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Abstract: This paper utilises data from Asian countries from 2000–2020 (with consideration of the COVID-19 period) to explore the linkage between international trade and environmental pollution in this region. After controlling for heteroscedasticity and autocorrelation, results of a fixed-effect regression show that the export turnover, import turnover, GDP per capita, electricity consumption, population growth rate, and net receipt ratio of FDI to GDP have significantly improved the level of CO₂ emission in Asia. In addition, the paper also confirms the existence of the environmental Kuznets curve and that maintaining a surplus trade balance will help reduce CO₂ emissions in a country. These empirical insights are particularly interesting to policymakers since they help build sensible policies about economic growth, energy conservation, and foreign direct investment to improve environmental quality.

Keywords: international trade; environmental pollution; FEM; environmental Kuznets curve; EKC; pollution haven hypothesis.

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1 Introduction

International trade is historically confirmed to be a significant driver of economic growth and poverty reduction in Asia (Deb et al., 2021). The Asian market accounts for nearly 40% of the total value of global trade. In 2020, according to UNCTAD (2020), Asia's merchandise export value reached more than 7.449 trillion USD, accounting for 42% of the world's merchandise export value. Besides, Asia is also a large import area, accounting for nearly 38% of the total global import value. Asia can also be considered the world's producer when it continuously maintains a trade balance surplus, reaching a surplus of 629 billion USD in 2020 (UNCTAD, 2020).

After the COVID-19 pandemic, trade liberalisation would invigorate durable growth and minimise post-pandemic scarring in Asian region (Deb et al., 2021). Therefore, lowering trade barriers is one of the priority strategies that many countries follow to obtain economic gains. However, it is inevitable that international trade is a driver of environmental pollution in many countries (Nathaniel et al., 2021; Ren et al., 2014). Air pollution (as the result of trade liberalisation) in recent years has maintained a worrying upward trend, even during the COVID-19 pandemic. In 2022, the world CO₂ concentration reached 417.06 ppm (parts per million) (NOAA GML, 2023). Since the beginning of the industrial era (1850), human activities have increased CO₂ concentrations by almost 49%, which is higher than the natural increase of CO₂ for 20,000 years, from the Last Glacial Maximum to 1850, from 185 ppm to 280 ppm (NASA, 2021).

The linkage between international trade and environmental pollution has been widely explored but the findings may vary in different contexts. For example, in developing countries, the expansion of trade will exacerbate air pollution because it is the first stage of development (Kukla-Gryz, 2009). In addition, enterprises in developed countries often shift their production to developing countries due to the lack of strict environmental policies, which causes developing countries to produce goods with high levels of pollution. In contrast, developed countries are more likely to choose cleaner goods (Chakraborty and Mukherjee, 2010), thus the international trade might have a positive impact in these nations (Low and Yeats, 1992; Mani and Wheeler, 1998; Managi et al., 2009; Baek et al., 2009).

Previous studies often use the trade openness or total trade as proxy for international trade in studies investigating trade – environmental nexus (Cole, 2004; Ertugrul et al., 2016; Hossain, 2011; Halicioglu, 2009; Ohlan, 2015; Shahbaz et al., 2013a). Fewer studies explore the impact of export and import separately on environmental pollution. Muhammad et al. (2020) found that the effect of import on CO₂ emission varies across income groups, thus it is important to breakout the impact of trade on environmental pollution via impacts of import and export. Many studies exploring the relationship between trade and environmental pollution might not yet reached specific conclusions because of limitation in dealing with heterogeneity in the data sample as well as not separating the impact of export and import. Therefore, this study aims to investigate the impact of international trade on environmental pollution in selected 20 Asian countries for the period 2000–2020. To overcome the limitation in previous studies, this paper utilises the fixed effect model for panel regression analysis because FEM can capture unobserved time-invariant factors, which helps eliminate the influence of potential problems such as autocorrelation and heterogeneity in the data sample. In the context of countries becoming more and more cautious in the direction of economic development along with environmental pollution, this paper has both scientific significance – contributing to current knowledge of international trade and environmental pollution, and practical significance – as a reference basis for proposing strategies and solutions to mitigate the negative impacts of international trade on environmental pollution.

In addition to trade effect, environmental quality might be affected by other factors including GDP per capita, energy consumption, foreign trade investment, urbanisation and population growth as these factors captures the differences across countries (Mohsin et al., 2019; Muhammad et al., 2020; Staddon et al., 2016; Vö and Lê, 2019). By considering the abovementioned factors, this paper has some novelties. First, it is among limited studies providing empirical evidence on the impact of import and export on environmental pollution in Asia. Second, it tests the ‘pollution haven effect’ of FDI on environmental pollution in the context of Asian countries.

The paper is organised as follows: Section 2 presents the theoretical framework, where several hypotheses are proposed to be tested in subsequent sections. In Section 3, the research method will be outlined, including the data sources utilised and the model adopted for analysis. Section 4 presents the results and discussion of these findings, and Section 5 concludes.

2 Theoretical framework and hypothesis development

2.1 Economic growth and the environmental quality

Grossman and Krueger (1991) found that the economic growth might lead to a deterioration in the environment but after reaching a certain level of growth, the environmental degradation starts reducing, which is called environmental Kuznets curve (EKC). According to this theoretical model, pollution tends to increase during the first stage of a country’s growth and decline when a certain income level is reached. The emission per capita is positively dependent on GDP per capita and there exists an inverted U-shape relationship between GDP and emission per capita (i.e., coefficient for GDP² is negatively significant). Such findings support the EKC hypothesis in this study. The empirical studies of Grossman and Krueger (1991, 1995), Selden and Song (1994)

and Hilton and Levinson (1998) all support an inverted U-shaped relationship between economic growth and environmental degradation. Grossman and Krueger (1991, 1995) used global environmental monitoring system (GEMS) data to investigate the relationship between per capita income and various environmental indicators and then determine the actual EKC turning point. In recent studies, Halicioglu and Ketenci (2016), Thanh et al. (2019) and Chu et al. (2021) investigate and support the existence of EKC. Çetin and Saygin (2019) investigated the existence of EKC hypothesis which explain the presence of inverted-U shaped for the period of 1960–2014 in Turkey. By utilising ARDL bounds test to determine the long term relationship, the study supported the relationship in an inverted-U shape between economic growth and CO₂ emission in observed country. Based on the above, EKC is expected to exist with the observed sample of this study. In this study, we propose the hypothesis:

H1 There is an EKC.

