Does the pollution halo hypothesis exist in this “better” world? The evidence from STIRPAT model

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Abstract
Multinational corporation has changed their host countries. The new wave of FDI inflow attracted the interest of policymakers. FDI has significant effects on both productivity and carbon dioxide emissions. The host countries should carefully consider the advantages and disadvantages of FDI to their nation. The previous literature has not illustrated the global context’s theoretical halo or haven pollution hypothesis. Using panel data of 96 countries between 2004 and 2014, our empirical results confirm the haven pollution hypothesis in both developing and developed countries. We employ the different general methods of moments (GMMs) to engage FDI in traditional STIRPAT theoretical frameworks. The empirical results contribute to the evidence of the EKC theory. The country’s income level has been used to modify our models. The affluence of the economy, urbanization, FDI, and industrial sector would cause harmful effects on carbon dioxin emissions globally. The paper implies the two models which can be used for both developed and developing countries. The policymaker can use both short-run and long-run elasticities from those models to implicate their country’s FDI inflow strategy.

Keywords Haven pollution hypothesis · Foreign direct investment · Urbanization · General method of moments · Stochastic impact by regression on population · Affluence · And technology · Carbon emissions

Introduction
Global climate change affects the global environment, the current issue worldwide. The United Nations Framework Convention on Climate Change (UNFCCC) committed to reducing greenhouse gas (GHG) emissions in 1992. Dangerous anthropogenic interference caused GHG emissions and damaged the climate system, which should be stopped. Historically, many global responses were generated to reduce GHG emissions. At the global level, the 1997 Kyoto Protocol was established, with many countries agreeing to the commitment to reduce GHG emissions. Besides, investment in energy-efficiency technologies provides an efficient approach to reducing GHG and global warming at the corporation level. GHG emissions also set some global energy standards for firms. Energy service companies (ESCOs) can develop and design energy efficiency technology, which is generated to reduce GHG emissions (Council 2008; Ellis 2010; Fang et al. 2012; Linares and Labandeira 2010; Popp 2004, 2010; Vine 2005). Recently, sustainable development goals have been established by United Nations. There are 17 goals in total, integrating six goals on balancing economic and environmental sustainability. While the country’s commitment to joining the SDGs, almost economic or environmental policies should be modified to reach SDGs standards before 2030. For example, the multinational corporations (MNCs), which ESCOs undertake, reduced GHG emissions in the host country’s operation and transferred energy-efficiency technologies to reduce GHG emissions in other countries via their foreign direct investment (FDI). Besides that, the ISO 14001 also contributes to the green growth strategy of the firm in Pakistan (Abid et al. 2022). Significantly, MNCs from developed countries

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can reduce GHG emissions in developing countries with their investments (He 2006; Hübeler 2011; Saikawa and Urpelainen 2014; Yang et al. 2014). In previous studies, many researchers successfully captured the shreds of evidence that FDIs affect economic growth (Borensztein et al. 1998; Crespo and Fontoura 2007; Greenaway and Kneller 2007), have a spillover effect on productivity (De Mello 1999; Wei and Liu 2006), and prompt host country’s entrepreneurship (Alfaro et al. 2004; 2009). Thus, many governments recently have specific strategies for observing FDI due to its importance towards economic growth. However, Phuc Nguyen et al. (2020) have failed to express the effect of FDI on pollution, while their study uses a tiny dataset only in emerging economies. At the same time, some other studies have reflected this significant hypothesis.

Furthermore, pollution halo and haven hypotheses are proposed to describe the causality relationship between pollution issues and FDI (Zhu et al. 2016). The host country’s government has two options to justify a foreign investment. The government accepts the FDI and its low energy-intensive technology that can reduce harmful pollution situations in the host country, which is called well-known the pollution halo hypothesis (Mert and Bölük 2016; Zhu et al. 2016). Besides the above benefits, FDI can harm the host country’s environment, called the pollution haven hypothesis. This phenomenon is proposed to appear under the context that the environmental issues are neglected or enforced under relaxed regulation by the government. Some studies indicate that FDI inflows harm the pollution situation in Vietnam, the Middle East North Africa (MENA) countries, other Southeast Asia countries, and the Middle East countries (Abdouli and Hammami 2017; Al-mulali 2012; Baek 2016; Tang and Tan 2015; Naz et al. 2019). Can FDI transfer and install an energy-efficient system for the host economy and reduce their CO2 emissions level, or provide an opposite effect? According to recent literature, the empirical results are mixed and depend on the affluence of the economy, the choice of countries, or specific cities. They used fixed and random effects OLS regression, GMM methods, ARDL regression, and VECM (Abdouli and Hammami 2017; Al-mulali 2012; Baek 2016; Tang and Tan 2015; Naz et al. 2019). However, some studies support the hypothesis that FDI inflow helps host countries to reduce carbon dioxide emissions in Kyoto Annex countries and ASEAN countries by panel quantile regression and panel ARDL approach (Mert and Bölük 2016; Zhu et al. 2016; Zameer et al. 2020). Matthew et al. (2017) conclude that a consistent effect of the pollution haven hypothesis is hard to find due to certain countries and specific pollution-intensive sectors (precisely sample size). Recently, the interest of researchers in the linkage between FDI and pollution has increased. The necessary trend is a more and larger sample size, which is expected to fulfill the understanding of researchers on existing phenomena. The last global events yield a new wave of FDI withdrawal from China.1

According to the government of ASEAN countries and Segis and Hauge (2020), due to the US-China trade war and unstoppable Covid-19 situation, the manufacturing FDI have runout China will be around 37%, which is known as the highest out-flow in recent 5 years. There is much academic and applied research on attracting FDI from firms looking for an alternative to China at this period. Even though the world is talking about the satellite imagery of an “unprecedented green China” resulting from industry imposed to halt the spread of Covid-19, the over-optimistic points of view emerge more and more in China’s neighboring countries. The policymakers seemed to forget China’s “Trade-offs” lesson two decades ago. The issue regarding FDI is predicted to happen in twofolds. First, MNCs in the USA, Japan, and South Korea will withdraw FDI from China, switching to neighboring countries. Moreover, the digital transformation era has promoted advanced manufacturing technologies such as AI, robots, and IoT and affected MNC’s strategy (Tassey 2014). Automatic manufacturing factory reduces the competition of the FDI, hosting factory economics (Asia) and cheap labor (Szalavetz 2019). FDI factories can move from emerging countries to high advantage technological economies. Second, Chinese enterprises craving inflow of FDI expect to reinvest in a third country to reduce the export tariffs exposed by the USA through the country-of-origin regime. Previous studies on the Chinese context support the pollution halo hypothesis, which can be explained by the fact that the seriously damaged local environment forced residents, enterprises, and government to be concerned.

