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Trade Openness and Environmental Quality
Evidence from 24 Asia-Pacific Economies (1995-2016)

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List of Acronyms

EKC	Environmental Kuznets Curve
GDP	Gross Domestic Product
GNI	Gross National Income
IEA	International Energy Agency
IPAT	Impact-Population-Affluence-Technology
NICs	Newly industrialized countries
STIRPAT	Stochastic Impacts by Regressions on Population, Affluence, Technology

Abstract

Aiming at analysing the environmental influence of trade openness in 24 Asia-Pacific economies over the period 1995-2016, this research found no strong evidence from the extended STIRPAT model for either *gains-from-trade* effect or *race-to-the-bottom* effect across all trade openness proxies upon examination of the direct connection between international trade openness and carbon dioxide emissions. Other more relevant determinants of carbon dioxide emissions for the region are urbanization, per capita income, renewable energy consumption, capital abundance, and financial development.

Relevance to Development Studies

Nearly all the 2030 Agenda for Sustainable Development Goals are centred around the pro-environment goals and activities in the context of brewing environmental degradation and climate change. Moreover, international trade openness plays a pivotal role as a key policy in the accomplishment of the Millennium Development Goals by 2015 and has still developed as a legitimate area that facilitates the essential resources for sustainable development across nations. Sustainable trade, hence should be of contemporary concerns in this day and age. All in all, the insights into the relationship between trade openness and environmental quality is important and useful for development studies.

Keywords

Trade openness, Carbon dioxide emissions, Asia-Pacific, Urbanization, Income, Trade policy, Energy consumption, Panel data

CHAPTER 1. INTRODUCTION

1.1 Background

Despite increasing concerns and concerted efforts, environmental problems have still been aggravated in the past decade, especially the contemporary worsened climate change accompanied by mainly carbon-based pollutants. Evidently, in accordance with the International Energy Agency (IEA), global carbon emissions amount has risen by approximately 90% since the 1980s, which is considered to generally link to the ever-explosive growth in economic activities for decades. Such environmental downturns make sustainable development attainment no longer a desire or a need, but a must. Thus, over half of sustainable development goals entail environmental protection in many economic, social, and even political aspects. Accordingly, exploring what determines environmental quality or pollution and understanding its interactions with socio-economic factors are truly of importance. Among the studied relevant relationships, the debate of economic globalization, particularly trade openness, and the environment remains prominent. In spite of huge welfare benefits and radical development transformations it has brought about, the costs of global economic integration are inevitable, especially those pertaining to negative environmental outcomes and externalities due to over-capacity of production. Since such blame on economic globalization has now been brought back to the table as a thrust in the intensified deglobalization waves and trade wars, the nexus between trade openness and environmental quality is worth a re-visit (Najam, Runnalls and Halle, 2016; Afesorgbor and Demena, 2018).

Since the 1990s, the link between international trade openness and the environment has been increasingly developed in which trade openness and environmental quality relationship dominates the literature (Sharma, 2011; Le, Chang and Park, 2016) . This line of research concentrates on examining whether and how trade flows and policies matter for pollution level and intensity, to which this study belongs. Although pollution can be related to a variety of environmental indicators, carbon dioxide emissions have been a focus in research agenda owing to its global significance and contemporary relevance.

The investigation of trade openness-environmental quality linkage in the literature is based largely on the two lines of theoretical arguments, neoclassical-environmental economics and ecological economics. The former is generally supported by trade proponents, whereas the latter is followed by trade opponents (Muradian and Martinez-Alier, 2001; Afesorgbor and Demena, 2018). According to the first approach, starting from the associated benefits from comparative advantage and specialization developed in Heckscher-Ohlin-Samuelson theory, enhanced trade openness is seen to do more good than harm to the environmental outcomes which is represented with the *gains-from-trade* hypothesis.

Trade-dominated globalization *per se* ultimately helps mitigate pollution as it encourages growth and welfare improvements, promotes technological diffusions and environmental awareness, and endorses global commitment and co-operation in solving environmental issues. As such, reduced trade openness, especially by implementing trade barriers driven by local environmental concerns, may not create suppressing effects on emissions as expected, not to mention the damage could be worsened.

The second group postulates that increased international trade openness coupled with heightened competitive pressures and the booming of economies of scale will be a detriment to environmental quality as economies, especially those in the South, pursue trade profits and wealth sacrificing the environment. Thus, it puts forward the *race-to-the-bottom* hypothesis which suggests the emissions build-up caused by downgraded environmental standards serving trade gains. These two opposing claims motivate the empirical literature to test the question of whether trade openness has a positive or negative impact on environmental quality. However, relevant studies including the importance of trade openness in the emissions model still produce conflicting results. While some conclude the adverse environmental effect of trade openness (Rock, 1996; Tamazian and Rao, 2010; Atici, 2012; Ahmed *et al.*, 2016; Ertugrul *et al.,* 2016; Le *et al.*, 2016; Zineb, 2016; Rahman, 2017; Munir and Ameer, 2018; Mahmoodi and Mahmoodi, 2018), others prove that fostering trade freedom helps decrease pollution (Alpay, 2000; Hossain, 2011; Al-Mulali *et al.*, 2015; Dogan and Seker, 2016; Gozgor, 2017). Even, there exist researches that fail to find a significant relationship between international trade openness and environmental quality, particularly CO_2 emissions (van Bergeijk, 1991; Atici, 2009; Sharma, 2011; Jobert *et al.*, 2015; Bernard and Mandal, 2016; Saidi and Mbarek, 2017).

Regarding the methodology aspects, most studies examine the impact of trade openness on environmental quality employing the extended Environmental Kuznets Curve (EKC) model or a simple multivariate framework. The Environmental Kuznets Curve, demonstrating the inverted-U curve relationship between economic growth and pollution level, is used as a standard empirical model and augmented with other explanatory variables including trade openness. Nevertheless, the application of this model has raised some potential issues such as multicollinearity, the questionable validity of EKC hypothesis in the literature, or the compatibility in the examination of global emissions like carbon dioxide (Martínez-Zarzoso *et al.*, 2007; Gozgor, 2017). Therefore, this study uses another alternative approach for modelling emissions and hypothesize trade openness as a key determinant – Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model which was developed by Dietz and Rosa (1994) from the IPAT framework proposed by Ehrlich and

Holdren (1971). Such application is inspired by studies of Zineb (2016) and Munir and Ameer (2018)[1] to analyse the independent pollution effect of trade openness more properly.

Moreover, in the literature related to trade openness-environmental quality analysis, the most widely used proxy for trade openness has been the sum of imports and exports as a proportion of nominal GDP. This is deemed as the conventional measure of a country's degree of openness to trade that reflects merely the country's trade volumes or outcomes across borders. However, trade openness measure construction has been a bone of contention in the literature due to there remains confused and unclear definitions of trade openness. Indeed, trade openness should, not only be described in terms of intensity, but also in terms of policy-orientation (Rodriguez and Rodrik,2000; Squalli and Wilson, 2011). As the current global trading system has been evolving more dependent on rules and agreements; therefore, it is more appropriate and robust to further take into account the role of trade restrictions or barriers when assessing the impact of international trade openness. Furthermore, some researches checked the robustness of the traditional trade openness measure by providing further evidences for other measures including exports share or imports share to GDP (Le *et al.*, 2016) , export growth rate and dummy of trade openness or trade repression (Rock, 1996), trade intensity with developed countries (Zineb, 2016), and trade potential index (Gozgor, 2017). In that sense, this paper also includes examinations of two other proxies for trade openness, namely Export Value Index and Trade Freedom Index.

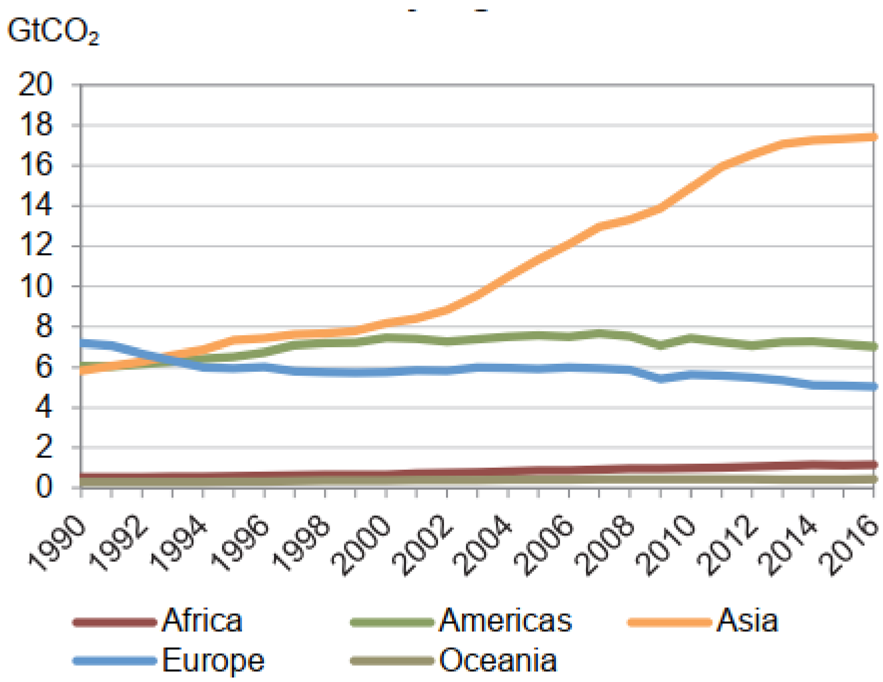
The choice of the economies in Asia-Pacific region is motivated by its significant contribution to global trade as well as global emissions. As can be seen in Figure 1.1, its total CO_2 emissions diverge from the global trends since 2000s and constitutes approximately 54% of the world emissions in 2016. Besides, to the best of my knowledge, the literature is still lacking in the empirical analysis concerning the connection between international trade openness and environmental quality in this region. According to ADB (2017), in 2016, the region accounts for over 40% of the world GDP (PPP adjusted); however, its rapid growth trend has come along with severe environmental consequences. Despite international trading system has recently been facing a downturn, we still can witness the Asia-Pacific economies' enthusiastic participation, especially in exports value. As shown in the first two columns of Table 1.1, the high exports share to GDP and extraordinary increase in export volumes of the selected 24 countries in the sample[2] indicates their export-led trade regime. Additionally, from column (5), it can be inferred that even as many Asia-Pacific countries has experienced substantial trade growth, there have not been enough efforts to be

[1] These two studies utilize extended STIRPAT model to investigate the effect of international trade openness on CO_2 emissions for a dynamic global panel and Asian emerging countries, respectively.

[2] The country selection for empirical analysis is based on data availability. To save space, I show the figures for those selected countries only.

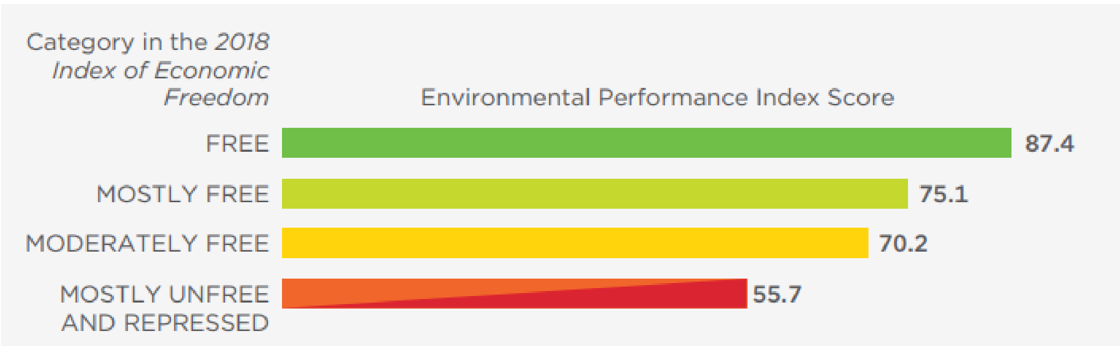
done against the decay in environmental pillar. In the context that trade facilitation is driving these economies, such trend poses a challenge to the region's sustainable development and accomplishing trade prospects. Thus, in order to steer trade openness policies towards a balanced economic and environmental development, the thrust lies in the understanding of to what extent trade openness affects emissions. The two last columns in Table 1.1 together with Figure 1.2 points out that those few countries (9 out of 24 countries) more exposed to world economy tend to be able to cope with environmental problems more effectively. This also puts a question towards the environmental effect of trade freedom in the region.