2.2 Foreign direct investment and the CO₂ emissions

Antweiler et al. (2001) developed a theoretical framework for empirical research and proposed three mechanisms for analysing the effects of emission determinants and developing them into scale effects, technique effects, and composition effects. The scale effect refers to an increase in production on emissions; for example, GDP and FDI produce a positive result of increased production output because resources are allocated more efficiently, and economic growth reaches a higher level. However, at the same time, environmental pollution is more serious. The engineering/technology effect indicates the negative impact of income on emission intensity, referring to the effect of stricter environmental regulations, promoting the use of produce more environmentally friendly, transfer new green technologies. Besides, rising income increases the demand for a better environment and higher standard of living, putting pressure on the government to maintain or raise environmental standards. The composition effect explains how emissions are affected by changes in the structure of the economy, and the structure of industries, as determined by the degree of trade openness and comparative advantage. This impact can be positive or negative, depending on the country's resource abundance and the strength of its environmental policy.

Besides, the EKC also shows that developed countries have a cleaner environment, increasing the social costs of environmental pollution in developing countries (Jbara '07, 2007). Accordingly, it may reflect the potential of the pollution haven hypothesis since one of the factors increasing environmental degradation in pre-industrial economies stems from waste streams in post-industrial countries, where environmental quality is improved. The pollution haven hypothesis explains that nations are the same except for exogenous differences in their environmental policies. Along with trade liberalisation, the heavy industries tend to be moved from developed countries with strict environmental regulations to less developed countries with looser environmental regulations. In contrast, clean sectors are more likely to migrate to developed countries, benefiting from the potential transfer of advanced technologies. Trade, due to deviations in environmental policy, thus creates pollution havens in poorer countries. There is extensive literature supporting the pollution haven hypothesis (Abdouli and Hammami, 2017; Chu et al., 2021; Hoffmann et al., 2005; Kostakis et al., 2017; Shahbaz et al., 2018). Hoffmann et al. (2005) analyse the relationship between foreign direct investment (FDI) inflows and the

environment. Research results show that, overall, in less developed countries, there is much evidence to support a positive correlation between FDI and environmental pollution. Abdouli and Hammami (2017) concluded that FDI and trade openness were responsible for increasing CO₂ emissions. Simultaneously, Kostakis et al. (2017), investigating the similarities and differences between Singapore and Brazil, also supported the pollution haven hypothesis in Brazil. The study of Chu et al. (2021) also proves the existence of the pollution haven hypothesis showing that trade openness has led to environmental degradation in Vietnam. Banerjee and Murshed (2020) reinvestigated the pollution haven hypothesis for G7 and BRICS countries for the period 2005–2015 using the second-generation unit-root and Westerlund-Edgerton LM bootstrap cointegration. The result shows that a rise in FDI and GDP will lead to an increase in CO₂ emission for BRICS countries but a reduction for G7 countries. Therefore, the net impact of FDI on the environment is an empirical question (Spilker, 2013). In a study by Seker et al. (2015), the impact of the GDP and energy consumption on environmental pollution are quite strong while the FDI has the small positive effect on it. In this study, FDI is expected to impact CO₂ emissions, but the specific direction has not been determined.

H2 FDI has a relationship with CO₂ emissions.

2.3 Export turnover and CO₂ emissions

The relationship between international trade and the environment has been analysed in many studies. However, the findings on such relationship are still controversial. While environmentalists focus on the negative impact of pollution created by international trade, advocates of trade show it has a positive impact on the environment. Though it is not clear, generally, international trade has positively affected environmental pollution. Shafik and Bandyopadhyay (1992) find that all trade policy indicators have negligible effects on water shortages, sanitation, and municipal waste. However, more open countries tend to have lower sulphur and carbon emissions by placing less pressure on forest resources. Since then, many scholars have studied this topic further. Ang (2007), Shafik (1994) and Soytaş et al. (2007) use the EKC, Copeland and Taylor (2004) and Kearsley and Riddel (2010) use the pollution haven hypothesis, yet they could not conclude whether trade opening has any impact on the environment or not.

On the other hand, Frankel and Rose (2005) found a positive and statistically significant correlation between trade openness and environmental degradation (through the factors NO₂ and SO₂), while Kellenberg (2008) showed mixed evidence on the relationship between trade openness and four pollutants (NO₂, SO₂, CO₂, and VOCs). Regarding trade policy, Low and Yeats (1992) studied that trade liberalisation has a negative impact on the environment in developing countries while in developed economies. Development and trade liberalisation to improve environmental quality. In this research, the impact of international trade on the environment is investigated through export and import turnover.

There are many views regarding the impact of exports, a factor of international trade, on environmental pollution. Three influences that can explain this relationship are the scale effect, composition effect, and the technical effect developed by Antweiler et al. (2001). Helpman (1998) supports the view that international trade will help countries specialise in production, make resources more efficient, and reduce environmental pollution. However, some schools believe that specialisation leading to high efficiency

will make people consume natural resources more quickly; this is the point stated in studies by Schmalensee et al. (1998) and Copeland and Taylor (2004). Recent studies, such as Liddle (2018b), have found that exporting reduces CO₂ emissions. Muhammad et al. (2020) found that increasing exports would increase CO₂ emissions in low-middle income countries and decrease CO₂ emissions in other countries. Khan et al. (2020) also find that exporting improves the country's environment in the short and long terms. Rahman et al. (2021) explore the effects of economic growth, energy use, exports and human capital on the environmental quality of newly industrialised countries (NICs) over the period of 1979 – 2017. The results show that the energy consumption and exports deteriorated environmental quality in the long run. Nevertheless, some studies show that exporting increases CO₂ emissions, as studied by Liddle (2018a) and Hossain (2011). Therefore, exports are expected to impact CO₂ emissions in an unspecified direction. In this research, we propose the hypothesis:

H3 Export turnover is related to CO₂ emissions.

2.4 Import turnover and the CO₂ emissions

Like exports, the impact of imports on CO₂ emissions has not found consensus among researchers. Sadorsky (2012) argues that imports will reduce CO₂ emissions in the importing country because CO₂ production does not occur there. However, some arguments believe importing too many goods will make transportation happen more, thereby harming the environment. Some imported goods require much energy, such as air conditioners, cars, etc., which will cause the importing country to emit a lot of CO₂ use (Sadorsky, 2012). Liddle (2018b) found that imports increased CO₂ emissions in Asian countries from 1990 to 2013. However, in another study, Liddle (2018a) also found that imports reduce CO₂ emissions with a sample of 102 countries for the period 1990 to 2013. Khan et al. (2020) demonstrated a positive relationship between CO₂ emissions and imports in both the short and long term with G7 countries. This argument is also supported by Muhammad et al. (2020). Therefore, the relationship between imports and environmental pollution is unclear, so it is only expected to have a particular relationship. In this article, we suggest the hypothesis:

H4 Import turnover has a relationship with CO₂ emissions.