It should be noted that not all inflow of FDI will run out of China, which will lead to the pollution halo hypothesis. Carbon dioxide (CO2) is recognized as the most important anthropogenic GHG by the International Panel on Climate Change (IPCC 2007) worldwide. The current study investigates the impact of inward FDI on emissions on a global scale. Testing this phenomenon can yield vital evidence about the trade-off between environmental conditions and economic growth. To test the halo or haven hypothesis, the effect of FDI on CO2 emission can be looked at through four philosophies like positivism, post-positivism, post-empiricism, and interpretivism (Lor 2017). The number of publications on pollution, which imply the pollution

1 After the US-China trade war and Covid-19, ASEAN governments analyzed the political and economic situation in future to react to trade war and Covid-19. MNCs tend to shift their factories to China’s neighbor. He (2006) directly addresses the haven pollution hypothesis and FDI-environmental regulation stringency in China, is the most recent. From Pao and Tsai (2011), researchers interested in the halo pollution hypothesis or EKC hypothesis.
The environmental perspective has changed from positivism to post-empiricism. Before, researchers reflected on the pollution phenomenon worldwide (pollution haven hypothesis) to analyze the antecedents of the pollution halo hypothesis (Zameer et al. 2020). Recently, the researchers usually refer to the empirical study with provinces data level, which includes the difference of the state’s policy on environmental, even when those entities are in China and other Asian countries (He 2006; Gui et al. 2017; Liu et al. 2017; Huang et al. 2018; Zhang and Zhang 2018). After Matthew et al. (2017) review, empirical results truthy convince the government based on recommendations with evidence from case studies, reflecting the unilateral pictures. Many researchers adopt positivism (quantitative) and interpretivism (qualitative) to investigate the causality between FDI and pollution. Thus, the limitations appear frequently in their dataset to explain case-oriented or variable-oriented, while the worldwide sample size data is available. Comparing the halo and haven phenomenon via developing and developed country data should be conducted.

Furthermore, does the pollution halo hypothesis be found in high-income countries? Moreover, does the pollution haven hypothesis be found in low-income countries? (Chang and Li 2019). Recent words-using also reflects this expectation. “The contradictory Pollution Haven Hypothesis” has appeared in the newest studies (Phuc Nguyen et al. 2020). The belief that FDI and its satellite factors can make up for the impact of “the pollution outsourcing hypothesis” is causing certain disturbances. In another context, policymakers should focus more on the cause of pollution issues rather than only on the reaction. Many improper decisions by policymakers are accused of lacking multidimensional empirical results, which can harm the host country’s environment. This study aims to provide an effect of FDI on the haven pollution hypothesis that will alert policymakers to consider the influence of accepting FDI seriously. The system GMM is employed to generate the empirical results of an extensive analysis via developing and developed country data should be conducted.

Contributing evidence contradicting the “Pollution Halo” hypothesis with a worldwide dataset. Our finding shows that the policymakers should treat the FDI as the factor that positively affects pollution. Their policy needs to be carefully built to exclude polluted MNCs and attract green technology investment. The affluence of the economy, urbanization, FDI, and industrial sector would cause harmful effects on carbon dioxin emissions globally. FDI is a good factor that should be considered in extending the STIRPAT model. This new outlook of the STIRPAT model can explain both the domestic and foreign factors in an environmental study. Moreover, our findings also yield evidence on EKC theory which illustrates the inverted U-shape of the effect of household income on pollution.

Moreover, this article conducts empirical results with worldwide sample data that support the halo hypothesis in the global platform. A relevant literature review is discussed in the “Literature review” section, followed by data description and methodology in the “Research methodology” section. The empirical results are in the “Estimation results” section. Critical implications and conclusions are highlighted in the “Discussion” and “Conclusion” sections, respectively.

### Literature review

In economic theory, Pao and Tsai (2011) yield the theoretical model for describing humanity’s effect on the environment. Then the environmental impact (I) is defined by the well-known IPAT (or I=PAT) as the product of components: population size (P), the affluence of the economy (A), and existing technology (T). The Kaya identity applies the IPAT identity, which considers the four driving forces of global CO2 emissions (Pao and Tsai 2011). The ImPACT, developed to predict total CO2 emissions, is not derived from some underlying theoretical model (Waggoner and Ausubel 2002). Leaning the IPAT model and its relative to the pollution study is an essential requirement. Previous researchers claim those four factors cannot be excluded to avoid the omitted variable (Li et al. 2015; Zhang and Zhou 2016; Gui et al. 2017; Phuc Nguyen et al. 2020). Furthermore, urbanization has also been added-in to the IPAT model (Fang and Miller 2013). The lack of foreign factors made the scholars less interested in the IPAT model. Similar to the idea of moving from the closed economic model to the open economic model in any macroeconomic syllabus, the need for the foreign factor in the IPAT model extracts the researchers dig in this field.

The population factor implies all the human activities in the environment. Unfortunately, population growth and human behavior claim to be the main factor that positively impacts the environment. Ehrlich and Holdren (1971) mention that the population’s elasticity of the environment should be near to one. For example, the higher population growth rate force using more fossil fuels to power is an example of their increasingly mechanized lifestyles. Recently, Zhang et al. (2017) found that human awareness can moderate the relationship between the population and the environment. Human activity and their living lifestyle...
support the explanation. For example, in countries where people are primarily medium or low income, cars are still luxury products, and many people tend to use one public vehicle. Those behavior causes reduce carbon dioxin levels. Researchers have found empirical results that consistently prove this point of view in developing countries (Rehman et al. 2021; Wu et al. 2021).

The researchers have noticed the relationship between household income and the environment from the beginning of UNFCCC commitment in the twentieth century. The affluence of the economy is claimed as a factor that can contribute to the diminishing returns on the harm of the environment before the thresholds (Tan and Tan 2015; Gökmenoğlu and Taspinar 2016). Besides that, Zhu et al. (2016) consider the environmental conditions as the inferior good in the household’s basket for consumption. Individuals with low income can accept low welfare conditions based on their unaffordable budget constraints (Hotte and Winer 2012). Hence, scholars tend to look for the threshold that can separately observe the inverted U-shape in the relation between income and environmental conditions. In the past, scholars used GDP per capita and its square to measure this threshold (Lau et al. 2014; Muhammad et al. 2020). Using $A$ and $A^2$ are famous for testing environmental Kuznets curve (EKC) theory (Balsalobre-Lorente et al. 2019).