Figure 1.1. Total CO_2 emissions by region (1990-2016)



Source: International Energy Agency (2018)

Figure 1.2 Economic Freedom and the Environment in the Asia-Pacific region



Source: Miller *et al.* (2018)

Table 1.1 Key indicators of 24 Asia-Pacific economies

Country Name	% change in export value (current $US) 1995-2017	Exports of goods and services (% of GDP) in 2017	CO_2 intensity (kg per kg of oil equivalent energy use) in 2014	CO_2 emissions (Mt)	% change in total CO_2 emissions 1995-2016	2018 Economic Freedom Score	2018 Economic Freedom World (Regional) Rank
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
China	1733.66%	19.76	3.37	10151	205.73%	57.8	110 (24)
India	1158.14%	18.87	2.71	2431	199.55%	54.5	130 (30)
Japan	74.27%	16.12	2.75	1209	2.16%	72.3	30 (8)
Korea, Rep.	357.35%	43.09	2.19	595	58.76%	73.8	27 (7)
Indonesia	288.97%	20.37	2.06	501	122.72%	64.2	69 (15)
Australia	327.85%	21.27	2.88	398	41.20%	80.9	5 (4)
Thailand	325.21%	68.11	2.35	327	102.91%	67.1	53 (12)
Malaysia	169.32%	71.47	2.71	265	118.77%	74.5	22 (6)
Kazakhstan	561.08%	31.84	3.24	232	37.14%	69.1	41 (11)
Pakistan	147.86%	8.24	1.85	189	123.71%	54.4	131 (31)
Vietnam	3241.29%	101.56	2.46	187	542.83%	53.1	141 (35)
Philippines	255.52%	30.55	2.22	128	110.84%	65	61 (13)

Bangladesh	810.93%	15.04	2.07	82	259.40%	55.1	128 (29)
Singapore	252.52%	173.35	2.01	63	49.38%	88.8	2 (2)
Azerbaijan	2229.48%	48.69	2.62	40	20.00%	64.3	67 (14)
New Zealand	166.85%	25.82	1.69	36	32.68%	84.2	3 (3)
Mongolia	1060.47%	59.47	3.88	26	228.25%	55.7	125 (27)
Sri Lanka	312.16%	21.93	1.72	21	255.70%	57.8	111 (25)
Kyrgyz Republic	447.40%	35.42	2.53	10	120.81%	62.8	78 (18)
Nepal	117.27%	9.76	0.69	9.1	347.13%	54.1	133 (32)
Cambodia	1154.07%	60.73	1.05	7.6	389.96%	58.7	101 (22)
Tajikistan	38.98%	15.71	1.85	5.5	124.53%	58.3	106 (23)
Lao PDR	1313.29%	34.34	0.68	2.1	502.82%	53.6	138 (34)
Fiji	5.59%	26.41	2.21	1.3	70.44%	62	84 (19)

Note: (1) Figures calculated by author from IMF and WB; (2) & (3) Figures drawn from WB; (4) Figures taken from Global Carbon Atlas (GCA); (5) Figures calculated by author from WB and GCA; (6) & (7) Figures collected from The Heritage Foundation report by Miller *et al.* (2018)

1.2 Research questions and contribution

Given the above background, this paper seeks to investigate whether international trade openness is a fundamental driver of pollution level in the long term for the Asia-Pacific economies. The research focus is on the independent trade openness effect rather than the trade-induced indirect effects. Hence, this research tries to address the following research question:

Does trade openness have a direct positive or negative effect on the level of per capita CO_2 emissions in the Asia-Pacific region?

Furthermore, this study uses three different proxies of trade openness variable to gauge the robustness of the relationship and see how it render varied results while assessing the impacts of trade openness on environmental quality in a multivariate framework.

Upon its findings, this present study hopes to contribute to the existing literature the Asia-Pacific unique view of the influence of openness to trade on the environmental quality, particularly the long run trade openness-CO_2 emissions nexus. I provide further evidence from other two trade openness measures besides the traditional proxy to capture the more relevant trade barriers. Also, this is the first empirical study of its kind to introduce the Export Value Index and Trade Freedom Index serving as trade openness proxies. In addition, based on previous studies, the importance of other relevant determinants of carbon dioxide emissions is considered in this research. This not only for reducing omitted variable bias but could also be of help in later development researches.

1.3 Scopes and limitations

The research performs analyses of trade openness-carbon emissions relationship based on the panel dataset of 24 Asia-Pacific economies over the period of 1995-2016. The specific countries selected for the study and the timeframe was constrained by data availability. Despite there exist some recent studies further considering indirect effects besides the direct openness effect in order to find out the net trade environmental impacts, it is out of the scope of this paper. Moreover, this research studies the dependence of carbon dioxide emissions only which may cause some degrees of subjectivity in the conclusion for pollution level. Besides, as suggested from the vast literature of the relationship, analysing the linkage between trade openness and environmental pollution in a dynamic and short-term manner might give better implications.

1.4 Data and methodology

The majority of data used in this research is acquired from the World Bank's World Development Indicators, apart from the Trade Freedom Index proxied for trade openness being collected from The Heritage Foundation database of economic freedom. All data are converted into the natural logarithmic form to use throughout the regressions.

Motivated by the studies of Zineb (2016) and Munir and Ameer (2018), this paper also adopts the modified STIRPAT model to include trade openness as the variable of primary interest, other than population, affluence, and technology, in examining environmental impact. The econometric approach involves conventional estimators used for panel data, namely Pooled OLS, Fixed Effects, and Random Effects, and model specification tests for preferable model choice.

1.5 Organization of the research paper

To this end, the rest of the paper is organized as follows. Chapter 2 presents the literature review on environmental quality in connection with trade openness and other determinants. Chapter 3 follows with two sections discussing the data and econometric model as well as techniques. Empirical results are demonstrated and interpreted in Chapter 4. Chapter 5 finalizes the research paper.

CHAPTER 2. LITERATURE REVIEW

2.1 Key concepts

2.1.1 Environmental quality

Since the 1960s, concerns about *environmental quality* and its desirable objective incorporated in the popular term "sustainable development" have become increasingly mainstream (Frankel, 2009). Indeed, with the contemporarily prominent emergence of global environmental problems not simply limited in the climate change, biodiversity losses, or the depletion of the ozone-layer, the strategic agenda for environmental sustainability has inarguably been prioritized among environmentalists and policy makers across nations. Furthermore, those issues' causes and policy development call for thorough economics-related analyses. Aiming at sustainable and long-term economic growth which means promoting and ensuring adequate environmental equity financing, it is commonly suggested that countries should, in different phases of economic development, accordingly implement macroeconomic reforms and liberalization policies that attract foreign investment. In that sense, innovative sustainable policies accompanied by integration of sustainable energy technologies to mitigate environmental costs (Ramakrishnan *et al.,* 2016). However, not as the economic growth which is commonly expressed by a single concept, the GDP, measurement of environmental quality is varied dependent on the aspect in question.

Based on the degree damaged and area affected, environmental quality objectives are classified into three main categories: internal pollution, national externalities, and international externalities. The second type, which entails most kinds of air and water pollution posing impacts within the country, is primarily discussed in the environmental economics literature via some typical indicators such as CO_2 (industrial carbon dioxide emissions), NO_x (nitrogen oxides), N_2O (nitrous oxide emissions), SO_2 (sulphur dioxide), BOD (biochemical oxygen demand), PM (total suspended particulate matter), or VOC (volatile organic compound) (Frankel, 2009; Le, Chang and Park, 2016). Some other composite environmental quality indices have recently been developed, including Environmental Performance Index or Ecological Footprint. Furthermore, with regards to carbon dioxide emissions, Knight *et al.* (2013) distinguished between carbon footprints and carbon emissions measures. The former is consumption-based and focused more on imports, whereas the latter are territorial emissions and mainly includes emissions sourced from exports. Based on such measure classifications, association with the Asia-Pacific region's trade and industrial activities, and its dominance in the literature, per capita CO_2 emissions is the pollutant employed in this research. Data availability for CO_2 emissions is also the most satisfying among others.

2.1.2 Trade openness

According to the immense literature addressing the relationship between *trade openness* and other different factors or concepts, trade openness has been proxied by a number of measures among which the most common and conventional way is employing the share of imports, exports, or total imports and exports to the country's nominal income (GDP). Irrespective of the trade openness measure used, in each case, the various measures provide a method for determining how open an economy is to world trade. Put simply, the higher, for example, the trade share for a particular country is, the more open its economy to trade benefits. One advantage of using output-based measures of openness is that they are not contrived and more readily obtainable from objective data sources (Squalli and Wilson, 2011). Moreover, there have been other variations based on such "trade share" measurements. In general, they basically show the volumes or intensity of trade or its components and reflect the extent to which an economy is open and integrated to trade benefits regionally and internationally. However, capturing trade openness purely through trade outcomes and flows measures has still been criticized to be flawed, confusing, and incomplete because of the definition problem. Also, while a great deal of research investigates the concept "trade openness" in the outcomes sense, they actually aim to give the answers in terms of policy processes (Rodriguez and Rodrik,2000; Yanikkaya, 2003; Squalli and Wilson, 2011).

There remain difficulties in obtaining a well-rounded and unbiased trade openness measure and the root cause lies in the clear definition of "trade openness" or an open economy. Trade openness and trade liberalization tend to be used interchangeably in the literature with various meanings offered. The earliest definition was raised by Krueger (1978) according to which openness equals export-oriented economic structure and favourable exchange rate regime. Later, Anderson and Neary (1992) developed a "trade restrictiveness index" that considers the degree of distortions by tariff and non-tariff barriers in certain economies' trade activities. Furthermore, Harrison (1996) highlighted the incentives differentials captured in a good trade policy measure and further took into account the import-substitution and neutral trade regimes.

Examining trade openness in terms of both trade volumes and trade policy may produce more comprehensive understanding of its impact on environmental quality since both measures are interrelated and environmental effects of trade also have to do with some trade deals and agreements underlying certain patterns of trade flows which can be included in trade policy measures. As the trade context in Asia-Pacific economies has increasingly been moderated with a rise in new trade-restrictive measures according to Akhtar *et al.* (2017), a measure beyond simple trade outcomes should be employed. The choice of proxy for trade policy, to be more precise, the tariff and non-tariff barriers affecting trade system would be the score of Trade Freedom Index – a component of the Economic Freedom Index obtained via The Heritage Foundation. This measurement is defined and calculated in the closest meaning provided by Anderson and Neary (1992, 2005). Furthermore, given the export-oriented trade activities of the economies in the sample, an export measure - Export Value Index is also introduced for robustness checks. Further explanation is mentioned in data sections. The investigation of trade openness and environmental quality that pays attention to effects of different measures of trade openness or orientation is comparable to studies of (Rock, 1996; Le, Chang and Park, 2016; Zineb, 2016; Gozgor, 2017).