2.5 Energy consumption and CO₂ emissions

The process of industrialisation and economic growth create a continuous increase in energy consumption (Staddon et al., 2016). Moreover, humans release CO₂ into the environment by exploiting and producing energy, causing pollution. Rai et al. (2019) pointed out that there is a strong joint un-directional causality running from energy consumption, FDI, gross domestic product, and trade openness to CO₂ in India from 1978 to 2014. Shahbaz et al. (2013b) have found that an increase in energy consumption per capita will increase CO₂ emissions per capita in both the short and long run. Al-mulali and Sheau-Ting (2014), Boamah et al. (2017), Chang et al. (2018) and Muhammad et al. (2020) also agree with this view when they also find a similar relationship between these two factors. Similar finding are also revealed in the study by Çetin and Yüksel (2018) in the context of Turkish economy. Based on the previous studies mentioned above, the

amount of electricity consumed per capita is expected to affect the CO₂ emission per capita positively. In this research, we propose:

H5 Energy consumption per capita has a positive relationship with CO₂ emissions.

2.6 Urbanisation and CO₂ emissions

Urbanisation is also a factor with a complex relationship with CO₂ emissions. The high rate of urbanisation leads to an increase in infrastructure and means of transport, which leads to a rise in CO₂ emissions. However, this may only happen when urbanisation is early and busts infrastructure and transport activities. In the later stage of urbanisation, the infrastructure has been sustainably developed, accompanied by improved government policies, and public awareness will help reduce CO₂ emissions (Sadorsky, 2014). Research by Mohsin et al. (2019), Muhammad et al. (2020) and Vö and Lê (2019) found that urbanisation has a positive impact on CO₂ emissions. Mignamissi and Djeufack (2022) investigated the correlation between urbanisation and the intensity of CO₂ emissions in a panel comprising 48 African countries from 1980–2016 by employing an augmented STIRPAT model. The findings indicate that urbanisation significantly contributes to pollution in Africa, although the magnitude of this effect varies across different pollution levels. Cetin et al. (2018) examined the relationship between urbanisation and CO₂ emissions in Turkey by using time series data over the period 1960–2014. The study utilised the autoregressive distributed lag bounds testing approach to investigate the long-run relationship and showed that industrialisation and urbanisation process had caused a steady increase in CO₂ level. However, in some studies, the authors also show the existence of urbanisation to reduce environmental pollution when people already have a high enough standard of living (Al-mulali et al., 2015; Ozturk et al., 2016). Therefore, the urbanisation rate is expected to affect CO₂ emissions per capita, but the specific impact direction has not been determined and we propose the hypothesis that:

H6 Urbanisation has a relationship with CO₂ emissions.

2.7 Population growth and CO₂ emissions

Birdsall (1992) pointed out two mechanisms of population growth that can contribute to increased greenhouse gas emissions. First, a larger population can increase energy demand for industry and transportation, thus increasing fossil fuel emissions. Second, population growth can contribute to greenhouse gas emissions through deforestation. Deforestation, land-use change, and wood-burning can contribute significantly to greenhouse gas emissions. Mohsin et al. (2019), Muhammad et al. (2020) and Shi (2001) have demonstrated a positive relationship between population growth and per capita CO₂ emissions. In this study, the population growth is expected to correlate with per capita CO₂ emissions based on these studies positively.

H7 Population growth is positively related to CO₂ emissions.

Our empirical study investigates whether there is an EKC and Pollution haven hypothesis in Asian countries. We test the impact of international trade on the environment, including the COVID-19 period from 2019–2020, which extends the current knowledge and contributes to the literature.

3 Research method

3.1 Data

Following previous studies (e.g., Ertugrul et al., 2016), we choose annual data the most updated period from 2000–2020 of 20 Asian countries. They are Bangladesh, Brunei Darussalam, Cambodia, China, Hong Kong, India, Indonesia, Israel, Japan, South Korea, Laos, Malaysia, Nepal, Pakistan, the Philippines, Qatar, Saudi Arabia, Singapore, Thailand, and Vietnam. Data sources and methods of measuring variables are detailed in Table 1.

It can be seen from Table 1 that the CO₂ emissions (per capita) vary across Asian countries. On average, each person emits 7.68 ton of CO₂ per year. Nepal's CO₂ emissions in 2006 had the lowest value in the observed sample at 0.09 tons/person, while Qatar had the largest at 67.01 tons/person in 2001. Regarding the import – export statistics, Laos experiences the lowest import and export value (475.68 million USD in 2002 for import, and 462.87 million USD in 2003 for export), while China had the largest import and export volume (in 2018 and 2020 respectively).

In terms of GDP per capita in the sample, Nepal had the lowest GDPpc in 2000 with a value of \$229.49, while the highest value belongs to Qatar at \$85,075.98 in 2012.¹ Additionally, Cambodia had the lowest per capita electricity consumption in 2000, with a value of 38.44 kWh and Qatar consumed highest level of electricity consumption in 2019 with a value of 16,656.46 kWh.

Urbanisation varies across Asian countries. Singapore and Hong Kong have achieved 100% urban population rate since 2000, whereas Nepal in 2000 was the country with the lowest urbanisation rate in the sample, at 13.39%.

This study utilised panel data to examine the relationship between international trade and environmental pollution. The panel model's popularity increased among researchers due to its several advantages over pure cross-sectional data or pure time-series data (Baltagi, 2013), as follows:

- 1 Since panel data relates to individuals, companies, countries, etc. over time, there is bound to be heterogeneity within units, which often cannot be observed. Panel data estimation techniques can explicitly account for such heterogeneity by introducing subject-specific variables.
- 2 By combining time series of cross-observations, panel data gives us 'more informative data, higher variability, less collinearity between variables, more degrees of freedom and more efficiency'.
- 3 By studying repeated observations of crossover units, panel data are more suitable for studying the time variation of these crossover units
- 4 Panel data can better detect and measure effects that cannot be observed in pure time series or cross-sectional data.