Technology has affected almost aspect of human life. Hence, Pao and Tsai (2011) built the IPAT model toward this perspective and included the factor of existing technology. Any efficient way to cut off the harm to the environment from economic activities should be linked to existing technology. Zgravu-Soilita (2015) uses a regulatory environment to measure the government’s efforts to reduce pollution. Even the nominal scale as the first-year countries allows ESCO company to start in the host country, which measures the dummy variable as the existing technology estimators (Fang et al. 2012). The most useful scale to measure the effect of the existing technology is the energy intensity level or the renewable energy consumption (Mert and Bölük 2016; Shahbaz et al. 2018; Ahmad et al. 2021; Yang et al. 2021); because it is roughly interested in investing the energy use directly with the other variables. Abid et al. (2020) described the causatively short-run relationship between the growth rate of carbon emission and non-renewable energy in Pakistan. Their study shows that the long-run positive effect of non-renewable energy on carbon emission still has a positive effect. At the global level, non-renewable energy is widely applied and used in life (Khan et al. 2022). Hence, the existing technology (energy intensive in the world development indicator) is assumed to affect carbon dioxin emissions positively.

Urbanization has contributed a significant effect on pollution. It is a crucial point of view when comparing the crowd of citizens between urban and rural areas in pollution studies. Many researchers consider urbanization an explaining variable to carbon emission (Fang and Miller 2013; Rehman et al. 2021; Wu et al. 2021). In general, pollution is higher in urban areas than in rural areas. For example, if the income level is affordable, the area shall have more cars when the cities have more citizens. Likewise, the scholar usually claims the positive effect of urbanization on most pollution indicators (Phuc Nguyen et al. 2020). However, the estimator of urbanization has been found as negative significant in the developing country contexts. Li et al. (2021a) and Li et al. (2021b) have found evidence that changing energy consumption can reduce pollution, such as moving from private transportation to public transportation and saving energy intensity. At the global level, the effect of urbanization on pollution is expectedly to have positive significance.

Foreign direct investment is used to clarify a factor that can affect the productivity of the host country (Alfaro et al. 2009). That is why the FDI always sticks with the citizen’s income. The policymaker usually considers FDI the crucial factor contributing to the host country’s income. For that reason, the effect of FDI on the environment should be comoved with household income. In other words, the public health condition is not their priority compared to the trade-off for income (Hotte and Winer 2012). Thus, the impact on the environment can also be assumed as inferior goods when the government in low-income countries chooses the FDI inflows or the national income level (GDP per capita). They tend to accept FDI-inflows without considering the impact on environments (Abdouli and Hammami 2017; Al-mulali 2012; Baek 2016; Tang and Tan 2015; Udemba 2020). Countries with a high level of pollution situations will prefer to attract the FDI within green technology spillover to reduce pollution situations (Huang et al. 2018; Hao et al. 2020; Horobet et al. 2021). Table 1 summarizes the relationship between FDI and the environment, conducted recently.

The research evidence is mixed in China, the most polluted globally regarding CO₂ emissions and air quality pollution (PM 2.5). At the city or province level, many types of research support the positive impact of inward FDI on the local environment in China (He 2006; Li et al. 2015; Xu et al. 2016). Besides, some articles support the Halo hypothesis that FDI inflows help reduce pollution in China. Yang et al. (2014) show that the increase in the R&D sector can decrease carbon dioxide emissions when FDI-inflows contribute an essential role in promoting the R&D sector. Following this direction, Auffhammer et al. (2016) conducted their research to confirm that the pollution halo hypothesis exerts more severe than the pollution haven hypothesis in Chinese cities. Again, the results confirm mixed implications among the pollution situations in each city or province in China. Balsalobre-Lorente et al. (2019) have also yielded evidence that FDI and environmental conditions have a nonlinear relationship in MINT countries. The two
Table 1  Previous studies that investigate the pollution halo or haven hypothesis

| Authors                  | Related hypothesis | Model/methodology                | No of variables | Developing | Developed | Specification of sample |
|--------------------------|--------------------|----------------------------------|-----------------|------------|-----------|------------------------|
| He (2006)                | Haven (negative: −) | GMM                             | 9               | v          | v         | China provinces        |
| Al-mulali (2012)         | Haven               | Panel FMOLS/VECM                | 5               | v          | v         | The Middle East countries |
| Lau et al. (2014)        | Haven               | EKC theory                      | 5               | v          | v         | Malaysia               |
| Yang et al. (2014)       | Haven               | Fixed/random effects/2SLS        | 9               | v          | v         | China provinces        |
| Li et al. (2015)         | Haven               | STIRPAT/PLS                     | 7               | v          | v         | Tian Jia City (China)  |
| Tang and Tan (2015)      | Halo (positive: +)  | EKC theory/Granger VECM         | 5               | v          | v         | Vietnam                |
| Zugravu-Solita (2015)    | Haven               | Fixed effect panel estimator    | 5               | v          | v         | France-Germany-Sweden-UK |
| Auffhammer et al. (2016) | Halo                | Decomposition/OLS               | 6               | v          | v         | China provinces        |
| Baek (2016)              | Haven               | PoolOLS estimator               | 6               | v          | v         | ASEAN countries        |
| Gökmenoğlu and Taspinar (2016) | Haven               | FMOLS/EKC theory                | 4               | v          | v         | Turkey                 |
| Mert and Bolük (2016)    | Halo                | PoolOLS/ADRL                    | 6               | v          | v         | Kyoto Annex countries  |
| Zhu et al. (2016)        | Halo                | Fixed effect panel quantile regression | 8 | v | v | 5 countries in ASEAN |
| Zhang and Zhou (2016)    | Halo                | STIRPAT/FGLS                    | 7               | v          | v         | China regions          |
| Abdouli and Hammami (2017) | Haven               | OLS/fixed and random effects/GMM | 6               | v          | v         | MENA countries         |
| Gui et al. (2017)        | Halo                | STIRPAT/PLS regression          | 7               | v          | v         | China                  |
| Liu et al. (2017)        | Halo                | OLS/Fixed effect/GMM            | 7               | v          | v         | China                  |
| Huang et al. (2018)      | Halo                | Fixed effect/FGLS               | 8               | v          | v         | China provinces        |
| Shahbuz et al. (2018)    | Haven               | ADRL/CUSUM/CUSUMsq              | 6               | v          | v         | France                 |
| Zhang and Zhang (2018)   | Haven               | ADRL/Granger causality          | 6               | v          | v         | China                  |
| Balsalobre-Lorente et al. (2019) | Haven               | FMOLS/DOLS/EKC theory          | 7               | v          | v         | Mexico, Indonesia, Nigeria, Turkey |
| Dauda et al. (2019)      | Halo                | EKC theory/FMOLS/DOLS           | 8               | v          | v         | Developed, MENA, BRICS |
| Hao et al. (2020)        | Halo                | SLM model/SEM                  | 8               | v          | v         | 30 provinces of China  |
| Muhammad et al. (2020)   | Haven               | EKC theory/2SLS                 | 8               | v          | v         | 65 belt and road initiative countries |
| Phuc Nguyen et al. (2020)| Halo                | STIRPAT model/panel Granger     | 11              | v          | v         | 33 emerging economies  |
| Udenba (2020)            | Haven               | ADRL/Granger                    | 4               | v          | v         | Turkey                 |
| Ahmad et al. (2021)      | Haven               | ARDL/VECM                      | 6               | v          | v         | China                  |
| Horobet et al. (2021)    | Haven/halo          | VECM                           | 7               | v          | v         | 24 European countries  |
| Yang et al. (2021)       | Haven/halo          | Path LS                        | 5               | v          | v         | 30 provinces of China  |