2.2 International trade openness and Environmental quality

2.2.1 Theoretical arguments

Theoretically, the debate over the relationship between trade openness and environmental quality, more precisely, emissions level can be classified into two broad perspectives. One school of thought has its roots in the neoclassical trade perspective and followed by environmental economists. The other perspective is based on ecological economics (Leveson-Gower, 1997; Muradian and Martinez-Alier, 2003). The former is in favour of the role of trade openness in solving environmental degradation and puts forward *gains-from-trade* hypothesis. The latter is against and in doubt of the environmental benefits of trade on account of *race-to-the-bottom* hypothesis.

The former holds an opinion that trade openness itself is a great benefit to the improvement of environmental quality thanks to its long-term growth-promoting effect that results in better environmental conservation with the assumption of environment being a normal good whose demand rises with income. The argument basically starts from the popular Heckscher-Ohlin-Samuelson theory of trade in which a country increases production of goods for which it enjoys the comparative advantage. With trade facilitation and boosted exports, any participants gain a win-win position as it leads to more efficient movements and transfers of environmentally-friendly production techniques. Therefore, trade restrictions that interfere in the form of local pollution prevention or protectionism regime may worsen the environmental problems. This is also supported by Afesorgbor and Demena (2018) in the sense that countries with incumbent weak environmental standards may further damage its environment if its trade activities are suppressed due to production duplication situation and inefficient resources allocation. Furthermore, this school highlights that it is not openness to trade *per se* that may cause harm to environmental quality, but the lack of participants' government effective measures for internalizing externalities and the neglect of or mis-valuation with regards to property rights. The associated gains from trade can be concerned with raised global awareness of environmental protection followed by easy access to a wide range of products, especially eco-friendly ones, as well as global co-operation chances with a view to fight climate change.

The ecological economists counter that there is higher possibility that trade stimulates the "race-to-the-bottom" phenomenon in terms of environmental standards in most of the joining parties. First, it criticizes the income effect of trade openness as GDP, an indicator that is most commonly used when discussing growth, has caused flawed thoughts regarding economic growth versus welfare. Second, its fears for the "race-to-the-bottom" is originated from the competitive forces and specialization mechanisms of free trade. The desire to gain economies of scale have pushed the trading economies to maximize profits at all costs including the environment. Back to the imposition of environmental standards, the viewpoint of this school is also that some countries take advantage of trade to protect their environment while damaging others'. Typically, it is argued that the history witnessed the excessive primary exports had distorted the benefits of export-led trade by the severity of environmental problems associated. Nonetheless, in the current circumstances, trade openness in a rule-based system means the local standards need to be aligned with the ones set internationally. As believing that the international trade openness have been putting a lot of efforts in promote sustainability, the *race-to-the-bottom* effect is unlikely.

Although there exist suggestions in the literature regarding further consideration for indirect trade openness effects besides the direct effect in order to find out the more reliable net trade impacts. The very beginning generalizations were implied in the pollution-economic development pattern of the inverted U-shaped Environmental Kuznets Curve (EKC) proposed by which predicts that environmental degradation is endured at the modest level of per capita income, then it becomes settled at the intermediate level, after which higher income is followed by declined environmental damage. In the context of the EKC and economic globalization, it has been argued that further insights on trade patterns would make the interpretation of the framework more meaningful (Antweiler et al., 2001; Aller et al., 2015). Fundamentally, EKC indicates that economic growth or income growth brings about both adverse environmental effects interpreted by scale/institutional structure changes and favourable ones explained by changes in national output composition as well as shifts toward environmentally-friendly production technologies. As trade also being a source of economic growth, such environmental impacts are reasoned to be trade-induced. Moreover, there exist effects stemming from trade-led non-income changes which focus on environmental standards and regulations (Frankel, 2008; Kearsley and Riddel, 2010). However, these indirect environmental effects of trade openness are outside the scope of this research.

2.2.2 Empirical findings

Empirical studies on explaining the direct relationship between trade openness and environmental quality provide mixed evidences. The lack of common consensus can be due to the different countries/country groups, time periods, data sources and econometric methods that have been used. Most of them use the traditional proxy of trade openness, which is volume-based measure – sum of exports and imports to GDP. As this paper focuses on the analysis for a country group, country-specific researches are filtered out in this review.

While some researches such as Ahmed *et al.* (2016) and Munir and Ameer (2018) found strong evidence supporting the *race-to-the-bottom* hypothesis for a selected panel of NICs and Asian emerging economies, respectively, Al-mulali *et al.* (2015) and Dogan and Seker (2016) proves that higher degree of openness to trade promote cleaner environment in most of European countries and top renewable energy economies. It seems that there exists the polarization of environmental conditions suggested by Muradian and Martinez-Alier (2001) as a result of trade openness as NICs and emerging economies are mostly developing nations whereas countries located in the Europe and belonging to the renewable energy forefronts are developed economies. Nevertheless, some other works of covering various panel from Central and Eastern Europe, integrated developing and emerging, and global panel like Atici (2009), Bernard and Mandal (2016) or Sharma (2011) found no significant relationship between trade openness and CO_2 emissions. Different methods used ranging from simple Random Effects to complicated System GMM, Granger causality estimations may cause varied results.

Importantly, concerning the studies examining the relationship with an emphasis on providing further evidences from other trade openness measures, they also yield different results. The earliest study is Rock (1996) use export share growth as well as dummy orientation variable to proxy for export-oriented trade policies of developing countries employing simple OLS estimates. He found contrasting and significant results for both proxies. His dependent variable, though, was pollution intensity of GDP. Meanwhile, the latest work of Gozgor (2018) provide consistently and significantly beneficial impact of trade openness on carbon dioxide emissions of OECD countries using another proxy for trade openness Trade Potential Index which captures imports intensity. Le *et al.* (2016), besides using conventional trade share measure, employ further share of exports and imports separately to examine both long-run and short-run causality of the trade openness-environmental quality nexus. The outcome vary according to different income panel. It is these studies that motivate me in incorporating other proxies for trade openness in assessing whether trade openness is pro-environment or not.

2.3 Other determinants of environmental quality

2.3.1 Population-Affluence-Technology

These determinants of carbon dioxide emissions are derived from the conceptual framework IPAT put forward by Ehrlich and Holdren (1971) to preliminarily learn the environmental impacts (I) of three main drivers Population (P), Affluence (A), and Technology (T). The initial identity expressed by the multiplicative equation I = P.A.T is considered to be "simple, systematic, and robust" (Dietz and Rosa, 1997). Thus, a stochastic version was developed by Dietz and Rosa (1994) allows for quantitative analysis to be conducted to validate the unsystematic effects and hypotheses of the determinants. The Stochastic Impacts by Regressions on Population, Affluence, Technology then be transformed as follows:

$$I_i = \alpha P_i^{\beta_1} A_i^{\beta_2} T_i^{\beta_3} \varepsilon_i$$

where I represents environmental impact, P is population, A is production and consumption activity per person (shortly referred to as Affluence), and T is the impact per unit of consumption or production, which is captured by the Technology used for the production of goods and services. α, β_1, β_2, and β_3 are the parameters, where α scales the model, while β_1, β_2, and β_3 are the shares of P, A and T, respectively, on environment (I) and ε is the error term. The added subindex i indicates the cross-sectional nature of I, P, A, T, and e.

Concerning population, it is reasoned that as population grows, emissions level will rise as it tends to put a strain on the scarce and limited resources in the economy. Moreover, given the surge of urban migration in the last couple of decades owing to the booming global growth and industrial activities, a large number of studies have focused more on the urban settlement pattern of population. They also suggest that the impact of urbanization on emissions is expected to be adverse because urbanized proportion of population involves more intense demand of production, consumption, and transportation as well. Empirically, the environmental effect of population is mixed though. The employed models in the literature include STIRPAT identity as well as simple multivariate analysis. While Al-mulali *et al.* (2015) and Zineb (2016) prove the strong and consistent polluting impact of urban population size, Sharma (2011), Saidi and Mbarek (2017), and Munir and Ameer (2018) show that urbanization is able to decrease CO_2 emissions in the long run. Martínez-Zarzoso (2008) and Hossain (2011) found out that the emissions effect of urbanization can vary conditional on income group, from country to country and even insignificant in some individual nation.

Regarding affluence, which refers to wealth or income of an economy, its effect is considered to be either positive or negative depending on the country's development phase. Most of empirical studies reveal the positive long-term impact of income on pollutant, such as Atici (2009), Ahmed *et al.* (2016), Dogan and Seker (2016), Ertugrul *et al.* (2016), and Munir and Ameer (2018). Using both real and nominal GDP to proxy for income, Gozgor (2018) also found similar results. Contrastingly, Atici (2012) found that increased per capita income leads to reduction in carbon emissions. Additionally, findings from Le *et al.* (2016) are largely inconclusive for CO_2 pollutant and only significant for global panel when particulate matter 2.5 is used as emissions indicator. The influence of affluence per capita can also be explained under EKC hypothesis, but it is out of the scope of this research.

In the original IPAT framework, Technology factor is a term with broad meaning which may capture any element inclusive of technological, institutional, and even cultural ones that may cause impact to environment. In this research, like others in the existing literature, technological component is of main interest. The driving force of technology towards emissions level is quite straightforward in the sense that obsolete and environmentally-damaging production techniques will exacerbate the emissions level in the long run, whereas more advanced technologies contribute to better environmental quality. As to examining to what extent technology directly affect the environmental quality, researchers use the proxy of either industrial share to GDP or aggregate energy consumption to represent technology in STIRPAT model. Some studies include both proxies in their estimation to produce more comprehensive impact. Positive association between energy intensity, which reflects technology content of techniques used, and pollution are found for both CO_2 and SO_2 emissions in Cole and Neumayer (2004), while manufacturing structure shows no relation to emissions. Munir and Ameer (2018) use absolute value of total energy use to proxy for technology and find positive but inconsistent effect across different estimators. Al-mulali *et al.* (2015) and Mahmoodi and Mahmoodi (2018), upon employing data on (disaggregated) renewable energy consumption find beneficial impact of increasing use of renewable energy or renewable electricity production.

2.3.2 Capital intensity

According to neo-classical model of trade, the production structure of an economy decided by its comparative advantage which is in turn led by factor endowment differentials. Here, the factors of production basically refer to the traditional ones, capital and labour Cole (2003). Coxhead (2003, p.32) also added the impact of prices as the other factor, but it is beyond this paper scope. Especially, he emphasized the alteration in production mix that is controlled by factor changes may affect pollution level. As indicated by Mani and Wheeler (1998) and Cole and Elliot (2005) since emissions-intensive industries tend to source from their uses of capital-intensive production processes, this research expect that higher capital accumulation leads to the higher propensity of a sector to pollute which then is coupled with increased emissions and environmental deterioration, which is given the notion of *factor endowment* effect. Besides, the assumption of factor mobility in the neo-classical trade theory is modified as being restricted but not impossible both at home and internationally.

In the relevant literature, some empirical works define capital intensity in a relative way in a sense that it is a comparative concept. However, this research goes for the absolute advantage as it still hold true contemporarily Muradian and Martinez-Alier (2001). While findings in Antweiler *et al.* (2001) support the polluting effect of capital abundance, Pascalau and Qirjo (2017) proved the reverse for the EU member countries during 1989-2013. Employing Random Effects model to determine the impact of capital intensity on different pollutants, Cole (2003) find the significant negative relationship for SO_2 emissions only.