Table 1 Descriptive statistics of variables used in the analysis

Indicator	Description	Mean	SD	Min	Max	Source	References
CO ₂ pc	CO ₂ emissions per capita (tons) (log)	7.68	10.82	0.09	67.01	Our World in Data	Antweiler et al. (2001), Copeland and Taylor (2004), Khan et al. (2020), Liddle (2018a, 2018b), Muhammad et al. (2020), Sadorsky (2012), Zaman et al. (2013)
Export	Export turnover (mil USD)	267,629.56	428,591.52	462.87	2,732,365.08	World Development Indicators	Khan et al. (2020), Liddle (2018a, 2018b), Muhammad et al. (2020), Sadorsky (2012)
Import	Import turnover (mil USD)	248,197.15	390,865.27	475.68	2,563,104.45	World Development Indicators	Chu et al. (2021), Grossman and Krueger (1991, 1995), Halicioglu and Ketenci (2016), Hilton and Levinson (1998), Muhammad et al. (2020), Selden and Song (1994), Vö and Lê (2019)
GDPpc	GDP per capita (constant 2015 USD) (log)	8.83	1.59	5.74	11.53	World Development Indicators	Al-mulali and Sheau-Ting (2014), Boamah et al. (2017), Chang et al. (2018), Muhammad et al. (2020), Shahbaz et al. (2013)
GDPpc squared	GDP per capita squared (constant 2015 USD) (log)	80.48	28.14	32.91	132.89	World Development Indicators	Al-mulali et al. (2015), Mohsin et al. (2019), Muhammad et al. (2020), Öztürk et al. (2016), Vö and Lê (2019)
Energy consumption	Electricity consumption per capita (kWh)	4,237.24	4,203.91	38.44	16,656.46	Our World in Data	Birdsall (1992), Mohsin et al. (2019), Muhammad et al. (2020), Shi (2001)
Urbanization	Urbanization rate (%) (log)	58.44	28.45	13.39	100.00	World Development Indicators	Abdoui and Hammami (2017), Chakraborty and Mukherjee (2010), Hoffmann et al. (2005), Kostakis et al. (2017), Shahbaz et al. (2018), Vö and Lê (2019)
Population growth	Population growth rate (%) per year	1.62	1.97	-1.47	17.51	World Development Indicators	
FDI	FDI net inflow ratio to GDP (%)	4.81	7.87	-2.76	58.52	World Development Indicators	

3.2 Regression model

Consider the fitting models of the form

$$y_{it} = \alpha + \beta X_{it} + v_i + \epsilon_{it} \quad (1)$$

In this model, $v_i + \epsilon_{it}$ is the error term. v_i is the unit-specific error term; it differs between units, but for any particular unit, its value is constant. ϵ_{it} is the ‘usual’ error term with the usual properties (mean 0, uncorrelated with itself, uncorrelated with X , uncorrelated with v , and homoskedastic).

If (1) is true, it must also be true that:

$$\overline{y_i} = \alpha + \beta \overline{X_i} + v_i + \overline{\epsilon_i} \quad (2)$$

where $\overline{y_i} = \sum_t y_{it} / T_i$, $\overline{X_i} = \sum_t X_{it} / T_i$, and $\overline{\epsilon_i} = \sum_t \epsilon_{it} / T_i$. Subtracting (2) from (1), it must be equally true that:

$$(y_{it} - \overline{y_i}) = \beta (X_{it} - \overline{X_i}) + (\epsilon_{it} - \overline{\epsilon_i}) \quad (3)$$

These three equations provide the basis for estimating β . In particular, fixed-effects estimator amounts to using OLS to perform the estimation of (3). Between-effects estimator amounts to using OLS to perform the estimation of (2). Random-effects estimator is a matrix weighted average of the estimates produced by the between and within estimators. In particular, the random-effects estimator turns out to be equivalent to estimation of:

$$(y_{it} - \theta \overline{y_i}) = (1 - \theta)\alpha + (X_{it} - \theta \overline{X_i})\beta + \{(1 - \theta)v_i + (\epsilon_{it} - \theta \overline{\epsilon_i})\} \quad (4)$$

where θ is a function of σ_v^2 and σ_ϵ^2 . If $\sigma_v^2 = 0$, meaning that v_i is always 0, $\theta = 0$ and (1) can be estimated by OLS directly. Alternatively, if $\sigma_\epsilon^2 = 0$, meaning that ϵ_{it} is 0, $\theta = 1$ and the within estimator returns all the information available.

We follow Park (2011) in choosing an appropriate regression model. First, pooled regression model (POLS), random effect model (RE model), and fixed-effect model (FE model) are carried out to obtain the results in Table 2. The Breusch-Pagan test (LM Test) was used to check whether POLS is suitable. If the POLS is not supported, the Hausman test could be helpful to decide between FE model and RE model.

The Hausman statistic is distributed as χ^2 and is computed as

$$H = (\beta_c - \beta_e)' (V_c - V_e)^{-1} (\beta_c - \beta_e)$$

where

β_c is the coefficient vector from the consistent estimator

β_e is the coefficient vector from the efficient estimator

V_c is the covariance matrix of the consistent estimator

V_e is the covariance matrix of the efficient estimator.

4 Results and discussion

In this section, we will delve into the model regressions and present the corresponding test results, thereby providing valuable insights into the relationship within our dataset. Table 2 provides results of the POLS model, RE model and FE model, respectively, for factors associated with the CO₂ emission in Asia. The Breusch-Pagan test does not support using POLS among three regression, whereas the Hausman test provide the evidence that FE model fits the given data most (see results at the end of Table 2).

Table 2 POLS, RE model, FE model regressions and test results

<i>Indicator (1)</i>	<i>POLS model (2)</i>	<i>RE model (3)</i>	<i>FE model (4)</i>
Export	0.7064*** (0.0633)	-0.1117* (0.0670)	-0.2444*** (0.0703)
Import	-0.6162*** (0.0629)	0.0848 (0.0660)	0.2051*** (0.0689)
GDPpc	1.3365*** (0.1770)	0.5649*** (0.1570)	0.8561*** (0.1710)
GDPpc squared	-0.0586*** (0.0095)	-0.0320*** (0.0083)	-0.0463*** (0.0088)
Energy consumption	0.5071*** (0.0351)	0.6306*** (0.0465)	0.6085*** (0.0486)
Urbanisation	-0.2977*** (0.1090)	0.6819*** (0.1580)	0.1656 (0.2180)
Population growth	0.1066*** (0.0192)	0.0712*** (0.0170)	0.0633*** (0.0165)
FDI	-0.0535*** (0.0124)	0.0296** (0.0123)	0.0313** (0.0122)
Intercept	-9.6932*** (0.6537)	-8.5655*** (0.5780)	-7.6717*** (0.6079)
No. of observation	380	380	380
R ²	0.9507	Overall: 0.9103	Within: 0.7972
F test	[0.0000]	F(19, 352)	61.47
Breusch-Pagan test	[0.0000]	χ^2 (01)	675.33
Hausman test	[0.0000]	χ^2 (08)	60.36

Notes: ***, **, * indicate significance levels at 10%, 5%, 1%, respectively.

The standard error is in parentheses (), and the p-value of the test is in square brackets [].

The next step is checking for any potential bias existing in our FE analysis result. The Wooldridge test for autocorrelation, the Pesaran test for cross-sectional dependence, and the Wald test for panel heteroskedasticity are conducted. The test results in Table 3 show that the model has heteroskedasticity and autocorrelation problems but does not have cross-sectional dependence problems, so the regression method using robust standard

error will be suitable for overcoming these problems (Hoechle, 2007). Therefore, we run the regression with consideration of robust standard error and reported in Table 2.