Several publications have concluded implications to the causality of FDI inflows on any kind of emission from Web of Science

| Year | Before 2016 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | Total |
|------|-------------|------|------|------|------|------|------|-------|
| Halo pollution hypothesis (or contradict to “Haven”) | 03 | 06 | 06 | 09 | 20 | 18 | 30 | 92 |
| Haven pollution hypothesis | 09 | 05 | 11 | 07 | 17 | 20 | 42 | 111 |

*The metadata is analysis via advanced search on Web of Science by keywords as “FDI”; “Halo/Haven”, and”emission”. https://webofknowledge.com. Authors do not count the paper with not concluding results*
last factors are the industry and service sectors. By their natural characteristics, industrial production lines usually harm environmental conditions. The service sector seems to be more green (Fang et al. 2012.)

Research methodology

Research model

This study follows the equation system proposed by Fang et al. (2012). Concerning the empirical model, which allows hypothesis testing. York et al. (2003) take the derivative of the IPAT model to become stochastic impact by regression on population, affluence, and technology (STIRPAT) model, which is as follows:

\[
I_i = aP_i^b A_i^c T_i^d e_i, \text{ or } \ln I_i = \ln a + b \ln P_i + c \ln A_i + d \ln T_i + \epsilon_i
\]  

(1)

The subscript \(i\) denotes the countries; \(a, b, c,\) and \(d\) are the parameters to be estimated; \(\epsilon_i\) is the error term; and \(\epsilon_i = \ln \epsilon\). A simple model of \(CO_2\) production is proposed to estimate equations like that of Eq. (1). Assuming a simple Cobb–Douglas production function for \(CO_2\) emissions as follows:

\[
I_i = a_i E_i^a \epsilon^b
\]

(2)

where \(I = CO_2\) emissions; \(a_i\) is the technological, structural, and other effects; \(E\) is the energy use; \(\epsilon\) is the Euler’s number, and \(\epsilon\) is the error term.

The equation is further augmented by dividing both sides of this production function for \(CO_2\) emissions by population (P), and real GDP (Y) is introduced as follows:

\[
\left(\frac{I_i}{P_i}\right) = a_i \left(\frac{E_i}{P_i}\right)^a \epsilon^b = a_i \left(\frac{E_i}{P_i}\right)^a \left(\frac{1}{P_i}\right)^{1-a} \epsilon^b = a_i \left(\frac{E_i}{Y_i}\right)^a \left(\frac{1}{P_i}\right)^{1-a} \epsilon^b
\]

(3)

Taking natural logarithms gives us the STIRPAT model

\[
\ln I_i = \ln a_i + a \ln P_i + \ln \left(\frac{E_i}{P_i}\right) + a \ln \left(\frac{E_i}{Y_i}\right) + \epsilon_i
\]

(4)

Equation (4) matches Eq. (1), where \(b = c = d = a\), \(A_i = (Y/P_i)\), and \(T_i = (E/Y_i)\). Equation (4) is a rather simple production function (for \(CO_2\) in this case). Additional control variables can enter through the constant term as follows:

\[
a_i = aX_i^a \text{ or } \ln a_i = \ln a + g \ln X_i
\]

(5)

Panel data techniques are adopted in the practical implementations of the STIRPAT model to analyze the effects of population, affluence, energy intensity, industry share, service share, and urbanization on various environmental effects (Shi 2003). The primary driving forces (i.e., population, per capita real GDP, and energy intensity) generate adverse environmental effects. Countries with a large share of service in GDP use less energy and produce fewer emissions; on the other hand, countries with a large share of manufacturing in GDP use more energy and produce higher \(CO_2\) emissions. Urbanization is inevitable in development; thus, it positively affects \(CO_2\) emissions. Many other works focus on an inverted-U relationship between environmental throwback and affluence. \(CO_2\) emissions worsen in the early stages of growth (developing era), named the EKC curve; however, they eventually peak and start declining as the income passes a certain threshold level of the developed era (Kijima et al. 2010). An inverted-U relationship exists with the condition that the coefficient of the squared term is proved significantly negative and the estimated extreme point falls within the data range (Fang and Miller 2013). However, there has been no unanimous evidence supporting the inverted-U relationship. Total \(CO_2\) emissions are focused on because it is directly associated with climate change and global warming. FDI-inflows can address these issues by developing high technological projects designed to improve energy efficiency. To examine the effect of FDI, a dynamic panel data model, which explicitly captures the adjustment in \(CO_2\) emissions, is developed.

Nevertheless, it takes time to reach lower \(CO_2\) emission targets like those in the Kyoto Protocol. In line with that, the previous evidence will be weak to convince policymakers to trust in better environmental conditions via good FDI. While both population and per capita income directly generate environmental pressure in either \(CO_2\) emission in developing or low-income countries. This dependency suggests using a dynamic model to capture the lagged effect. The following estimation equation is used to assess the effect of FDI-inflows on \(CO_2\) emissions:

\[
\ln I_{it} = \mu_i + \eta_i + b \ln I_{t-1} + \epsilon_i \ln P_{it} + d \ln A_{it} + e \ln T_{it} + f \ln X_{it} + \epsilon_{it}
\]

(6)

where the subscript \(t\) denotes the year. With panel data, in \(a\) Eq. (5) becomes a country-specific fixed-effect \(\mu_i\), along with a year-specific fixed-effect \(\eta_i\) and the error term \(\epsilon_{it}\). The dynamic panel data model \(I_{it}(I_{t-1})\) denotes \(CO_2\) emissions in country \(i\) at year emissions in kilotons. \(P_{it}\) denotes total population. \(A_{it}\) denotes real per capita GDP in PPP (purchasing power parity 2005 constant international dollars). \(T_{it}\) denotes energy intensity defined as energy use per unit of real GDP. \(X_{it}\) denotes a set of control variables: per capita GDP squared to test for the EKC hypothesis (Caviglia-Harris et al. 2009), the percentage share of industry (including manufacturing) and service sectors value-added in GDP (Shi 2003), the percentage of the total population living in urban areas (Martinez-Zarzoso and Maruotti, 2011) and the FDI-inflows, which aims to test pollution Halo or
Haven hypothesis. The inclusion $ln I_{t-1}$ leads to biased and inefficient OLS estimates due to the correlation between the lagged dependent variable and the error term. Moreover, from Eq. (6), two additional econometric problems may arise due to endogenous explanatory variables and correlation of country-specific effects with the explanatory variables. The system GMM estimators proposed in Levine et al. (2000) are employed to address these problems. This regression, which must pass two standard specification tests as Sargan and panel serial autocorrelation, is valid.