2.3.3 Foreign Direct Investment (FDI) inflows

FDI has long become a vital factor in any economy, especially the FDI recipients. According to what Shahbaz *et al.* (2015) has consolidated, FDI growth represents not only a strong enhancement for development process, spill-over effects, improved productivity, but also of huge assistance in terms of novel production processes, know-hows, and managerial practices. Therefore, its potential impact on environmental quality of the host countries should inarguably be of concern. In accordance with Zarsky (1999) , inward FDI can make the recipients experience either *pollution haven* effect or *pollution halo* effect. If the FDI flows to the host country from multinational enterprises for avoiding increased production costs due to environmental regulatory compliance at home countries, the former effect is created which results in rising negative externalities and pollution levels and environmental deterioration locally and globally. This happens also because some recipients have focused more on growth and investment than the quality of environment. Meanwhile, it is also pointed out that FDI inflows provide host countries with *pollution halo* as they possibly serve as the channel for more extensive positive externalities and the aid for improved research and development in low carbon technology, which directly paves the way for environmental progress. Moreover, in this modern era with the promotion of "green growth", "clean revolution", and sustainability commitment creating comparative differentials from firm to firm, the *pollution halo* effect should be expected.

Since there exist two extremes in the theory, some empirical studies should be presented. Tamazian and Rao (2010) examines the impacts of some drivers, including FDI, on environmental degradation for 24 transitional economies from 1993 to 2004. Employing Random Effects and System GMM estimator to run various model specifications, the research produces results in supportive of *pollution halo* effect. Studying the relationship in a non-linear manner for the global panel of 99 countries as well as disaggregated panel in terms of income levels, Shahbaz (2016) came to the conclusion that FDI inflows-CO_2 emissions nexus varies across country groups of different income level, that is FDI is monotonically pro-environment in high-income countries whereas it exerts polluting effect in low-income ones. The global and middle-income panel witnessed an inverted-U curve of the relationship which means FDI initially is harmful for environment but starts improving it in later phases. Applying Dynamic Fixed Effects estimator, Jobert *et al.* (2015) found no significant relationship even when estimating the results for each country in the panel. Similarly, results from as Lee (2013) and Bernard and Mandal (2016), indicate that FDI does not necessarily matter for emissions level.

2.3.4 Financial development and Inflation

Variation in carbon dioxide emissions in an economy might depend on the level of financial development or financial deepening. This driving force has recently been discussed in the literature of examining environmental degradation. It is argued that financial development can either be a cause or a solution to the environmental deterioration and pollution level. In the former case, financial development accompanied by reduced costs of financing may enable the economies of scale of pollution-intensive sectors in the economy Jensen, 1999; Sadorsky, 2010). On the other hand, financial development plays an effective role in evaluating and steering the financial resources to projects in favour of the environmental quality. Moreover, along with the development of financial sectors, businesses operations are exposed to more opportunities in getting access to energy-efficient technologies contributing to improved emissions level Frankel and Rose, 2002; Tamazian and Rao, 2010).

Some empirical studies have provided evidence for the importance of financial development with regards to CO_2 emissions. A study of Al-Mulali *et al.* (2015) employed fully-modified OLS (FMOLS) estimation method to examine the causal impact of financial development proxied by domestic credit to private sector, together with some other relevant explanatory variables, on pollution for a panel dataset of 23 European countries during 1990-2013. Their findings support the first standpoint, which means as domestic credit increases, so as the carbon dioxide emissions and the coefficients ranging from 0.05-0.1 are consistently positive and significantly entering all models estimated. A comparable research was conducted by Dogan and Seker (2016) for 23 out of top 40 countries consuming renewable energy over the period 1985-2011. However, they found the contrasting results that financial development, also indicated by domestic credit as a percent to GDP, in the analysed countries mitigates CO_2 emissions in the long run by 0.03%. Similar impacts for varied panels of transitional and emerging economies are provided by Tamazian and Rao (2010) and Saidi and Mbarek (2017) using Random Effects and System-GMM models. It is implied that developing countries or newly industrialized economies may count on financial development and reforms to curb the pollution.

Nevertheless, financial development was found to be in no relation to either CO_2 emissions or Environmental Performance Index in Bernard and Mandal (2016). Taking financial development into consideration in the STIRPAT model with FMOLS technique for a panel of 3 middle-income Asian countries-Bangladesh, India, and Pakistan, Khan *et al.* (2018) prove that financial development significantly and negatively correlated with per capita CO_2 emissions in all three countries except for India. Regarding the effect of macroeconomic stability, which is reflected via inflation level, on environmental quality, Tamazian and Rao (2010) and Bernard and Mandal (2016) justify that it helps achieve the sustainable investment and development. However, while Bernard and Mandal (2016) found no significant results for this connection, Tamazian and Rao (2010) show that inflation has an ameliorating effect on per capita CO_2 emissions, despite the inconsiderable magnitudes.

CHAPTER 3. DATA AND METHODOLOGY

3.1 Data sources and variable explanation

The empirical study employs a dataset that covers the 24 Asia-Pacific countries (see Appendix 1 for the countries list) spanning the 22-year period from 1995 until 2016. Data required for this analysis are collected from the World Development Indicators consolidated by the World Bank, apart from the Trade Freedom Index obtained from The Heritage Foundation. Originally, annual data for the Asia-Pacific region containing over forty economies and the time component being 1990-2017 inclusive had been collected; however, the sample is limited to those countries for which data availability is as commensurable as possible and allows a strongly balanced panel. Furthermore, all the data are transformed into the natural logarithmic form prior to conducting the related analyses. Especially, due to some negative values of FDI inflows and inflation rate causing missing data, the logarithmic conversion for these two variables follows the method suggested by Busse and Hefeker (2007). The summary of data sources and definitions for all variables used is provided in Table 3.1. Besides, I am going to present further explanations below.

- *Dependent variables:*

Environmental quality is proxied by the per capita Carbon Dioxide emissions (denoted with CO_2): the more CO_2 emitted, the worse the environmental quality will become. Data for this key dependent variable is collected from the World Development Indicators (WDI) database provided by the World Bank (WB) and measured in metrics ton. In accordance with the trade-environment literature, among various environmental quality indicators and pollutants, carbon dioxide emissions have remained the most extensively cited and researched (Hossain, 2011; Ertugrul *et al.,* 2016; Dogan and Seker, 2016; Rahman, 2017). Despite the fact that international trade openness might embody several kinds of environmental impacts and externalities, air quality and global warming primarily attributable to the carbon dioxide are still of particular concern even from the global or local scale. Thus, this study opts for employing the CO_2 emissions per capita which is inclusive of the amount of carbon dioxide emitted through the combustion of solid, liquid, and gaseous fuels, as well as from gas flaring and the cement manufacture and exclusive of emissions from land use change or from bunker fuels used in international transportation. In that sense, according to Knight *et al.* (2013), this territorial measure mainly reflects the production-based emissions which is more associated with the export-oriented trade regimes and development path of almost all Asia-Pacific economies. Moreover, since carbon dioxide is also considered as global pollution, its examination may help draw inference on the global environmental effects of trade openness in the Asia-Pacific region.

Table 3.1 List of variables with description

Variable		Description	Data Source
Dependent variable			
Carbon dioxide emissions (CO_2)		Per capita carbon dioxide emissions originating from fossil fuels burning and cement manufactures; unit of measure is metrics ton per capita	World Bank's World Development Indicators (2018)
Independent variables			
Main explanatory variables			
Trade openness (Trade)	Trade share (TO)	The ratio of sum of exports and imports of goods and services to GDP, unit of measure: %	World Bank's World Development Indicators (2018)
	Trade policy (TFI)	A composite indicator of the extent to which the presence of tariff and non-tariff barriers (NTBs) influences imports and exports of goods and services. It consists of two inputs: trade-weighted average tariff rate and NTBs penalty. Graded within the score range of 0-100, with higher values indicating lower trade barriers and greater freedom to trade.	The Heritage Foundation (2018)
	Export value index (EVI)	The current value of exports converted to U.S. dollars and expressed as percent of the average for the base period (2000) which is 100.	World Bank's World Development Indicators (2018)
Urban population (Pop)		Total number of people living in urban areas	World Bank's World Development Indicators (2018)
Income per capita (GDPpc)		Per capita real GDP in constant 2010 US$	World Bank's World Development Indicators (2018)
Renewable energy consumption (EC)		Consumed renewables energy as a percentage of total final energy consumption, unit of measure: %	World Bank's World Development Indicators (2018)
Control variables			
Capital consumption (KI)		The ratio of fixed capital consumption to the size of Gross National Income (GNI), representing the replacement value of capital used up in the process of production, unit of measure: %	World Bank's World Development Indicators (2018)
FDI Inflows (FDI)		The share of net inflows of investment (consisting of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments) from foreign investors in GDP, unit of measure: %	World Bank's World Development Indicators (2018)
Domestic credit (Findev)		Refers to the financial resources provided to the private sectors by banks (apart from Central Bank) divided by GDP, unit of measure: %	World Bank's World Development Indicators (2018)
Inflation rate (Inflation)		Inflation rate as measured by the annual growth rate of the GDP implicit deflator shows the rate of price change in the economy as a whole. The GDP implicit deflator is the ratio of GDP in current local currency to GDP in constant local currency.	World Bank's World Development Indicators (2018)

- *Independent variables:*

The key explanatory variable of interest in this research, degree of openness to trade, enters into the regression under three different proxies owing to the criticisms over the appropriateness of the conventional proxy – trade share to GDP. The first proxy is the commonly used output-based or outcome-based measure, the ratio of trade to GDP (indicated as TO). Following an empirical study of (Gomez, 2018) investigating the trade openness-food insecurity nexus, the second proxy is chosen based on its relevance with the region mainly comprising export-driven economies, namely Export Value Index (indicated as EVI). Rock (1996) once introduced variables of export outcomes to find out impact of trade openness policy on the pollution intensity of GDP. Also, Zhao and Hong (2008), Atici (2012), Rahman (2017) once considered exports intensity, in particular, the important factor in the examination of carbon emissions in Asian countries. Concerning the policy aspects with tariffs and non-tariffs restrictions to trade as noted in the literature review, the third alternative measure – Trade Freedom Index (indicated as TFI) – is experimented in the regression for a more thorough analysis. The index along with the other eleven components constitutes the Index of Economic Freedom compiled annually by The Heritage Foundation. Besides considering the average tariff rate, the index further quantifies the level of non-tariff barriers and classifies them into six groups, namely restrictions in terms of quantity, price, regulations, investment, customs, and direct government intervention. The detailed calculation method for this index can be found in Miller *et al.* (2018) . Data for the two first proxies are extracted from the database of the World Bank's WDI. Meanwhile. data for the composite policy measure TFI is derived from The Heritage Foundation dataset and available from 1995 onwards for the majority of the countries in the sample.

Population, Affluence, and Technology, which are the benchmark determinants of carbon dioxide emissions taken from the aforementioned stochastic IPAT model (STIRPAT), are proxied by urbanization population (Pop), per capita real income (GDPpc), and renewable energy consumption (EC), respectively. The World Bank's WDI supplies the data for these variables. As discussed in section 2.3.1, the use of the urbanized proportion of the total population expressed in absolute terms captures not only the impact of rising population but that of the urbanization as well. Following the literature, gross domestic product (GDP) per capita is used to measure the "affluence" factor of an economy and the technological level is represented by the share of renewable energy use in total final energy consumption. Regarding other control variables including fixed capital consumption share of GNI (KI), inward FDI stock (FDI), domestic credit to private sectors by banks (Findev), and inflation rate (Inflation) that serve as proxies for capital intensity, FDI flows, financial development, and inflation respectively, their data also come from the World Bank's WDI. The choice of these control variables has been rationalized in the review of literature.