From Table 2, exports have a negative impact on CO₂ emissions, while imports have a positive effect on CO₂ emissions. Specifically, when export turnover increases by 1%, per capita CO₂ emissions will decrease by 0.24%, and when import turnovers increase by 1%, per capita CO₂ emissions will increase by 0.21%. This also implies that countries that maintain a trade surplus will reduce their CO₂ emissions. These findings are consistent with ones found in Muhammad et al. (2020) in the study on the impact of international trade on CO₂ across 65 Belt and Road Initiative (BRI) countries from 2000 to 2016. The export is claimed to increase the CO₂ emission especially in low-middle income countries, which is consistent with the theory of scale effect.

To roughly evaluate the total effect of international trade on CO₂ emission, one compares the magnitude of the effects of exports and imports on CO₂ emissions. Imports have a more substantial effect when there is a statistically higher significance level than exports. The results show that promoting exports helps countries specialise in producing products in which they have strengths, thereby helping to avoid wasting resources in production and improving environmental quality. The findings are similar to such of Khan et al. (2020) and Liddle (2018b). In addition, import increases CO₂ emissions and shows the need to develop an optimal logistics system to reduce emissions from the transportation of goods. Some imported goods with high polluting potential, such as cars or air conditioners are also causes of environmental pollution in the importing country.

The Kuznets's theory of environmental curve is supported when the slope of the variable GDPpc is greater than 0 and the slope of the variable GDPpc squared is smaller than 0 for all three regression results. The estimated turning point of the Kuznets curve through the derivative for result of FE model can be calculated as:

$$\begin{aligned}\frac{\delta CO_2 pc}{\delta GDPpc} &= 0.8561 - 0.0926 \times GDPpc = 0 \\ \Rightarrow GDPpc &= 9.2451\end{aligned}$$

With $GDPpc = 9.2451$, we can calculate the GDP per capita at the peak with an approximate value of about 10,354 USD/person.

By calculation, we have Figure 1 of the difference between the average GDP per capita of the countries in the period 2000–2020 and the value at the peak point, where the countries lying above the zero line will have the net effect of economic growth is inversely related to environmental pollution and vice versa; countries below the zero line will have a net impact of economic growth in the same direction as environmental pollution.

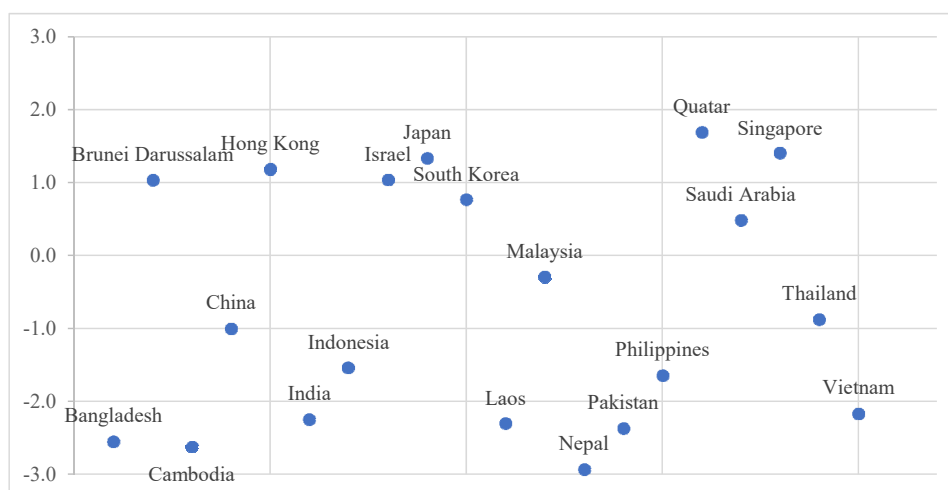
Through observations combined with the World Bank's ranking of economies in 2020, most countries above the zero line are developed countries, such as Korea, Japan, etc., or developing countries with upper-middle income, such as Thailand and Malaysia, etc. and vice versa, the countries below the zero line are mainly developing countries with low middle-income such as Vietnam, Cambodia, etc.

Electricity consumption is one source of CO₂ emission based on the finding in Table 2. A 1% increase in electricity consumption per capita would increase CO₂ emissions by 0.61%. This is an entirely understandable phenomenon because humans leave carbon footprints in the environment, including CO₂, in generating and consuming

electricity. This result is similar findings by Al-mulali and Sheau-Ting (2014), Boamah et al. (2017), Chang et al. (2018), Muhammad et al. (2020) and Shahbaz et al. (2013a).

Urbanisation has no impact on the environment; this result may be due to the sample's insufficient number of developed countries and the heterogeneous of the urbanisation rate among the nations. Therefore, the effect of urbanisation on the environment has not been observed since this effect may or may not be found depending on the group of countries observed (Muhammad et al., 2020). Moreover, the impact of urbanisation on the environment is also susceptible depending on the estimation method used (Sadorsky, 2014). This study supports the research by Boamah et al. (2017), in which the authors also found that urbanisation does not impact CO₂ emissions.

Figure 1 Difference between the average of the logarithm of GDP per capita across observed countries in the period 2000–2020 and the value at the Kuznets's peak point (see online version for colours)



The result shows a positive effect of population growth on air pollution (i.e., CO₂ level) which is consistent with previous studies by Mohsin et al. (2019) and Shi (2001). It is reasonable because as the population increase, the demand for energy, natural resources, fossil fuels would rise faster, resulting in the higher level of CO₂ emission.

Table 3 Tests for model problems

<i>Pesaran test</i>	<i>Wooldridge test</i>	<i>Wald test</i>
[0.3229]	[0.0000]	[0.0000]
	$F(1, 19) = 49.228$	$\chi^2(20) = 17249.31$

Note: The p-value of the test is in square brackets.

It is evident that increasing the ratio between FDI net inflows and GDP will increase environmental pollution in Asia as shown in this study. Specifically, when this ratio increases by 1%, CO₂ emissions per capita will increase by 0.03%. The results of this study also support previous studies that prove the pollution haven hypothesis, such as Chakraborty and Mukherjee (2010), Hoffmann et al. (2005), Kostakis et al. (2017) and Vö and Lê (2019). There is not much evidence to show whether FDI provides additional

technical expertise, production, or technological improvements in the host country (Võ and Lê, 2019). Moreover, FDI inflows tend to go to countries with less stringent environmental protection laws to reduce environmental protection costs (Chakraborty and Mukherjee, 2010; Võ and Lê, 2019).

From the results and discussions above, the conclusions of research hypotheses are presented in Table 4.