Data

The panel data of 96 countries from 2004 to 2014 with 1056 observations of CO$_2$ emissions and components are collected in world development indicators. The world bank reports those indicators in yearly data. Our STIRPAT model includes the energy intensity level of primary energy, which was stopped report in 2015. Hence, our data is the most updated track by the world bank (Table 2). All the variables are discussed in the literature review section. The analysis steps by steps will show in Fig. 1. In model 1, the original IPAT model in literature is presented. Model 2 is extended the effect of FDI (foreign technology) in the host environment. In model 3, the EKC hypothesis is estimated. By adding the effects of urbanization, industry, and service, models 4 and 5 continuously extend model 2. In models 6 and 7, the high-income threshold is set, which is also classified by the World Bank to separate the sample into developed countries sample as 297 observations (model 6) and 242 observations (model 8); developing and low-income countries sample as 759 observations (model 7) and 693 (model 9).

### Table 2 Descriptive statistic

| Variables | Mean   | Std. deviation | Maximum | Minimum | Explanation (indicator name) |
|-----------|--------|----------------|---------|---------|------------------------------|
| $ln I$    | 10.4229| 1.9068         | 16.1469 | 6.5411  | CO$_2$ emissions (metric tons per capita) |
| $ln P$    | 16.5195| 1.5486         | 21.0339 | 12.7925 | Population, total            |
| $ln A$    | 8.3515 | 1.3194         | 10.9496 | 4.9109  | GDP per capita = GDP (current USS)/Population, total |
| $ln T$    | 1.6895 | 0.5134         | 3.4004  | 0.4482  | The energy intensity level of primary energy (MJ/2011 PPP GDP) |
| $ln FDI$  | 21.4900| 1.9165         | 27.3218 | 15.5905 | Foreign direct investment, net inflows (BoP, current USS) |
| $ln UB$   | 15.9166| 1.5084         | 20.4253 | 12.4787 | Urban population             |
| $ln IN$   | 3.0162 | 1.0938         | 4.3492  | 1.1516  | Industry, value added (% of GDP) |
| $ln SV$   | 3.5900 | 1.2555         | 4.5338  | 2.9396  | Services, etc., value added (% of GDP) |

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3 Data come from the following source: https://data.worldbank.org/indicator?tab=all.

4 The high-income thresholds are published by United Nation every year, respectively GDP per capital greater than USD 10,065 in 2004 and then USD 12,735 in 2014. The different number of observations are in model 6 and 8 (developed countries) or model 7 and 9 (developing countries), respectively the available data of preventative number of industrial value and service sector value on GDP in some countries have deleted in models 8 and 9.
Estimation results

The unit-roots test

Table 3 reports the results of the panel unit root tests. The data series used as inputs of the regression model should be stationary for solid robustness. The Im et al. (2003) and Levin et al. (2002) unit root tests are adopted to address this problem. The data series must pass one of the unit-roots tests and the evidence that the input values can use for GMM’s regression. The logarithm forms of original data should be used.

The extends of the STIRPAT model

First, the dynamic IPAT model is estimated, where FDI is included in model 2, on top of the estimators in model 1. The coefficient of the FDI variable proves significantly positive at a 1% significance level statistically. This outcome suggests that an increase in FDI results in higher \( CO_2 \) emissions. A 1% change in FDI is associated with a 0.0198% increase in \( CO_2 \) emission. The long-run elasticity is 0.7279 for FDI. All other diagnostic statistics match the baseline model (model 1). So, the robustness of model 2 is similar to model 1 as nonsignificant.

Second, model 3 adds squared real GDP per capita to model 2 to examine the existence of an inverted U-shape EKC. The estimate of the squared term proves significantly negative at the 1% level. The positive coefficient for real GDP per capita and the negative coefficient for squared real GDP per capita indicate that \( CO_2 \) emission shows evidence of the EKC hypothesis.

Third, in model 4, we expand the dynamic IPAT model by including the urbanization variable in model 3. The 1% significance positive FDI still holds when we accommodate the potential linkages between urbanization and \( CO_2 \) emission. This means a 1% increase in urbanization is associated with a 0.0551% increase in \( CO_2 \) emission. The extended model does not revamp the models affecting the coefficients for the lagged dependent variable, total population, real GDP per capita, squared real GDP per capita, and FDI. Urbanization increases \( CO_2 \) emissions. However, the main thing that we need to pay attention to is the transformation of the real GDP per capita variable. It goes from being 1% positively significant in model 3 to being 1% negatively significant in model 4. This means that the 1% increase in population reduces the \( CO_2 \) emission by 0.3773% and suggests that in the long run, a 1% increase in FDI leads to a 0.1366% change in \( CO_2 \) emission. The change

Results of IPAT estimators

Table 4 reports the results from the system GMM estimator of Eq. (6). Under each variable coefficient is the coefficient’s standard error in parenthesis. The Sargan test examines over-identification and AR(1) and AR(2) tests for first-order and second-order autocorrelation, respectively, with the \( p \) values in the parenthesis for each testing.

In model 1, \( CO_2 \) emission is regressed on the lagged \( CO_2 \) emission, total population, real GDP per capita, and the energy intensity level of primary energy. This baseline model incorporates the essential elements from the IPAT framework (Fang and Miller 2013). The results indicate that all four independent variables are statistically significant at the 1% significance level and are positive to the dependent variable. The lagged \( CO_2 \) emission variable makes up most of the \( CO_2 \) emission, supporting the dynamic specification. In the log–log specification, the estimators represent the long-run elasticities or the ratios of percent changes. The 1% change in the total population is associated with a 0.0641% increase in \( CO_2 \) emission. The 1% change in real GDP per capita brings the \( CO_2 \) emission up by 0.0754%. At the same time, a 1% change in technology leads to a 0.2752% increment in \( CO_2 \) emission.

Meanwhile, the long-run elasticities equal the estimators divided by one minus the coefficient of \( ln(I_{it-1}) \) the lagged \( CO_2 \) emission variable. Therefore, the long-run elasticities equal 1.9663 for population, 2.319 for real GDP per capita, and 8.4117 for energy intensity, accordingly to Eq. (1). The Sargan tests for over-identification do not reject the null at the 1% level but reject the null at the 5% significance level. The test for autocorrelation rejects the null of no first-order serial correlation, but it does not reject the null of no second-order serial correlation. The result of model 1 is not robust.