Table 3.2 Summary statistics (24 Asia-Pacific countries, 1995-2016)

Variables	Observations	Mean	Standard deviation	Minimum	Maximum
Dependent variables					
Carbon dioxide emissions (CO_2)	528	.6227419	1.432503	-2.63388	2.901432
Independent variables					
Urban population (Pop)	528	16.31098	1.813833	12.77372	20.47836
Real GDP per capita (GDPpc)	528	8.052336	1.474756	5.834735	10.9283
Renewable energy consumption (EC)	504	2.82856	1.489023	-1.123564	4.518876
Trade share (TO)	528	4.316828	.6260213	2.814179	6.090413
Trade Freedom Index (TFI)	511	4.183686	.2863676	2.580217	4.49981
Export Value Index (EVI)	528	5.146198	.7833141	3.545889	7.589227
Fixed capital consumption (KI)	528	2.405599	.4721927	.5826124	3.242542
FDI inflows (FDI)	527	1.645068	1.127679	-4.308713	4.701942
Domestic credit (Findev)	513	3.658717	.9990036	.1536173	5.251759
Inflation rate (Inflation)	528	2.107135	1.405527	-3.634578	6.995209

Note: All variables' data are logged.

Table 3.3 Pairwise correlation matrix for the panel data

	1	2	3	4	5	6	7	8	9	10	11
1. CO_2	1.0000										
2. Pop	0.2534*	1.0000									
3. GDPpc	0.8721*	0.1434*	1.0000								
4. EC	-0.8080*	-0.0654	-0.7007*	1.0000							
5. TO	0.1155*	-0.4934*	0.0740	-0.3071*	1.0000						
6. TFI	0.4246*	-0.2460*	0.5215*	-0.3941*	0.3426*	1.0000					
7. EVI	0.2131*	0.1068*	0.1436*	-0.1458*	0.1110*	0.3058*	1.0000				
8. KI	0.6389*	0.2112*	0.6170*	-0.4735*	0.0856*	0.3421*	0.1369*	1.0000			
9. FDI	0.1758*	-0.2944*	0.0380	-0.3282*	0.5551*	0.1685*	0.2591*	0.0599	1.0000		
10. Findev	0.5521*	0.4106*	0.6705*	-0.2971*	0.0374	0.2291*	0.2194*	0.3809*	-0.1020*	1.0000	
11. Inflation	-0.3693*	-0.1888*	-0.5149*	0.3072*	0.0454	-0.2071*	-0.0556	-0.3071*	0.0668	-0.4754*	1.0000

Note: All variables' data in natural logs; * indicates correlation coefficients significant at 5%.

The descriptive statistics and pairwise correlation matrix for the log-transformed data are reported in Table 3.2 and Table 3.3 above. Furthermore, the descriptive statistics for the original dataset is shown in Appendix 2. The maximum and minimum amount of per capita CO_2 emissions was found in Australia (in 2009) and Laos (in 1995), respectively. In terms of trade share proxy, the volumes traded to GDP was largest and smallest in Singapore (in 2008) and Japan (in 1995), respectively. The highest and lowest Export Value Index belongs to Azerbaijan in 1998 and 2011. Lastly, in respect of Trade Freedom Index, the freest economy in the sample within the analysed timeframe is Singapore (2016) while India is the most repressed in 1996.

According to descriptive statistics shown, the average of log of carbon dioxide emissions, whose observations is 528, is approximately 0.62 and it ranges from -2.6 (minimum value) to 2.9 (maximum value). Regarding standard deviations, the corresponding figures imply that data for all variables, except for CO_2, are more concentrated around the mean and contain very few outliers. This indicates the low possibility of cross-sectional heterogeneity issue for analysed variables and hence the heterogeneous panel techniques are unnecessary.

As can be seen from Table 3.3, almost all the correlation coefficients are small (less than 0.7) which means potential multicollinearity problem in the estimations is avoidable. The 0.7007 negative correlation between per capita income and renewable energy consumption is still acceptable though. The noticeably high and significant correlations between carbon emissions and GDP per capita (0.87) as well as renewable energy consumption (-0.8) are in line with the expectations from IPAT model hypotheses. Besides, the relationships between the main variable of interest, trade openness proxies, and CO_2 emissions in the Asia-Pacific are positive and statistically significant although the contributions are lower than average. Meanwhile, the variables of capital intensity and financial

Figure 3.1 The relationship between Trade Share and CO_2 Emissions

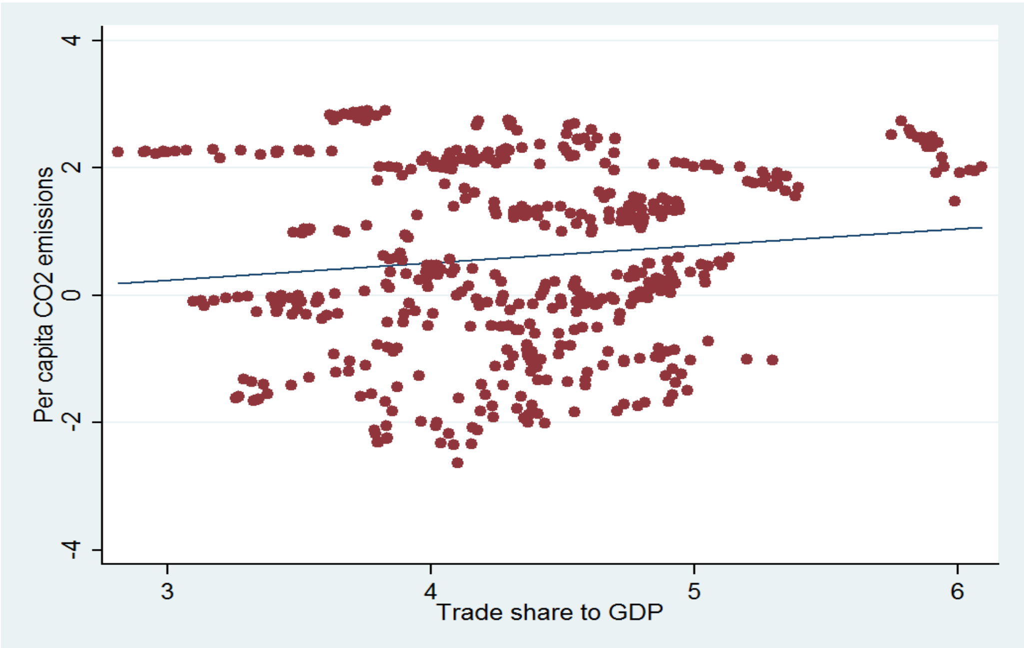


Figure 3.2 The relationship between Export Value Index and CO2 Emissions

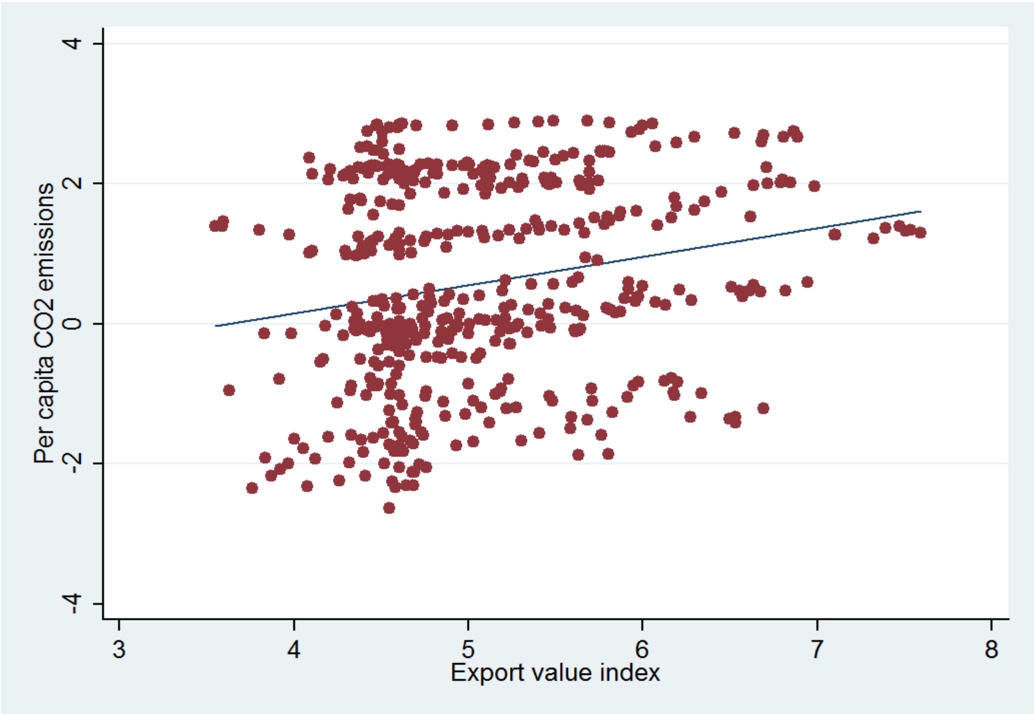
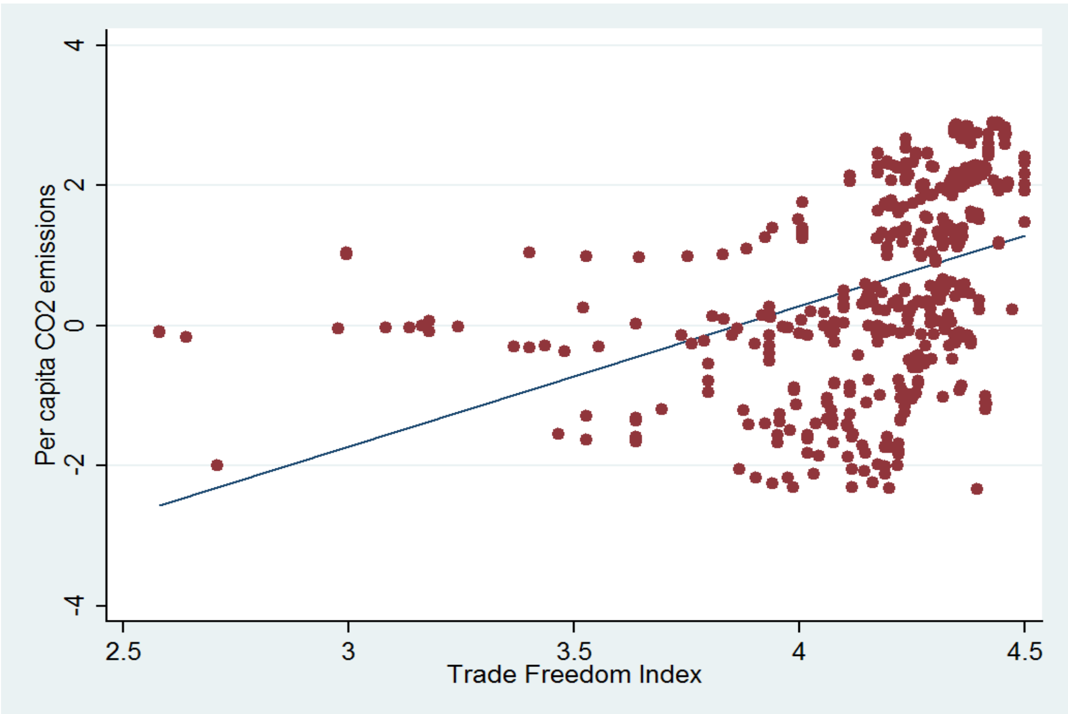


Figure 3.3. The relationship between Trade Freedom Index and CO_2 Emissions



development show stronger positive correlation with CO_2 emissions. The correlations among three proxy variables of trade openness are significant at 5% level as well, with the coefficient for trade freedom index-trade share larger than export value index-trade share. The two-way graphs shown in Figures 3.1-3 above demonstrating the relationships between different openness measures and carbon emissions also share similar results as in the correlations table.

