Econ Stat 61:653–670
Pedroni P (2001) Purchasing power parity tests in cointegrated panels. Rev Econ Stat 83:1371–1375
Pedroni P (2004) Panel cointegration. Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. Economet Theor 20:597–625
Peng H, Tan X, Li Y, Hu L (2016) Economic growth, foreign direct investment and $CO_2$ emissions in China: a panel granger causality analysis. Sustainability 8(233):1–13
Ramirez MD (2006) A panel unit root and panel cointegration test of the complementarity hypothesis in the Mexican Case, 1960–2001. Center Discussion Paper No. 942, Economic Growth Center Yale University, P.O. Box 208629, New Haven, CT 06520–8269
Ren S, Yuan B, Ma X, Chen X (2014) International trade, FDI (foreign direct investment) and embodied CO2emission: a case study of Chinas industrial sectors. China Econ Rev 28:123–134
Rezza AA (2013) FDI and pollution havens: evidence from the Norwegian manufacturing sector. Ecol Econ 90:140–149
Salahuddin M, Alam K, Ozturk I, Sohag K (2018) The effects of electricity consumption, economic growth, financial development and foreign direct investment on CO2 emissions in Kuwait. Renew Sust Energ Rev *81*:2002–2010
Shaari MS, Hussain NE, Abdullah H, Kamil S (2014) Relationship among foreign direct investment, economic growth and $CO_2$ emission: a panel data analysis. Int J Energy Econ Policy 4(4):706–715
Shahbaz M, Nasreen S, Abbas F, Omri A (2015) Does foreign direct investment impede environmental quality in high, middle and low-income countries? Energy Econ 51:275–287
Shahbaz M, Balsalobre-Lorente D, Sinha A (2019) Foreign direct investment–$CO_2$ emissions nexus in Middle East and North African countries: importance of biomass energy consumption. J Clean Prod 217: 603–614
Solarin SA, Al-Mulali U, Musah I, Ozturk I (2017) Investigating the pollution haven hypothesis in Ghana: an empirical investigation. Energy *124*:706–719
Tang CF, Tan BW (2015) The impact of energy consumption, income and foreign direct investment on carbon dioxide emissions in Vietnam. Energy 79:447–454
Tasri ES, Karimi K (2019) Emission study and pollution haven hypothesis in economic development of developed country in Social Sciences on Sustainable Development for World Challenge: The First Economics, Law, Education and Humanities International Conference, KnE Social Sciences, pages 260–270. DOI https://doi.org/10.18502/kss.v3i14.4313
UNCTAD (2006) World investment report 2006: FDI from developing and transition economies: implications for development New York-Geneva
UNCTAD (2016) World investment report 2016: investor nationality: policy challenges. United Nations Conference on Trade and Development, Switzerland
UNEP (2016) Premature deaths from environmental degradation threat to global public health. United Nations Environment Programme. UNEP Report Says Mon, May 23, 2016. Available at "http://www.unep.org/newscentre/Default.aspx?DocumentID=27074&ArticleID=36186&l=en"
Vinh CTH (2015) The two-way linkage between foreign direct investment and environment in Vietnam –from sectoral perspectives. Working paper, Foreign Trade University, Vietnam
World Bank (2013) The year the World Bank fused sustainable development with its goals for the future. Available at http://www.worldbank.org/en/news/feature/2013/12/23/year-world-bank-fused-sustainable-development-goals-future
World Bank (2015) Sustainable development. The World Bank Group A to Z 2016 Published: October 2015. Pages: 173c - 173c. https://doi.org/10.1596/978-1-4648-0484-7 _sustainable_development
World Bank (2017) Reducing pollution. Available at http://www.worldbank.org/en/topic/environment/brief/pollution
World development indicators (2018) published by the World Bank (http://datacatalog.worldbank.org/)
Xing Y, Kolstad CD (2002) Do lax environmental regulations attract foreign investment? Environ Resour Econ 21(1):1–22
Yang J, Wang Y (2016) FDI and environmental pollution nexus in China. Department of economics, Lund University Working Paper, 2nd June 2016
Yoon H, Heshmati A (2017) Do environmental regulations effect FDI decisions? The pollution haven hypothesis revisited. Discussion Paper Series- IZA DP No. 10897, IZA – Institute of Labor Economics, Germany
Zakarya GY, Mostefa B, Mohammed S, Abbes SM, Seghir GM (2015) Factors affecting $CO_2$ emissions in the BRICS countries: a panel data analysis. Procedia Economics and Finance 26:114–125
Zhang Y-J (2011) The impact of financial development on carbon emissions: an empirical analysis in China. Energy Policy 39(4):2197–2203

**Publisher's note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.