Table 3 Panel unit-root test

| Variables | ln I | ln P | ln A | ln T | ln FDI | ln UB | ln IN | ln SV |
|-----------|-----|-----|-----|-----|-------|------|------|------|
| LLC test  | I(0) | -20.154*** | -4.577*** | -14.881*** | -20.888*** | -15.177*** | -14.530*** | -20.4837*** | -26.8857*** |
| Im test   | I(0) | -5.864*** | 10.945 | -1.719** | -6.158*** | -8.261*** | -9.4357 | -4.6207*** | -5.6676*** |
| I(1)      |     | -1.244* |      |      |       |      |      |      |

The Levin et al. (2002) and the Im et al. (2003) unit root tests consider the null hypothesis that all panels contain unit roots. *10% level; **5% level; ***1% level.
Table 4  Estimation results

| Variables      | Model 1          | Model 2          | Model 3          | Model 4          | Model 5          | Model 6          | Model 7          | Model 8          | Model 9          |
|----------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| ln \(I_{t-1}\) | 0.9674***        | 0.9728***        | 0.9869***        | 0.8631***        | 0.5043***        | 0.9768***        | 0.0232          | 0.9228***        |                  |
|                | (0.1336)         | (0.1480)         | (0.0157)         | (0.0249)         | (0.0205)         | (0.0288)         | (0.0065)         | (0.0591)         | (0.0049)         |
| ln \(P\)       | 0.0641***        | 0.0367***        | 0.0306***        | -0.3773***       | -0.5078***       | 0.2288*          | -0.1278***       | 3.4286*          | -0.1865***       |
|                | (0.0092)         | (0.0102)         | (0.0100)         | (0.0167)         | (0.0581)         | (0.1347)         | (0.0324)         | (1.7622)         | (0.0298)         |
| ln \(A\)       | 0.0754***        | 0.0598***        | 0.3772***        | 0.3157***        | 0.4189***        | -1.1647**        | 0.3839***        | 0.6143           | 0.4190***        |
|                | (0.0082)         | (0.0092)         | (0.0612)         | (0.0578)         | (0.0524)         | (0.4516)         | (0.0497)         | (1.3366)         | (0.0476)         |
| ln \(T\)       | 0.2752***        | 0.2758***        | 0.2927***        | 0.3607***        | 0.4581***        | 0.6948***        | 0.3189***        | 0.6153***        | 0.3476***        |
|                | (0.0197)         | (0.0168)         | (0.0163)         | (0.0260)         | (0.0240)         | (0.0321)         | (0.1717)         | (0.0729)         | (0.0151)         |
| ln \(A^2\)     | 0.0754***        | 0.0598***        | 0.3772***        | 0.3157***        | 0.4189***        | -1.1647**        | 0.3839***        | 0.6143           | 0.4190***        |
|                | (0.0082)         | (0.0092)         | (0.0612)         | (0.0578)         | (0.0524)         | (0.4516)         | (0.0497)         | (1.3366)         | (0.0476)         |
| (EKC test)     | 0.0198***        | 0.0199***        | 0.0187***        | 0.0187***        | 0.0187***        | 0.0200***        | 0.0231***        | 0.0155***        |                  |
|                | (0.0031)         | (0.0035)         | (0.0034)         | (0.0030)         | (0.0035)         | (0.0028)         | (0.0048)         | (0.0019)         |                  |
| ln \(FDI\)     | 0.0511***        | 0.6277***        | 0.1990           | 0.1915***        | -1.8933          | 0.2569***        |                  |                  |                  |
|                | (0.0739)         | (0.0679)         | (0.1343)         | (0.3096)         | (1.3167)         | (0.0348)         |                  |                  |                  |
| ln \(UB\)      | 0.0115           | -0.2992          | 0.0068           |                  |                  |                  |                  |                  |                  |
|                | (0.0285)         | (0.2706)         | (0.0164)         |                  |                  |                  |                  |                  |                  |

In denotes the natural logarithms; the Sargan test examines over-identification. AR (1) and AR (2) test for the first-order and second-order autocorrelation, respectively. *10% level. **5% level. ***1% level.
should come from mixed data, leading to model 4 bias. That is the main reason for this study to separate the sample into two datasets and re-estimate model 4 as models 6 and 7. The other diagnostic statistics from model 1 stay significant at the 1% level in models 3 and 4.

Fourth, model 5 covers all the variables included in model 4 and the industrial sector as percentage of GDP and service sector as percentage of GDP. Authors extend the theoretical model with a proposition by (Martinez-Zarzoso and Maruotti 2011; Shi 2003). The result indicates that the industrial sector estimator is significant at a 1% level while the service sector parameter is insignificant. The service sector may not affect emission levels. However, the inclusion of the two new estimators affects the significance of the urbanization variable, where the urbanization variable altered from being 1% significance to 5% significance. Hence, the author has also separated the sample into developing and developed datasets, different by income level. Because this study treats emission levels as inferior goods (Hotte and Winer 2012), citizens’ perspective about the emission is also different in high- and low-income countries. Model 5 also passed the Sargan and autocorrelation tests, which implies its robustness. The square of real GDP per capita stays negatively significant at a 1% level in model 5, implying that this study’s EKC hypothesis is confirmed using a large dataset.

The developing countries model and developed countries model

First, further check the model’s efficiency when under two different groups of observation; the observations are divided into the developed and developing areas. Model 6 is model 4 applied to 297 observations over 10 years in developed countries (observations), whereas model 7 is model 4 applied to 759 observations over the 10 years in developing counties (observations). Models 6 and 7 show that Sargan’s overidentifying restrictions are valid. AR(1) and AR(2) are valid in first-order and second-order autocorrelation tests. In model 6, the total population variable changes from a 1% negative significance to 10% positively significant. The changing of the population parameter is 0.2288, which implies the long-run emission level elasticity of the population is 0.4616. Unlike the study of Phuc Nguyen et al. (2020), our study does not ignore the population variable in the STIRPAT model, which would support us in reaching the correct results. The omitted variable would be the main reason that causes the coefficient of correlation of FDI in their study to become nonsignificant (Phuc Nguyen et al. 2020). The emission level elasticity of the population is less than one that is reasonable in the scenarios of a good environment and a tiny increasing birth ratio in developed countries. The elderly population is a significant issue in developed countries. Because of the good environmental situation, the change in emission level usually strikes high when the country increases its economic capacities. The real GDP per capita variable changes from the 1% positive significance to the 5% negative significance compared to model 4. In high-income countries, citizens may not accept a trade-off between public health conditions and income. Hence, even the increase of FDI or the other economic capacities should not be approved if it increases the emission level. So, the negative significance of income on the dependent variable is reasonable. This negative effect is also the proof of the EKC hypothesis and unnecessary to concern the square terms. The squared real GDP per capita in model 4 was 1% negative significance, but after the application to the developed countries group, it is now at 1% positively significance. The real GDP per capita had switched sign, so its square is also absolutely switched. The long-run elasticities equal 2.3095 and 1.4017, respectively, for real per capita GDP and energy intensity, which match closely the estimated 2.1412 and 1.7690 in Fang and Miller (2013), who include the same variables excepted FDI in their equations. It shows that our developed dataset is adequate to analyze the STIRPAT model as other studies (Phuc Nguyen et al. 2020). In model 6, we have confirmed that the long-run elasticity of FDI on emission is 0.0379 for high-income countries, inferring that the tiny change of harmful FDI will highly increase the emission. In addition, Wang et al. (2021) have caught up a positive signal of the effect of urbanization on emission intensity in OECD countries.