3.2 Empirical model and methodology

3.2.1 Model specification

The design of the empirical model in this research is largely based on the IPAT conceptual framework and its stochastic form STIRPAT model. As presented in section 2.3.1, the IPAT systematic equation – I(mpact) = P(opulation) x A(ffluence) x T(echnology) – was first put forward by (Ehrlich and Holdren, 1971) and reformulated into STIRPAT version for enabling quantitative assessments by Dietz and Rosa (1994, 1997). Furthermore, there has recently been studies that modified and elaborated the STIRPAT model using different proxies for the benchmark factors or including other potential drivers of environmental degradation such as financial deepening, income inequality, or working hours (York, Rosa and Dietz, 2003; Martínez-Zarzoso *et al.*, 2007; Knight *et al.*, 2013; Shafiei and Salim, 2014; Sadorsky, 2014; Zineb, 2016; Khan *et al.*, 2018; Munir and Ameer, 2018). I adopt STIRPAT as the analytical framework since it explicitly explains the pollution change in the connection with principal socio-economic forces and flexibly allows for the inclusion of other explanatory variables (York *et al.*, 2003; Knight *et al.*, 2013). Inspired by Zineb (2016) and Munir and Ameer (2018), this paper builds a modified STIRPAT model where trade openness, together with population, affluence, technology, is integrated as the primary determinant and other factors entering as control variables.

Derived from the initial specification of STIRPAT identity developed by (Dietz and Rosa, 1997) in Equation (2) and further considered the time specificity for panel regression, the exponential form of the baseline model can be given as follows:

$$I_{it} = \alpha P_{it}^{\beta_1} A_{it}^{\beta_2} T_{it}^{\beta_3} \varepsilon_{it} \qquad (3)$$

where the subscripts i and t denotes the country dimension (i = 1 to N = 24) and time dimension (t = 1 to T = 22), respectively. α, β_1, β_2, and β_3 still refers to the environmental impact (I) elasticities with respect to population (P), consumption or production per person (A) and pollution per unit of production or consumption (T), respectively. Taking natural logarithms of Equation (3) for making it additive, we have:

$$ln\, I_{it} = \alpha_i + \beta_1 ln\, P_{it} + \beta_2 ln\, A_{it} + \beta_3 ln\, T_{it} + \mu_t + e_{it} \qquad (4)$$

where α_i captures country-specific variables that affect environmental changes, μ_t indicates time-varying effects, and e_{it} stands for the error term.

As discussed, in estimating the econometric emissions models, per capita carbon dioxide emissions (CO_2) is used to measure environmental degradation (I); real GDP per capita (GDPpc) quantifies the affluence of an economy (A); the proxy of population size (P) is the total urban population (Pop); and technology (T) is measured as the share of renewable energy consumption (EC). Therefore, the baseline STIRPAT model of carbon emissions can be rewritten alternatively from Equation (4) as follows:

$$(lnCO_2)_{it} = \alpha_i + \beta_1 lnPop_{it} + \beta_2 lnGDPpc_{it} + \beta_3 lnEC_{it} + \mu_t + e_{it} \quad (5)$$

Following previous studies using and modifying STRIPAT model in examining the emissions' determinants other than the core ones, i.e. population, affluence, and technology, the model in this study is also extended to include potential explanatory variables. As openness to trade has been argued to contribute to the emissions' variation, the equation (6) below provides the augmented STIRPAT model by inserting trade openness (Trade) that represents the three proxies: TO, EVI, and TFI:

$$(lnCO_2)_{it} = \alpha_i + \beta_1 lnPop_{it} + \beta_2 lnGDPpc_{it} + \beta_3 lnEC_{it} + \beta_4 lnTrade_{it} + \mu_t + e_{it} \quad (6)$$

Additionally, the dependence of CO_2 pollutant on FDI levels, capital abundance, financial development, and inflation recently increasingly investigated in the literature has motivated the extension with a corresponding set of control variables (Z_{it}). They are FDI inflows (FDI), consumed fixed capital (KI), domestic credit to private sectors (Findev), and inflation rate (Inflation). So, it yields the following specification:

$$(lnCO_2)_{it} = \alpha_i + \beta_1 lnPop_{it} + \beta_2 lnGDPpc_{it} + \beta_3 lnEC_{it} + \beta_4 lnTrade_{it} + \gamma lnZ_{it} + \mu_t + e_{it} \quad (7)$$

in which β_{1-4} are the coefficients estimating the direct effects of the variables of main interest; γ is the vector of coefficients that show the influence of control variables on CO_2.

Regarding the expected signs and magnitudes of the included variables, the propositions are as follows. Following the posits of initial IPAT model and related empirical studies, the environmental effects of urban population size, per capita income, and renewable energy use have not reached a consensus in general. Nevertheless, considering the unique effect of each determinant, I expect the rising urbanized population and income will accelerate CO_2 emissions whereas renewable energy consumption linked to environmentally sound technology will mitigate those (Cole and Neumayer, 2004; Hossain, 2011; Dogan and Seker, 2016; Rahman, 2017). In the case of trade openness per se, it is expected to benefit environmental quality in the Asia-Pacific regardless of the measure used despite its inconclusiveness in the relevant literature. This can be argued that as countries become more liberalized and integrated to the international trading system, the pros may far outweigh the cons and they have a tendency to conserve the environment and better curb the CO_2 emissions (Alpay, 2000; Atici, 2012; Dogan and Seker, 2016; Gozgor, 2017). Higher capital intensity is expected to exert adverse effects on environmental quality as economic structure of consumption and production shifts to capital-intensive, hence pollution-intensive sectors (Coxhead, 2003; Jung, 2016). For the remaining determinants of pollution emissions in Asia-Pacific economies, the expectation is increased inward FDI, higher domestic credit, and lower inflation rate will lead to reductions in CO_2 emissions thanks to more improved and efficient resource utilization and technical level that is conducive to environmental protection (Dinda, 2004; Bernard and Mandal, 2016; Saidi and Mbarek, 2017; Khan, Saleem and Fatima, 2018). Furthermore, it is because during the last decade especially, the Asia-Pacific region has received a considerable amount of greenfield investment and the FDI strategies in the region tend to further promote sustainability Akhtar *et al., 2017*.

3.2.2 Model estimation

The employment of panel data suggests the use of Pooled OLS, Fixed Effects, or Random Effects estimators for running regressions. In order to find the most suitable estimation method, I will first regress carbon emissions on the main regressors which is expressed in Equation (5). Trade openness proxies are used in alternative order. Then, the choice of model is based on the Breusch-Pagan Lagrange multiplier (Random effects over Pooled OLS) and the Hausman tests (Fixed effects over Random effects). The tests' outcomes shown in Appendix 3 indicate that Fixed Effects models may produce most consistent and meaningful results; hence more favourable. Furthermore, I decided to use one-way fixed effects model because the control for time-fixed effects is unnecessary. Consequently, Equations (5)-(7) yield the corresponding fixed-effects model 1-3 as below, respectively:

Model 1: $(lnCO_2)_{it} = \beta_0 + \beta_1 lnPop_{it} + \beta_2 lnGDPpc_{it} + \beta_3 lnEC_{it} + \vartheta_i + e_{it}$

Model 2: $(lnCO_2)_{it} = \beta_0 + \beta_1 lnPop_{it} + \beta_2 lnGDPpc_{it} + \beta_3 lnEC_{it} + \beta_4 lnTrade_{it} + \vartheta_i + e_{it}$

Model 3: $(lnCO_2)_{it} = \beta_0 + \beta_1 lnPop_{it} + \beta_2 lnGDPpc_{it} + \beta_3 lnEC_{it} + \beta_4 lnTrade_{it} + \gamma lnZ_{it} + \vartheta_i + e_{it}$

where β_0 is the intercept, and ϑ_i represents country fixed effects, while other designations have already been mentioned from above.

As for Model 3, the additional control variables included in vector Z_{it} enter the regressions in an alternate order of two regressors once, which means KI & FDI first, then Findev & Inflation follow. For each of three proxies for trade openness, I estimate the above model specifications each. The empirical analysis for the STIRPAT-based model – Model 1 – is conducted from the beginning to test IPAT framework. Finally, I also tackle the heteroskedasticity problem by reporting the estimated results of Fixed effects models with robust standard errors.

CHAPTER 4. RESULTS AND ANALYSIS

The estimation results for carbon dioxide emissions in the Asia-Pacific region from all three estimators pooled OLS, Fixed-, and Random effects are given in Tables 4.1 to 4.4, respectively. Even though Fixed effects model with heteroskedasticity-adjusted standard error being the most relevant one, estimates from other models are still presented for comparison. Each Table provides results in 10 columns I-X, in which: column I reports outcomes for the basic Model 1; columns II-IV report outcomes for the extended specifications with trade openness proxied by trade share measure; columns V-VII and VII-X give the similar sets of estimations but with Export Value index and Trade Freedom Index, respectively, as proxies for trade openness. Given the functional form of the models estimated is log-log, the coefficients will be interpreted as elasticities of the emissions with respect to the determinants considered. This indicates, in the long run, how CO_2 emissions vary in percentage terms in response to a one-percentage point increase in a certain explanatory variable, holding other variables' effects constant. The main findings are that in the long run, the CO_2 emissions in 24 Asia-Pacific economies investigated are positively determined by population, affluence, capital intensity, and financial development, whereas negatively driven by technology. Especially, there is still no clear evidence for the independent role of the main variable of interest – trade openness – in carbon emissions function.

With regards to the basic determinants of CO_2 drawn from STIRPAT model, which are urban population, income per capita, and renewable energy consumption, the overall signs and significances are as expected and consistent across the used estimators. Their coefficients' magnitudes are much greater compared to other variables. Specifically, from Table 4.2, other factors held constant, a 1% increase in total urban population size pushes the per capita carbon emissions level up by 0.5% in the basic model, by maximum 0.45%, 0.52%, and 0.43% in specifications including trade share, EVI, and TFI, respectively, as trade openness proxy. It is also found that, other things equal, an increase of up to 0.43% (column IX) in CO_2 emissions is associated with a 1% rise in real GDP per capita. However, when corrected for heteroskedasticity, the variable significance weakens or disappears in some specifications which raises doubts about the importance of income or affluence as a driving force of carbon emissions when more variables are incorporated. Anyway, in the basic model, it is still statistically highly significant and exhibit adverse effect to environmental quality. The environmental effect of technology represented with renewable energy reveals to be beneficial as expected with a negative and highly significant correlation. As a result, as the share of renewable energy in total energy use rises by 1%, the environmental degradation might be ameliorated with a nearly 0.4% reduction in carbon emissions per capita, ceteris paribus.