Table 4 Conclusion about research hypotheses

<i>Hypotheses</i>	<i>Conclusion (at 10% significance level)</i>
H1: There is an environmental Kuznets curve	Accept
H2: Foreign direct investment has a relationship with CO ₂ emissions	Accept
H3: Export turnover is related to CO ₂ emissions	Accept
H4: Import turnover has a relationship with CO ₂ emissions	Accept
H5: Energy consumption per capita has a positive relationship with CO ₂ emissions	Accept
H6: Urbanisation has a relationship with CO ₂ emissions	Not support
H7: Population growth is positively related to CO ₂ emissions	Accept

5 Conclusions

This study provides new insights on the impacts of international trade on CO₂ emissions on the basis of export turnover and import turnover by using panel data of 20 Asian countries from 2000 to 2020. Empirical results show that exports have a negative impact on CO₂ emissions, while imports have a positive impact on CO₂ emissions. This also implies that countries that maintain a trade surplus will reduce their CO₂ emissions. Through the regression results, the amount of electricity consumed per capita has a negative impact on the environment. Urbanisation has no impact on the environment; this result may be due to the sample's insufficient number of developed countries and the uneven urbanisation rate among the nations. The population growth rate is the most influential factor in the estimation model, showing that population growth is the leading cause of increased CO₂ emission and global warming. The ratio between FDI net inflows and GDP will increase environmental pollution. In addition, the paper also confirms the existence of the EKC in selected Asian countries.

- 1 Several policy implications are recommended based on research findings.
- 2 As import has significant positive effect on the environmental pollution, it is vital to consider switching from resource-incentive or energy-incentive products to greener imported products or patent-intensive products as suggested by Muhammad et al. (2020). It is because if a country continue importing energy-incentive goods/services, it may exacerbate the environmental pollution.
- 3 The export may reduce the environmental pollution in Asia, which is consistent with the composition effect of international trade (Zarsky, 1999). Composition effect hypothesises that, exports in high income countries lower environmental pollution by

using environmentally friendly technologies and strong government policies. Whereas, low-income countries experience the negative effect of export on pollution because they mainly export the less pollution incentive product such as fruit, nuts, vegetables. Therefore, Asian countries would consider investing in the environmentally friendly technology in production, focus on exporting the less polluted goods/services.

- 4 Environmental policy in FDI negotiations should be set stricter. Asian countries need to limit FDI projects that cause environmental pollution and prevent environmental incidents. Moreover, it is necessary to appraise technology before the project implementation process, end incentives for cheap resources, and strengthen supervision of FDI enterprises on compliance with environmental protection criteria, dust, wastewater, and noise right from the design and selection of technology to construction and operation.
- 4 The governments of Asian countries should complete import and export policies toward environmental protection. Countries need to perfect their tax policies in the direction of combining adjustment of import-export tax policies and domestic tax systems to meet the requirements of integration commitments and environmental protection; perfecting non-tax policies on the principle of not distorting trade and improving the effectiveness of environmental protection; research and develop regulations and standards for imported products and goods, form technical barriers to limit and prevent the import of poor quality goods.

Although this paper contributes to current literature related to exploring the association between international trade (i.e., import and export) and CO₂ emission, it still has some limitations. First, there might exist the reverse causality between economic growth (i.e., GDPpc) and the CO₂ emission, thus to extract the causality of trade and environmental pollution, addressing endogeneity is necessary. However, as we only conclude about the linkage (i.e., the association), the result of empirical analysis is acceptable. Future studies would find the way to deal with potential endogeneity such as using two stage least square regression analysis with instrumental variable(s). Second, although the data cover COVID-19 pandemic period (2020), yet when checking the variable, we do not see the significant difference of CO₂ emission and trade between 2019 and 2020. Future research with more updated data should consider this issue as it may show more interesting findings related to the linkage between trade and environmental pollution.

References

- Abdouli, M. and Hammami, S. (2017) 'Economic growth, FDI inflows and their impact on the environment: an empirical study for the MENA countries', *Quality & Quantity*, Vol. 51, No. 1, pp.121–146.
- Al-mulali, U. and Sheau-Ting, L. (2014) 'Econometric analysis of trade, exports, imports, energy consumption and CO₂ emission in six regions', *Renewable and Sustainable Energy Reviews*, May, Vol. 33, pp.484–498 [online] <https://www.sciencedirect.com/science/article/pii/S136403211400121X?via%3Dihub>.
- Al-mulali, U., Weng-Wai, C., Sheau-Ting, L. and Mohammed, A.H. (2015) 'Investigating the environmental Kuznets curve (EKC) hypothesis by utilizing the ecological footprint as an indicator of environmental degradation', *Ecological Indicators*, January, Vol. 48, pp.315–323 [online] <https://www.sciencedirect.com/science/article/pii/S1470160X14003951?via%3Dihub>.