Furthermore, the urbanization estimator also has a tremendous change in model 6. It was at a 1% positive significance level, but now, according to model 6, it shows positive but insignificant. Model 7 closely follows model 4, where all seven variables stay significant at the 1% level, and all the signs stay the same without changes. In model 7, the estimator parameter of population level and emission intensity is negative, confirming the consistent signal in the recent studies about developing economies (Li et al. 2021a, 2021b; Rehman et al. 2021; Wu et al. 2021). No doubt, human population growth is a significant contributor to CO2 emissions. Using fossil fuels to power is an example of their increasingly mechanized lifestyles. However, environmental awareness could reduce CO2 emissions (Zhang et al. 2017). In addition, citizens’ attention to highly polluted environments in developing countries that been enhanced dramatically. As living in a harmful environment and the spiritual civilization are elevated, people in urban areas tend to care more about environmental issues such as global warming. For that reason, the fostering of environmental awareness in developing countries is high. More than 60% of the population live in the metropolitan area but not rural, and then that group of people supports controlling the intensity of carbon dioxide levels in Pakistan (Rehman et al. 2021). Wu et al. (2021) have also found evidence of the population flow from...
Western (rural) to Eastern (urban), supporting to reduce the growth of carbon emissions in China. This effect may easily explain as the high intensity of population can control and save fossil fuels used at one time. If we look at the carbon footprint, it will be easily recognized that countries with a larger carbon footprint usually have a smaller population size (Li et al. 2021a, b, c). For example, in countries where people are primarily medium or low income, cars are still luxury products, and many people tend to use one public vehicle. Those behavior causes reduce carbon dioxin levels. The result of models 6 and 7 shows us that the characteristics of the observations influence the outcome model heavily.

Furthermore, models 8 and 9 were modeled after model 5, where model 8 is to analyze the 242 developed countries (observations) and model 9 is to analyze the 693 developing countries (observations), similar to models 6 and 7, where the 1056 observations were divided into two groups. The number of observations in models 8 and 9 differs from models 6 and 7 because of the lack of data for industrial (ln IN) and service sector (ln SV) parameters. Model 8 is considerably disparate from model 5. In this model, six parameters have their property changed. They have started with the lagged variable where it was positively significant at the 1% level, and now the coefficient is negative where the parameter itself is insignificant. The total population parameter was negatively significant at the 1% level, and now the parameter is positively significant at the 10% level. Moreover, the real GDP per capita parameter and its squared change from significant at the 1% level to insignificant. In addition, the urbanization parameter goes from being 5% positively significant to negatively insignificant. Not only that, the application of model 5 in developed countries (observations) leads to the industrial sector parameter going from a 1% significance level to negatively insignificant. Different from model 8, model 9 closely follows model 5. The property of every parameter in model 5 stays the same for the parameters in model 9, other than the coefficient value itself since the data is not entirely the same.

Robustness test

Lastly, the Sargan test detects error cross-sectional dependency and over-identification. Model 8 does not reject the null hypothesis in AR(1) and AR(2) autocorrelation tests. The lagged dependent variable is not robust in models 1, 2, 3, 4, and 8 according to AR(1) autocorrelation test. Hence, the long-run estimators’ parameters (ln \( I_{t-1} \)) are also biased in those models. Models 5, 6, 7, and 9 show that overidentifying restrictions are valid. AR(1) and AR(2) are first-order and second-order autocorrelation tests. Model 5 is the baseline model with a global scale dataset. Model 6 is the only one that performs robustness with the developed country’s dataset. Comparing models 7 and 9, this study uses the criteria proposed in the literature review of the SRITPAT model. Which model has the absolute value of long-run population elasticity of carbon emission as near the natural population ratio as 1, implying the better model (Ehrlich and Holdren 1971).

Computing long-run elasticity

From models 7 and 9, the coefficient of correlation for the population is \(-0.1278\) and \(-0.1865\), respectively. As for the long-run population elasticities, the values are calculated as 5.5086 and 2.4158. So, model 9 outperforms model 7 in terms of robustness with developing country’s datasets. The industrial sector should be employed as an essential exogenous of emission. The authors compute the long-run elasticities of all the dependence variables from models 5, 6, and 9 in Table 5, contributing to the models of developed and developing countries, respectively.

In general, this study mainly focuses on the effect of FDI on CO\(_2\) emission. The coefficient estimates prove positive and significant at the 1% level in all models. The results are consistent with the other study about foreign investment in Pakistan (Hussain and Rehman 2021). This study shows that FDI harms the CO\(_2\) emission as a foreign investment component, confirming the haven hypothesis worldwide. In Table 5, it is crucial to notice that the coefficient estimate for FDI in model 6 (developed countries data) is less in model 9 (developing countries data). However, it is less than in model 5, where the coefficient estimate for FDI in global data worldwide. From models 5, 6, and 9, the coefficient of correlation for FDI is as follows: 0.0187, 0.0188, and 0.0155, respectively (Table 4). As for the long-run FDI elasticities, the values are calculated as follows: 0.09176,

### Table 5 Computing long-run elasticities for developed and developing models

| Long-run elasticities on CO\(_2\) emission | ln \( P \) | ln \( A \) | ln \( T \) | ln \( A^2 \) (EKC test) | ln FDI | ln \( UB \) | ln \( IN \) | ln SV |
|------------------------------------------|----------|----------|----------|-----------------|--------|--------|--------|-------|
| Baseline (global) model                  | -2.4917*** | 2.0554*** | 2.2478*** | -0.0952*** | 0.0918*** | 3.0800*** | 0.1909*** | 0.0564 |
| Developed country model                  | 0.4616*  | -2.3496*** | 1.4017*** | 0.1388*** | 0.0379*** | 0.4015 |        |
| Developing country model                 | -2.4158*** | 5.4275*** | 4.5026*** | -0.2876*** | 0.2008*** | 3.3277*** | 0.7448*** | 0.0881 |

In the log–log specification, the estimators represent the long-run elasticities or the ratios of percent changes. Each elasticity equals their estimators divided by one minus the lagged CO\(_2\) emission variable coefficient in Table 4. The value is present as absolute value, where * denotes 10% level, ** denotes 5% level and *** denotes 1% level.