Table 4.1 Carbon dioxide emissions per capita – Pooled OLS Estimates

Dependent variable: $lnCO_2$	I	II	III	IV	V	VI	VII	VIII	IX	X
lnPop	0.1159*** (0.014)	0.1305*** (0.016)	0.1212*** (0.015)	0.1138*** (0.019)	0.1119*** (0.013)	0.1271*** (0.014)	0.1298*** (0.015)	0.1192*** (0.015)	0.1323*** (0.015)	0.1287*** (0.016)
lnGDPpc	0.5583*** (0.023)	0.5647*** (0.024)	0.5347*** (0.025)	0.5409*** (0.038)	0.5542*** (0.023)	0.5336*** (0.025)	0.5680*** (0.035)	0.5634*** (0.026)	0.5603*** (0.028)	0.5767*** (0.037)
lnEC	-0.3836*** (0.023)	-0.3670*** (0.025)	-0.3211*** (0.024)	-0.3264*** (0.027)	-0.3784*** (0.023)	-0.3170*** (0.024)	-0.3074*** (0.025)	-0.3697*** (0.023)	-0.2996*** (0.024)	-0.3014*** (0.025)
lnTO		0.0845* (0.049)	-0.0704 (0.051)	-0.1016* (0.055)						
lnEVI					0.1097*** (0.032)	0.0480 (0.032)	0.0713** (0.032)			
lnTFI								0.0252 (0.106)	-0.0559 (0.101)	-0.0991 (0.097)
lnKI			0.3188*** (0.063)	0.3726*** (0.063)		0.3088*** (0.063)	0.3505*** (0.062)		0.2765*** (0.063)	0.3380*** (0.062)

lnFDI			0.1586***	0.1678***		0.1312***	0.1314***		0.1502***	0.1523***
			(0.026)	(0.026)		(0.026)	(0.025)		(0.024)	(0.024)
lnFindev				0.0484			0.0020			0.0189
				(0.041)			(0.037)			(0.038)
lnInflation				0.1003***			0.0962***			0.0920***
				(0.019)			(0.019)			(0.019)
R-squared	0.857	0.858	0.874	0.884	0.861	0.874	0.884	0.859	0.875	0.884
Observations	504	504	503	490	504	503	490	488	488	478

Note:
Standard errors in parentheses.
*, **, *** denote the statistical significance at 10%, 5%, 1% confidence level, respectively.

Table 4.2 Carbon dioxide emissions per capita - Fixed Effects Estimates

Dependent variable: $lnCO_2$	I	II	III	IV	V	VI	VII	VIII	IX	X
lnPop	0.4986***	0.4480***	0.2872***	0.4443***	0.5053***	0.3210***	0.5212***	0.4312***	0.2440***	0.4094***
	(0.074)	(0.074)	(0.076)	(0.080)	(0.076)	(0.079)	(0.082)	(0.078)	(0.079)	(0.082)
lnGDPpc	0.3334***	0.3335***	0.3707***	0.1976***	0.3593***	0.3689***	0.3426***	0.3891***	0.4321***	0.2273***
	(0.041)	(0.040)	(0.039)	(0.052)	(0.075)	(0.072)	(0.077)	(0.046)	(0.044)	(0.055)
lnEC	-0.3743***	-0.3970***	-0.3739***	-0.3726***	-0.3738***	-0.3529***	-0.3612***	-0.3788***	-0.3559***	-0.3644***
	(0.041)	(0.041)	(0.040)	(0.039)	(0.041)	(0.040)	(0.038)	(0.042)	(0.040)	(0.039)
lnTO		0.1518***	0.1239***	0.0515						
		(0.038)	(0.037)	(0.039)						
lnEVI					-0.0124	0.0012	-0.0800***			
					(0.030)	(0.029)	(0.031)			
lnTFI								-0.0423	-0.0407	-0.0314
								(0.045)	(0.043)	(0.043)
lnKI			0.1785***	0.1788***		0.1885***	0.1749***		0.1923***	0.1812***
			(0.030)	(0.029)		(0.030)	(0.029)		(0.030)	(0.029)

lnFDI			0.0187*	0.0058		0.0226**	0.0082		0.0279***	0.0098
			(0.010)	(0.010)		(0.010)	(0.010)		(0.010)	(0.011)
lnFindev				0.1226***			0.1422***			0.1336***
				(0.022)			(0.023)			(0.023)
lnInflation				0.0101			0.0168**			0.0090
				(0.007)			(0.007)			(0.007)
F-statistic	264.4353	208.6224	155.7651	125.6911	198.0233	150.3246	127.6751	190.5173	148.8836	120.0234
r-squared	0.6245	0.6368	0.6640	0.6871	0.6246	0.6560	0.6904	0.6236	0.6611	0.6828
Observations	504	504	503	490	504	503	490	488	488	478

Note:
Standard errors in parentheses.
*, **, *** denote the statistical significance at 10%, 5%, 1% confidence level, respectively.

Table 4.3 Carbon dioxide emissions per capita - Random Effects Estimates

Dependent variable: $lnCO_2$	I	II	III	IV	V	VI	VII	VIII	IX	X
lnPop	0.2719*** (0.048)	0.2714*** (0.048)	0.1859*** (0.047)	0.1913*** (0.044)	0.2544*** (0.047)	0.1838*** (0.048)	0.1982*** (0.042)	0.2377*** (0.049)	0.1557*** (0.048)	0.1786*** (0.047)
lnGDPpc	0.4336*** (0.033)	0.4119*** (0.032)	0.4171*** (0.031)	0.3410*** (0.039)	0.4581*** (0.054)	0.4450*** (0.053)	0.4378*** (0.053)	0.4737*** (0.037)	0.4728*** (0.035)	0.3576*** (0.043)
lnEC	-0.4182*** (0.037)	-0.4292*** (0.036)	-0.3924*** (0.035)	-0.4116*** (0.035)	-0.4194*** (0.037)	-0.3793*** (0.036)	-0.3958*** (0.035)	-0.4090*** (0.038)	-0.3716*** (0.036)	-0.3981*** (0.035)
lnTO		0.1690*** (0.037)	0.1289*** (0.036)	0.0746** (0.038)						
lnEVI					-0.0077 (0.023)	-0.0062 (0.023)	-0.0495** (0.022)			
lnTFI								-0.0350 (0.044)	-0.0422 (0.042)	-0.0349 (0.042)
lnKI			0.1908*** (0.029)	0.2054*** (0.029)		0.2052*** (0.029)	0.2145*** (0.028)		0.2030*** (0.029)	0.2066*** (0.028)

lnFDI			0.0197*	0.0115		0.0249**	0.0157		0.0295***	0.0157
			(0.010)	(0.011)		(0.010)	(0.011)		(0.010)	(0.011)
lnFindev				0.0901***			0.1058***			0.1076***
				(0.021)			(0.022)			(0.022)
lnInflation				0.0089			0.0147**			0.0081
				(0.007)			(0.007)			(0.007)
Wald Chi-squared	882.9082	933.6816	1069.3470	1135.3559	901.2816	1039.5028	1161.7022	865.7391	1030.8037	1081.1352
Observations	504	504	503	490	504	503	490	488	488	478

Note:
Standard errors in parentheses.
*, **, *** denote the statistical significance at 10%, 5%, 1% confidence level, respectively.

Table 4.4 Carbon dioxide emissions per capita - Fixed Effects Estimates with heteroskedasticity correction

Dependent variable: $lnCO_2$	I	II	III	IV	V	VI	VII	VIII	IX	X
lnPop	0.4986*** (0.167)	0.4480*** (0.155)	0.2872** (0.114)	0.4443*** (0.126)	0.5053*** (0.171)	0.3210** (0.122)	0.5212*** (0.124)	0.4312** (0.196)	0.2440* (0.136)	0.4094*** (0.145)
lnGDPpc	0.3334** (0.148)	0.3335** (0.143)	0.3707*** (0.104)	0.1976 (0.132)	0.3593 (0.218)	0.3689* (0.196)	0.3426* (0.185)	0.3891** (0.178)	0.4321*** (0.124)	0.2273 (0.149)
lnEC	-0.3743** (0.137)	-0.3970*** (0.127)	-0.3739*** (0.114)	-0.3726*** (0.121)	-0.3738** (0.137)	-0.3529*** (0.122)	-0.3612** (0.131)	-0.3788** (0.140)	-0.3559*** (0.124)	-0.3644*** (0.129)
lnTO		0.1518** (0.071)	0.1239** (0.056)	0.0515 (0.052)						
lnEVI					-0.0124 (0.082)	0.0012 (0.073)	-0.0800 (0.061)			
lnTFI								-0.0423 (0.054)	-0.0407 (0.063)	-0.0314 (0.060)
lnKI			0.1785** (0.067)	0.1788*** (0.057)		0.1885** (0.073)	0.1749*** (0.060)		0.1923** (0.074)	0.1812*** (0.060)

lnFDI			0.0187	0.0058		0.0226	0.0082		0.0279	0.0098
			(0.018)	(0.017)		(0.018)	(0.017)		(0.018)	(0.017)
lnFindev				0.1226**			0.1422***			0.1336**
				(0.047)			(0.043)			(0.049)
lnInflation				0.0101			0.0168			0.0090
				(0.009)			(0.011)			(0.010)
F-statistic	40.2675	34.8267	38.9753	70.7749	31.2344	32.5840	50.3525	27.1450	28.7494	49.0586
r-squared	0.6245	0.6368	0.6640	0.6871	0.6246	0.6560	0.6904	0.6236	0.6611	0.6828
Observations	504	504	503	490	504	503	490	488	488	478

Note:
Robust standard errors in parentheses.
*, **, *** denote the statistical significance at 10%, 5%, 1% confidence level, respectively.

The finding for population factor is consistent with results from York *et al.* (2003) and Hossain (2011) but is contrary to what was found in Sharma (2011) Munir and Ameer (2018) and Saidi and Mbarek (2017). The finding for income factor is in line with Cole and Neumayer (2004) but not with Rahman (2017). Finally, the technology factor's finding is the same as Dogan and Seker (2016). However, this research, together with all those studies, have proved the validity of the IPAT framework in terms of the importance of three aspects: population, affluence, and technology in determining environmental impact. This also suggests the different panels causing varied effects. The negative emissions sensitivity towards changes in urban population and per capita income in the Asia-Pacific region implies that the economies in the sample still have yet to reach a threshold where the two determinants can benefit the environmental quality.

In respect of trade openness impact, the outcomes in fixed effects models are rather consistent in signs within specifications of each proxy but inconclusive between them. Trade openness seems to contribute to the CO_2 emissions and inflict more harm to the environmental quality in the long term, but only by using the commonly used trade share as a proxy. Fixed effects estimates are quite similar to the Random effect ones. For the conventional measure of trade as ratio of GDP, trade openness is positively correlated with emissions which implies the *race-to-the-bottom* environmental effects of increased openness to trade in Asia-Pacific economies in the sample. It should be noted that the coefficients become smaller in magnitude (from 0.15% down to 0.05%) and lose significance in specification IV when all determinants are added. The finding for this outcome measure is not as expected to be the same as Gozgor (2017) or Dogan and Seker (2016) but confirms the results reported by Zineb (2016), Ahmed *et al.* (2016), Bernard and Mandal (2016), and Munir and Ameer (2018). When replaced by the policy measures of Export Value Index or Trade Freedom Index for robustness purpose, the coefficients are consistently negative yet modest (ceteris paribus, a 1% rise in the EVI leads to 0.001%-0.08% reduction in emissions, while a 1% rise in the TFI results in a decline of 0.04% in emissions) and insignificant except for specification VII of Export Value Index (significant at 1% level). Nonetheless, all become insignificant when it comes to the Fixed effects model adjusted for heteroskedasticity. The result for exports measure is opposite to Rock (1996), Atici (2012), Le *et al.* (2016) and Rahman (2017). Meanwhile, the trade policy measure finding is in line with a study of Rock (1996) using a simple dummy variable for trade policy except that his research proved the significance.

It should be underlined that using different proxies for trade openness does render varied results in assessing whether trade openness is a cause or solution to CO_2 emissions. On one hand, the positive and considerably significant interaction between trade intensity measure and pollution is basically consistent with the arguments from ecological economics' approach of the nexus. Enhanced trade volumes are inevitably accompanied by environmental deterioration due to greater consumption, production, and transportation. In other words, there is supporting evidence for the trade-offs between promoting trade openness or global efficiency and environmental quality. The worsening independent effect of trade share on emission levels in the region, though, is not as strong as that of population size or income per capita and may be spurious, which may explain the insignificance of the variable eventually. On the other hand, the use of export values or policy measure suggests the *gains-from-trade* hypothesis and disconfirms the *export-based* carbon pollution but fails to be statistically significant. It implies that stimulating trade openness via export promotion or further lowering NTBs in the country sample does not necessarily coincide with increased CO_2 emissions and harm the environmental quality. Furthermore, the underlying reason could be that reducing trade restrictions do not homogeneously alleviate pollution levels which may require the further consideration of panel disaggregation in the analysis (Jobert *et al.*, 2015) .