- Ang, J.B. (2007) 'CO₂ emissions, energy consumption, and output in France', *Energy Policy*, Vol. 35, No. 10, pp.4772–4778.
- Antweiler, W., Copeland, B.R. and Taylor, M.S. (2001) 'Is free trade good for the environment?', *American Economic Review*, Vol. 91, No. 4, pp.877–908.
- Back, J., Cho, Y. and Koo, W.W. (2009) 'The environmental consequences of globalization: a country-specific time-series analysis', *Ecological Economics*, Vol. 68, No. 8, pp.2255–2264.
- Baltagi, B.H. (2013) *Econometric Analysis of Panel Data*, 5th ed., Wiley, Hoboken, New Jersey.
- Banerjee, S. and Murshed, M. (2020) 'Do emissions implied in net export validate the pollution haven conjecture? Analysis of G7 and BRICS countries', *International Journal of Sustainable Economy*, Vol. 12, No. 3, pp.297–319.
- Birdsall, N. (1992) *Another Look at Population and Global Warming*, Policy Research Working Paper No. 1020, World Bank.
- Boamah, K.B., Du, J., Bediako, I.A., Boamah, A.J., Abdul-Rasheed, A.A. and Owusu, S.M. (2017) 'Carbon dioxide emission and economic growth of China – the role of international trade', *Environmental Science and Pollution Research*, Vol. 24, No. 14, pp.13049–13067.
- Çetin, M. and Saygin, S. (2019) 'Çevresel Kuznets Eğrisi Hipotezi'nin Ampirik Analizi: Türkiye Ekonomisi Örneği (Empirical analysis of environmental Kuznets curve hypothesis: the example of Turkish economy)', *Yönetim ve Ekonomi Dergisi (Journal of Management and Economics)*, Vol. 26, No. 2, pp.529–546.
- Çetin, M. and Yüksel, Ö. (2018) 'Türkiye ekonomisinde enerji tüketiminin karbon emisyonu üzerindeki etkisi (The impact of energy consumption on carbon emissions in Turkish economy)', *Mehmet Akif Ersoy Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, Vol. 5, No. 2, pp.169–186.
- Cetin, M., Ecevit, E. and Yucel, A.G. (2018) 'Structural breaks, urbanization and CO₂ emissions: evidence from Turkey', *Journal of Economics and Business Research*, Vol. 8, No. 2, pp.122–139.
- Chakraborty, D. and Mukherjee, S. (2010) 'The relationship between trade, investment and environment', *Foreign Trade Review*, Vol. 45 No. 2, pp. –37.
- Chang, C.-P., Wen, J., Dong, M. and Hao, Y. (2018) 'Does government ideology affect environmental pollutions? New evidence from instrumental variable quantile regression estimations', *Energy Policy*, February, Vol. 113, pp.386–400.
- Chu, T.M., Tu, T.A. and Dinh, T.T. (2021) 'Factors of environmental degradation and economic growth in Vietnam: the role of innovation', *The Russian Journal of Vietnamese Studies*, Vol. 5, No. 3, pp.52–70.
- Cole, M.A. (2004) 'Trade, the pollution haven hypothesis and the environmental Kuznets curve: examining the linkages', *Ecological Economics*, Vol. 48, No. 1, pp.71–81.
- Copeland, B.R. and Taylor, M.S. (2004) 'Trade, growth, and the environment', *Journal of Economic Literature*, Vol. 42, No. 1, pp.7–71.
- Deb, P., Estefania-Flores, J., Kothari, S. and Tawk, N. (2021) 'How trade can help speed Asia's economic recovery', *IMF Blogs* [online] <https://www.imf.org/en/Blogs/Articles/2021/11/19/blog-how-trade-can-help-speed-asias-economic-recovery> (accessed 15 December 2022).
- Ertugrul, H.M., Cetin, M., Seker, F. and Dogan, E. (2016) 'The impact of trade openness on global carbon dioxide emissions: evidence from the top ten emitters among developing countries', *Ecological Indicators*, Vol. 67, pp.543–555.
- Frankel, J.A. and Rose, A.K. (2005) 'Is trade good or bad for the environment? Sorting out the causality', *The Review of Economics and Statistics*, Vol. 87, No. 1, pp.85–91.
- Grossman, G.M. and Krueger, A.B. (1991) *Environmental Impacts of a North American Free Trade Agreement*, NBER Working Paper No. 3914.
- Grossman, G.M. and Krueger, A.B. (1995) 'Economic growth and the environment', *The Quarterly Journal of Economics*, Vol. 110, No. 2, pp.353–377.

- Halicioglu, F. (2009) 'An econometric study of CO₂ emissions, energy consumption, income and foreign trade in Turkey', *Energy Policy*, Vol. 37, No. 3, pp.1156–1164.
- Halicioglu, F. and Ketenci, N. (2016) 'The impact of international trade on environmental quality: the case of transition countries', *Energy*, 15 August, Vol. 109, pp.1130–1138.
- Helpman, E. (1998) 'Explaining the structure of foreign trade: where do we stand?', *Weltwirtschaftliches Archiv*, Vol. 134, No. 4, pp.573–589.
- Hilton, F.G.H. and Levinson, A. (1998) 'Factoring the environmental Kuznets curve: evidence from automotive lead emissions', *Journal of Environmental Economics and Management*, Vol. 35, No. 2, pp.126–141.
- Hoechle, D. (2007) 'Robust standard errors for panel regressions with cross-sectional dependence', *The Stata Journal*, Vol. 7, No. 3, pp.281–312.
- Hoffmann, R., Lee, C.-G., Ramasamy, B. and Yeung, M. (2005) 'FDI and pollution: a granger causality test using panel data', *Journal of International Development*, Vol. 17, No. 3, pp.311–317.
- Hossain, M.S. (2011) 'Panel estimation for CO₂ emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries', *Energy Policy*, Vol. 39, No. 11, pp.6991–6999.
- Jbara '07, B.W. (2007) *Exploring the Causality between the Pollution Haven Hypothesis and the Environmental Kuznets Curve*, Honors Projects No. 21, Illinois Wesleyan University.
- Kearsley, A. and Riddel, M. (2010) 'A further inquiry into the pollution haven hypothesis and the environmental Kuznets curve', *Ecological Economics*, Vol. 69, No. 4, pp.905–919.
- Kellenberg, D.K. (2008) 'A reexamination of the role of income for the trade and environment debate', *Ecological Economics*, Vol. 68, No. 1, pp.106–115.
- Khan, Z., Ali, S., Umar, M., Kirikkaleli, D. and Jiao, Z. (2020) 'Consumption-based carbon emissions and international trade in G7 countries: the role of environmental innovation and renewable energy', *The Science of the Total Environment*, 15 August, Vol. 730, p.138945.
- Kostakis, I., Lolos, S. and Sardianou, E. (2017) 'Foreign direct investment and environmental degradation: further evidence from Brazil and Singapore', *Journal of Environmental Management and Tourism*, Vol. 1, No. 17, pp.45–59.
- Kukla-Gryz, A. (2009) 'Economic growth, international trade and air pollution: a decomposition analysis', *Ecological Economics*, Vol. 68, No. 5, pp.1329–1339.
- Liddle, B. (2018a) 'Consumption-based accounting and the trade-carbon emissions nexus', *Energy Economics*, January, Vol. 69, pp.71–78.
- Liddle, B. (2018b) 'Consumption-based accounting and the trade-carbon emissions nexus in Asia: a heterogeneous, common factor panel analysis', *Sustainability*, Vol. 10, No. 10.
- Low, P. and Yeats, A. (1992) 'Do 'dirty' industries migrate?', in Low, P. (Ed.): *International Trade and the Environment*, Discussion Paper No. 159, World Bank, Washington DC, pp.89–103.
- Managi, S., Hibiki, A. and Tsurumi, T. (2009) 'Does trade openness improve environmental quality?', *Journal of Environmental Economics and Management*, Vol. 58, No. 3, pp.346–363.
- Mani, M. and Wheeler, D. (1998) 'In search of pollution havens? Dirty industry in the world economy, 1960 to 1995', *The Journal of Environment & Development*, Vol. 7, No. 3, pp.215–247.
- Mignamissi, D. and Djeufack, A. (2022) 'Urbanization and CO₂ emissions intensity in Africa', *Journal of Environmental Planning and Management*, Vol. 65, No. 9, pp.1660–1684.
- Mohsin, M., Abbas, Q., Zhang, J., Ikram, M. and Iqbal, N. (2019) 'Integrated effect of energy consumption, economic development, and population growth on CO₂ based environmental degradation: a case of transport sector', *Environmental Science and Pollution Research*, Vol. 26, No. 32, pp.32824–32835.