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0.0379, and 0.2008 (Table 5). We can see here that in model 9, the long-run elasticity for FDI with respect to CO₂ emission is at its highest level. Whereas in model 9, with the inclusion of FDI and squared real GDP per capita on the baseline model, FDI has the highest long-run elasticity value regarding CO₂ emission.

Discussion

The post-pandemic economy is a challenge that faces global climate change emissions. Because emissions should yield poverty worldwide and with poverty accompanied by war and violence, in Covid-19 scenarios, the manufacturer’s global supply chain disruptions and closures will reduce pollution worldwide. The economic growth speed can recover faster as the environment is cleaned. Because the EKC hypothesis would be considered reducing harmful conditions. This study shows that the high-income level has significantly contributed to adverse CO₂ emissions. The long-run elasticity would be computed as $-2.3496$ respectively in developed countries. EKC hypothesis has also been confirmed in developing countries, and the long-run elasticity would be computed as $-0.2876$, respectively. The square variable of affluence of economic ($A^2$) represents the futuro income level of developing countries; therefore, the countries that would gain from EKC theory should promote the income level consistently for many years. From that point of view, the policymaker should attend to the foreign technology interface and industrial policy, which are proven to support Malaysia and Chile cases, escaping the middle-income trap. The opportunity cost of economics is the environment. The people who live in the countries facing the haven hypothesis scenario are paying high costs for healthcare issues in the future. So, policymakers should provide suitable policies for assuring their people have been afforded a living environment to escape the middle-trap income. The GHG emissions were lowest in 2020. Suppose this criterion of emissions can be maintained every year until 2050. In that case, the UNFCCC expectation in 1992 will be reached to net-zero emission. However, the pandemic has expressed an emergency for the government to establish policies supporting a cleaner environment. The capital outflows from emerging market economies in the Covid-19 pandemic should be five times more than in the past crisis.\(^5\) Foreign direct investment (FDI) is most concerned as the main factor that caused the pollution in China at the beginning of the twentieth century. The recent pandemic forces the daily temperature to fall lower than the threshold of 30 °C. So the FDI-environmental regulation stringency in China at the most recent is becoming promising. For example, the ESCOs standard can be proposed as a critical condition for observing the FDI regime.

The other scenario that policymakers should be concerned about is after the US-China trade war and Covid-19, where there is significant FDI inflow. ASEAN governments analyzed the political and economic situation to react to trade war and Covid-19. FDI is one of the rich sources that countries can gain sovereign wealth funds (SWFs). Multinational corporations (MNCs) tend to shift their factories to China’s neighbor. Hence, China’s neighbors shall prepare well-developed policies to attract the green FDI and need to consider the pollution from MNCs deeply. Both India and Australia require prior government approval of the origin of MNCs. India invests in countries with shared borders to protect their domestic company vulnerabilities and carefully consider the applicant’s historical business activities or the environmental causes. Australia attends the approval process on time, which will be extended from 30 days to 6 months during the pandemic. This regulation supports Australia’s monetary system to protect national interests from lower profits to at least zero. In Western countries, the economy seems not to be highly restricted by FDI. Only the MNCs which want to develop, manufacture, producing vaccines or other medical equipment will become the target of the constraint policies. Spain, Germany, and France are confident about their monetary system and fiscal policy because they are not facing the liquidity trap. So eco-green FDI or not will be the only concentration. On the opposite side, Hungary, Italy, and Canada tend to protect the domestic economy from the recession due to the zero interest rate causing the deflation. However, even the need to protect national security interests is high or low. All developed countries should not trade off the long-term goal as an environment for the short-term target of economic recovery. Countries will protect the low level of CO₂ emissions in the period of present pandemics. Post-crisis, government actions and economic incentives will likely influence the global CO₂ emissions path for decades. For all the reasons above, the decision about the FDI regime is always extremely hard for decision-makers. Nevertheless, the FDI should not be traded off for environmental conditions, even in developed or developing countries.

Conclusion

For the FDI approval, the host countries should be considered carefully to attract the unpolluted investment multinational corporations. Outsourcing capitalism can help recover the economy and reduce the pressure on the
nation’s wealth of fiscal budget. Hence, the long-run steady-state can reach sustainability. This study uses GMM methods to successfully indicate the empirical results for developed and developing countries to understand better the effects of FDI on CO₂ emissions in line with the other macroeconomic variables. The policymaker shall base on the results to make better decisions.

Unfortunately, carbon dioxin emissions are the most severe issues, but not overall the pollution. Other pollution issues should be investigated, such as air quality pollution (PM 2.5), sulfur dioxin (SO), or the ecological footprint, that can use as dependent variables in the STIRPAT model. The existing technology factor sometimes can be measured by nominal scale as a dummy variable in a country or city context—for example, the country’s new regulation for environmental conditions or the global standard energy in wide scale. Future studies can also look for the threshold conditions for the inverted U-shape of urbanization on carbon emission, which is expected to contribute a new lens to reduce pollution.

This study does not clarify the service sector’s effect on carbon dioxin emission. Even the sub-dataset of developed countries has a higher share of the service sector in the economy and does not come out with a significant relationship. The limitation may come from the small observations. While energy-intensive is the best to measure the existing technology in global scenarios, the lack of observations remains. Our study has also failed to discuss renewable energy instead of non-renewable strategy. This limitation can be claimed on the small and disperse of the renewable dataset. In the future, the researchers can estimate the effect of renewable energy with others factors to enlarge the pollution knowledge.

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Author contribution All the individuals who participated in contributing to this study are mentioned as authors on the title page. The first author Nhan Nguyen-Thanh has contributed in part 1, Introduction and part 2, Literature review. The second author Kuo-Hsuan Chin has contributed in part 4, Discussion and conclusion. The third author Van Nguyen has contributed in part 3, Data and estimation results.

Declarations

Ethics approval The authors confirm that this work is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere. “I have not submitted my manuscript to a preprint server before submitting it to Environmental Science and Pollution Research”. The manuscript that is intended for a different group of readers.

Consent to participate Data and the coding materials have been attached in the submission and conducted with the panel data from the World Bank and do not involve human participants and/or animals.

Consent for publication The authors confirm that all the figures, tables, or text passages have not already been published elsewhere. Authors contribute all the contents. All co-authors have approved the manuscript if any, and by the responsible authorities — tacitly or explicitly — at the institute where the work has been carried out. Authors either grant the publisher an exclusive license to publish the article or agree to transfer the article’s copyright to the publisher.

Competing interests The authors declare no competing interests.

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