In columns III, VI, and IX, capital intensity and FDI inflows are additionally looked at as control variables. Hence, two variables, the share of fixed capital consumption to GNI and FDI inflows as a percentage of GDP, are entered into the panel regressions. As expected, capital abundance is found to have a positive and significant impact on carbon dioxide emissions at 1% level. All other explanatory variables held constant, 0.17%-0.19% is the range of increase in emissions level in response to 1% increase in the proportion of consumption of fixed capital. This outcome is supported by Jung (2016) and different from Pascalau and Qirjo (2017). It provides evidence for the *factor endowment* hypothesis stating that capital-abundant economies tend to experience economic structure shift towards carbon-intensive sectors, with an assumption that more capital-intensive industries have higher propensity to pollute (Cole and Elliott, 2003). When it comes to the specifications with all variables added, even in the robust fixed-effects model, the degree of consumed capital maintains its significance in polluting effect for the analysed Asia-Pacific economies. Moreover, the positive relation remains unchanged irrespective of the estimation technique used.

Regarding the dependence CO_2 emissions on the inward FDI flows, the coefficients show the converse to the expectations. In specifications III, VI, and IX which add FDI variable for the first time, FDI is positively linked to the emissions at conventional statistical significances. On average, for every 1% rise in FDI net inflows, per capita CO_2 emissions increase by 0.02%, all other variables being equal. However, the significance of the relationship fails to be found in all-variable regressions and the sizes of impact also decline. Completely contradicting what OLS estimates produce, Table 4.4 shows that FDI level alone exerts no long-term relation to CO_2 emissions in the region. Thus, neither *pollution haven* nor *pollution halo* hypothesis, which proposes the aggravating or alleviating emissions effect of FDI volumes, can be validated. This study shares the same results as Lee (2013), Jobert *et al.* (2015) and Bernard and Mandal (2016).

Finally, I take the determinants of financial development and inflation into account by incorporating corresponding variables in columns IV, VII, and X.

The consistent results in Tables 4.2-4.4 indicate that financial deepening tends to exacerbate environmental pollution and plays a significant role in determining CO_2 emissions level in the region. As can be seen from Table 4.4, with a moderate significant level, a 1% increase in the share of domestic credit to private sectors brings about 0.12, 0.13, and 0.14% increase in CO_2 emissions, respectively, for the model employing trade share, freedom index, and export index. This implies that private sectors' financed investments and projects in the region have not been in favour of environmental quality, which contradicts what were found by Tamazian and Rao (2010), Dogan and Seker (2016), and Saidi and Mbarek (2017) yet is comparable to the results of Al-Mulali *et al.* (2015). Through the regressions, it can be concluded that inflation is not a source of environmental deterioration in the region, which is not as expected. Table 4.4 demonstrates that inflation rate has a detrimental yet no statistically significant influence on per capita CO_2 level. This outcome is in line with Bernard and Mandal (2016) ; however, Al-Mulali *et al.* (2015) proved the negative and significant relationship between these two variables.

CHAPTER 5. CONCLUSION

Acknowledging the prominence of the matter of sustainable trade nowadays and the significant economic outlook of the Asia-Pacific region, this research attempts to empirically assess the long-run direct linkage between trade openness and environmental quality for a selected group of 24 Asia-Pacific economies from 1995 to 2016. With a view to providing a more comprehensive impact of trade openness, three different measures reflecting both outcomes and policy terms are incorporated in the empirical models. Besides measuring independent effect of trade openness, this present study takes other potential determinants of CO_2 emissions into consideration, namely urban population, per capita income, renewable energy consumption, capital intensity, inward FDI, financial development, and inflation rate.

This paper utilizes the extended STIRPAT model with trade openness for the Asia-Pacific panel. Employing panel dataset requires this paper to use three conventional estimation techniques: Pooled OLS, Fixed Effects, and Random Effects. Data attainment is mostly based on the World Bank's World Development Indicators, apart from that of Trade Freedom Index is drawn from The Heritage Foundation database. Furthermore, potential heteroskedasticity issue is solved for the most preferred model. Consequently, the Fixed Effects model corrected for heteroskedasticity reveals the most robust outcomes. As the estimated model is in log-log functional form, the results can be interpreted in terms of elasticity.

The most important finding in this research is that trade openness exerts inconclusive effect on carbon dioxide emissions. Specifically, while trade share measure exhibits significant yet inconsistent polluting impact, Export value index and Trade Freedom Index shows no correlation with pollution. It seems that trade openness *per se* does not necessarily matter in determining carbon dioxide emissions. With regards to other determinants, while the benchmark factors (Population, Affluence, Technology) produce expected results which validates the IPAT framework, only capital intensity and financial development are vital determinants, despite yielding results not as expected, of CO_2 among the control variables.

Finally, this study is able to fill a gap in the analysis of trade openness and carbon dioxide emissions for the Asia-Pacific country panel. Moreover, this paper is also the first one of its kind to use Trade Freedom Index provided by The Heritage Foundation database to examine the relationship from the perspective of openness policy. However, as suggested from the literature, the environmental effect of trade openness may also vary across countries and pollutant types or the short-term effect may differ from long-terms one, the failure to address those features in the analysis more or less affects the reliability of the findings.

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Appendices

Appendix 1

List of countries in the sample

No.	Country
1.	Australia (AUS)
2.	Azerbaijan (AZE)
3.	Bangladesh (BGD)
4.	Cambodia (KHM)
5.	China (CHN)
6.	Fiji (FJI)
7.	India (IND)
8.	Indonesia (IDN)
9.	Japan (JPN)
10.	Kazakhstan (KAZ)
11.	Republic of Korea (KOR)
12.	Kyrgyz Republic (KGZ)
13.	Lao PDR (LAO)
14.	Malaysia (MYS)
15.	Mongolia (MNG)
16.	Nepal (NPL)
17.	New Zealand (NZL)
18.	Pakistan (PAK)
19.	Philippines (PHL)
20.	Singapore (SGP)
21.	Sri Lanka (LKA)
22.	Tajikistan (TJK)
23.	Thailand (THA)
24.	Vietnam (VNM)

Appendix 2

Summary Statistics of the original dataset

Variables	Observations	Mean	Standard deviation	Minimum	Maximum
Dependent variables					
Carbon dioxide emissions	528	4.204791	4.674628	.0717994	18.20018
Independent variables					
Urban population	528	5.94e+07	1.31e+08	352821	7.83e+08
Real GDP per capita	528	9615.57	15006.61	341.9742	55731.5
Renewable energy consumption	504	33.26381	26.80823	.3251189	91.7324
Trade share	528	92.34851	70.74528	16.67948	441.6038
Trade Freedom Index	511	67.79315	14.47662	13.2	90
Export Value Index	528	247.1623	273.9572	34.67049	1976.785
Fixed capital consumption	528	12.24105	5.058353	1.79071	25.59872
FDI inflows	527	4.459574	6.670327	-37.16565	55.0759
Domestic credit	513	57.76362	45.03073	1.166045	190.9018
Inflation rate	528	10.26089	35.57	-18.92973	545.6953

Appendix 3

Breusch-Pagan Lagrange multiplier and Hausman test outcomes for three trade openness measures on CO_2 emissions

```
. quietly xtreg lnCO2mtpc lnGDPpc lnPop lnEC lnTO, re

.
. est sto co2re2

.
. xttest0

Breusch and Pagan Lagrangian multiplier test for random effects

        lnCO2mtpc[Country,t] = Xb + u[Country] + e[Country,t]

        Estimated results:
                        |       Var     sd = sqrt(Var)
                ---------+-----------------------------
               lnCO2mtpc |   2.071382       1.43923
                       e |   .0256979      .1603058
                       u |   .3356247      .5793313

        Test:   Var(u) = 0
                             chibar2(01) =  4138.07
                          Prob > chibar2 =   0.0000

. quietly xtreg lnCO2mtpc lnGDPpc lnPop lnEC lnTO, fe

.
. est sto co2fe2
. quietly xtreg lnCO2mtpc lnGDPpc lnPop lnEC lnTO, re

.
. est sto co2re2
. hausman co2fe2 co2re2

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     co2fe2       co2re2        Difference          S.E.
-------------+----------------------------------------------------------------
     lnGDPpc |    .3334789     .4118965       -.0784176        .0236191
       lnPop |    .4479536     .2714304        .1765232        .0561347
        lnEC |   -.3969946    -.4292173        .0322227        .0184117
        lnTO |    .1517559     .1690307       -.0172748        .0086181
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       11.75
                Prob>chi2 =      0.0193
```

```
. quietly xtreg lnCO2mtpc lnGDPpc lnPop lnEC lnEVI, re

.
. est sto co2re5

.
. xttest0

Breusch and Pagan Lagrangian multiplier test for random effects

        lnCO2mtpc[Country,t] = Xb + u[Country] + e[Country,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
               lnCO2mtpc |   2.071382       1.43923
                       e |   .0265571      .1629635
                       u |   .2529714      .5029626

        Test:   Var(u) = 0
                             chibar2(01) =  3851.09
                          Prob > chibar2 =   0.0000


. quietly xtreg lnCO2mtpc lnGDPpc lnPop lnEC lnEVI, fe

.
. est sto co2fe5

. quietly xtreg lnCO2mtpc lnGDPpc lnPop lnEC lnEVI, re

.
. est sto co2re5
. hausman co2fe5 co2re5

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     co2fe5       co2re5        Difference          S.E.
-------------+----------------------------------------------------------------
     lnGDPpc |    .3593147      .458128       -.0988133        .0517061
       lnPop |    .5052766     .2543914        .2508852        .0600204
        lnEC |   -.3737776    -.4193927        .0456151        .0183014
       lnEVI |    -.012402    -.0076522       -.0047498        .0195341
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       18.08
                Prob>chi2 =      0.0012
                (V_b-V_B is not positive definite)
```

```
. quietly xtreg lnCO2mtpc lnGDPpc lnPop lnEC lnTFI, re

.
. est sto co2re8

.
. xttest0

Breusch and Pagan Lagrangian multiplier test for random effects

        lnCO2mtpc[Country,t] = Xb + u[Country] + e[Country,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
               lnCO2mtpc |   2.025672       1.423261
                       e |   .0258322       .1607239
                       u |   .3285072       .5731555

        Test:   Var(u) = 0
                             chibar2(01) =  3839.45
                          Prob > chibar2 =   0.0000

. quietly xtreg lnCO2mtpc lnGDPpc lnPop lnEC lnTFI, fe

.
. est sto co2fe8
. quietly xtreg lnCO2mtpc lnGDPpc lnPop lnEC lnTFI, re

.
. est sto co2re8
. hausman co2fe8 co2re8

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     co2fe8       co2re8        Difference          S.E.
-------------+----------------------------------------------------------------
     lnGDPpc |    .3891461     .4737263       -.0845802        .0273698
       lnPop |    .4312051     .2377327        .1934725        .0608982
        lnEC |   -.3787897    -.4090178         .030228        .0190284
       lnTFI |   -.0423328    -.0349731       -.0073597        .0097944
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       10.34
                Prob>chi2 =      0.0351
                (V_b-V_B is not positive definite)
```