- Muhammad, S., Long, X., Salman, M. and Dauda, L. (2020) 'Effect of urbanization and international trade on CO₂ emissions across 65 belt and road initiative countries', *Energy*, 1 April, Vol. 196, p.117102.
- NASA (2021) *Global Climate Change: Vital Signs of the Planet* [online] <https://climate.nasa.gov/vital-signs/carbon-dioxide/> (accessed 23 May 2023).
- Nathaniel, S.P., Murshed, M. and Bassim, M. (2021) 'The nexus between economic growth, energy use, international trade and ecological footprints: the role of environmental regulations in N11 countries', *Energy, Ecology and Environment*, Vol. 6, No. 6, pp.496–512.
- NOAA GML (2023) National Oceanic and Atmospheric Administration, Global Monitoring Laboratory, https://gml.noaa.gov/webdata/ccgg/trends/co2/co2_annmean_gl.txt (accessed 23 May 2023).
- Ohlan, R. (2015) 'The impact of population density, energy consumption, economic growth and trade openness on CO₂ emissions in India', *Natural Hazards*, Vol. 79, No. 27, pp.1409–1428.
- Ozturk, I., Al-mulali, U. and Saboori, B. (2016) 'Investigating the environmental Kuznets curve hypothesis: the role of tourism and ecological footprint', *Environmental Science and Pollution Research*, Vol. 23, No. 2, pp.1916–1928.
- Park, H.M. (2011) *Practical Guides To Panel Data Modeling: A Step-by-step Analysis Using Stata*, Tutorial Working Paper, Graduate School of International Relations, International University of Japan.
- Rahman, M.M., Nepal, R. and Alam, K. (2021) 'Impacts of human capital, exports, economic growth and energy consumption on CO₂ emissions of a cross-sectionally dependent panel: evidence from the newly industrialized countries (NICs)', *Environmental Science and Policy*, July, Vol. 121, pp.24–36.
- Rai, S.K., Bembey, A.M. and Sarfare, D. (2019) 'Empirical verification of causality between CO₂ emissions, energy consumption, foreign direct investment, gross domestic product, and openness of the economy: evidence from India', *International Journal of Sustainable Economy*, Vol. 11, No. 3, pp.237–257.
- Ren, S., Yuan, B., Ma, X. and Chen, X. (2014) 'The impact of international trade on China's industrial carbon emissions since its entry into WTO', *Energy Policy*, June, Vol. 69, pp.624–634.
- Sadorsky, P. (2012) 'Energy consumption, output and trade in South America', *Energy Economics*, Vol. 34, No. 2, pp.476–488.
- Sadorsky, P. (2014) 'The effect of urbanization on CO₂ emissions in emerging economies', *Energy Economics*, January, Vol. 41, pp.147–153.
- Schmalensee, R., Stoker, T.M. and Judson, R.A. (1998) 'World carbon dioxide emissions: 1950–2050', *The Review of Economics and Statistics*, Vol. 80, No. 1, pp.15–27.
- Seker, F., Ertugrul, H.M. and Cetin, M. (2015) 'The impact of foreign direct investment on environmental quality: a bounds testing and causality analysis for Turkey', *Renewable and Sustainable Energy Reviews*, December, Vol. 52, pp.347–356.
- Selden, T.M. and Song, D. (1994) 'Environmental quality and development: is there a Kuznets curve for air pollution emissions?', *Journal of Environmental Economics and Management*, Vol. 27, No. 2, pp.147–162.
- Shafik, N. (1994) 'Economic development and environmental quality: an econometric analysis', *Oxford Economic Papers*, October, Vol. 46, pp.757–773.
- Shafik, N. and Bandyopadhyay, S. (1992) *Economic Growth and Environmental Quality: Time-series and Cross-country Evidence*, Policy Research Working Paper No. 904, World Bank.
- Shahbaz, M., Destek, M.A. and Polemis, M.L. (2018) 'Do foreign capital and financial development affect clean energy consumption and carbon emissions? Evidence from BRICS and Next-11 countries', *SPOUDAI – Journal of Economics and Business*, Vol. 68, No. 4, pp.20–25.

- Shahbaz, M., Hye, Q.M.A., Tiwari, A.K. and Leitão, N.C. (2013a) 'Economic growth, energy consumption, financial development, international trade and CO₂ emissions in Indonesia', *Renewable and Sustainable Energy Reviews*, September, Vol. 25, pp.109–121.
- Shahbaz, M., Kumar Tiwari, A. and Nasir, M. (2013b) 'The effects of financial development, economic growth, coal consumption and trade openness on CO₂ emissions in South Africa', *Energy Policy*, October, Vol. 61, pp.1452–1459.
- Shi, A. (2001) 'Population Growth and global carbon dioxide emissions', presented at *IUSSP General Conference*, 18–24 August, Salvador, Brazil, Session-S09.
- Soytas, U., Sari, R. and Ewing, B.T. (2007) 'Energy consumption, income, and carbon emissions in the United States', *Ecological Economics*, Vol. 62, No. 3, pp.482–489.
- Spilker, G. (2013) *Globalization, Political Institutions and the Environment in Developing Countries*, Routledge New York.
- Staddon, S.C., Cycil, C., Goulden, M., Leygue, C. and Spence, A. (2016) 'Intervening to change behaviour and save energy in the workplace: a systematic review of available evidence', *Energy Research & Social Science*, July, Vol. 17, pp.30–51.
- Thanh, P.N., Phuong, N.D. and Ngoc, B.H. (2019) 'Economic integration and environmental pollution nexus in ASEAN: a PMG approach', in Kreinovich, V., Thach, N.N., Trung, N.D. and Van Thanh, D. (Eds.): *ECONVN 2019: Beyond Traditional Probabilistic Methods in Economics*, pp.427–439, Springer International Publishing.
- UNCTAD (2020) *Beyond 20/20 WDS – Table View – Merchandise: Total Trade and Share, Annual* [online] <https://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=101> (accessed 23 May 2023).
- Võ, T.T.K. and Lê, T.T. (2019) 'The impact of FDI on the environment in terms of the existence of the Kuznets environmental curve (EKC)', *Journal of Asian Business and Economic Studies*, Vol. 8, pp.26–44.
- Zarsky, L. (1999) 'Havens, halos and spaghetti: untangling the evidence about foreign direct investment and the environment', in Chung, C. (Ed.): *Foreign Direct Investment and the Environment*, pp.47–73, OECD, Paris.

Notes

- 1 Table 1 reports the value of the mean of log(GDPpc). The GDPpc is calculated by taking GDP at the purchase price (constant 2015 \$US) divided by population by country, annually. GDP is reported yearly at <https://data.worldbank.org/indicator/NY.GDP.MKTP.KD>.