ECONOMIC GROWTH, FOREIGN DIRECT INVESTMENT, ENVIRONMENT AND ENERGY CONSUMPTION: EVIDENCE FROM VIETNAM

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ECONOMIC GROWTH, FOREIGN DIRECT INVESTMENT, ENVIRONMENT AND ENERGY CONSUMPTION: EVIDENCE FROM VIETNAM

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A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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ABSTRACT

The Renovation (Doi Moi) reform launched in 1986 has dramatically transformed Vietnam's war-torn economy to be one of the fastest growing economies in Asia with the growth rate of gross domestic product (GDP) averaging 6.3 per cent per annum over the 2005-2018 periods. This impressive economic performance was largely attributable to the opening up of the economy to foreign markets and investors. Foreign direct investment (FDI), and foreign trade, particularly exports, are considered to be the key driving forces of economic growth in Vietnam over the past few decades. However, rapid export-driven economic growth enhanced by large investment inflows from abroad has come at a cost. The level of environmental pollution in Vietnam has increased significantly as a result of high energy consumption and economic growth over the past decades.

In this thesis, we firstly investigate the so-called pollution haven hypothesis (PHH); we then examine the income-pollution nexus for industrial pollution emissions at the provincial level in Vietnam as well as examine the impact of all economic sectors on waste emissions; and finally, we observe the nexus between energy consumption and economic growth at national and city level in Vietnam. This thesis is organized into six chapters.

Chapter 1 provides a research background by conducting a literature review. Besides, we present the structure of the thesis, and the research objectives.

In the following chapter, we carefully evaluate the body of work on the current circumstance of Vietnamese economy, FDI, environment, and energy consumption. At the same time, it reviews the extant literature, discusses central findings and states the research questions of this thesis.

Chapter 3 examines the relationship among FDI, economic growth, and carbon dioxide (CO_2) emissions in Vietnam during the period 1988-2015 by applying the autoregressive distributed lag (ARDL) approach. We find that in the long-run, the causality relationship is found among variables; GDP has a significantly positive impact on CO_2 emission while FDI has a slightly negative effect. However, in the short-run, the causality relationship cannot be found for all variables. The results reveal that the pollution haven hypothesis does not exist in Vietnam since FDI is good for the environment in the long-run.

In Chapter 4, we investigate the relationship between economic growth and industrial waste emissions in Vietnam by using panel data for 63 provinces in Vietnam between 2000 and 2013. Also, we separate the impact of the state economic sector, non-state economic

sector and foreign investment economic sector on waste emissions including gaseous, solid waste and liquid waste. By applying two-way fixed effects and random effects error component models, the results reveal that economic development will induce more industrial pollution emissions, that is, the net effect of economic growth on environment quality is negative. Notably, the increase in income induces more liquid waste than gaseous and solid waste due to a large amount of wastewater discharged from industrial zones, and manufacturing establishments without proper treatment as well as the subsectors significantly contributed to water pollution. In respect to the impact of economic sectors on waste emissions, the results suggest that state economic sector tended to have relatively more high waste emissions in all kind of wastes, and foreign investment economic sector also had relatively high waste emissions in gaseous and liquid waste; whereas the outcome for non-state sector is insignificant in all kind of wastes.

The last empirical analysis is in Chapter 5. Here, we examine the direction of causality and sign (in the panel sense) between energy consumption including coal, oil, and electricity and GDP for total of 63 provinces in Vietnam between 2000 and 2013. The results from our empirical tests show that there is a long-run equilibrium relationship among the variables, and the majority of energy consumption variables have a positive sign, indicating that an increase in GDP would lead to greater use of energy. When turning to the city-specific coefficients, the relationship between energy consumption and GDP across provinces is positive and statistically significant; but it changes slightly among cities due to the geographic location, population, and natural resources. This research results suggest that energy consumption is not a limiting factor for Vietnam's economic growth, and it implies that the rise in energy prices can be a good opportunity for the economy to promote substitution and technological innovation.

From the Granger causality test, there is a short-run unidirectional causal relationship running from GDP to energy consumption. This implies that in the short-run, economic growth leads to energy consumption in Vietnam, and energy is only one of the essential inputs to production in Vietnam, supporting the conservation hypothesis.

Finally, Chapter 6 offers an integrated summary, the contribution of the thesis, and lays out the agenda for future work.

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ABBREVIATION

ADF	Augmented Dickey Fuller
AIC	Akaike's Information Criteria
ARDL	Autoregressive Distributed Lag
BOD	Biochemical Oxygen Demand
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CIEM	Central Institute for Economic Management
DF	Dickey Fuller
DOLS	Dynamic Ordinary Least Square
EC	Energy Consumption
ECT	Error-Correction Term
EKC	Environmental Kuznets Curve
FDI	Foreign Direct Investment
FMOLS	Fully Modified Ordinary Least Square
FGLS	Feasible Generalised Least Square
FTAs	Free Trade Agreements
GSO	General Statistic Office
GLS	Generalized Least Square
IPS	Im-Pesaran-Shin
kTOE	thousand Tons of Oil Equivalent
LLC	Levin-Lin-Chu test
LM	Lagrange Multiplier
MONRE	Ministry of Natural Resource and Environment
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
NAFTA	North American Free Trade Agreement

OLS	Ordinary Least Square
OECD	Organization for Economic Co-operation and Development
PHH	Pollution Haven Hypothesis
SIC	Schwarz Information Criterion
SO_2	Sulfur Dioxide
SPM	Suspended Particulate Matter
USD	United States Dollar
VND	Vietnam Dong
VECM	Vector Error Correction Model
WTO	World Trade Organization

CHAPTER 1
OVERVIEW AND RESEARCH QUESTIONS

1.1. Introduction and structure of thesis

The thesis empirically investigates the relationship between economic growth and environment in Vietnam in general, and at city level; besides, it also examines the direction of causality between the GDP and energy consumption (EC) for total of 63 provinces. Although the thesis comprises of three essays relating to economic growth, environment, and energy consumption in Vietnam; each essay focuses on a different aspect of the topic. Chapter 2 carefully evaluates the body of work on the current circumstance of Vietnamese economy, FDI, environment, and energy consumption. Also, it reviews the extant literature, discusses central findings and the objectives of this thesis. Chapter 3 (the first essay) examines the relationship between FDI, economic growth, and CO_2 emissions in Vietnam during the period 1988 – 2015 by applying the autoregressive distributed lag (ARDL) approach. Chapter 4 (the second essay) takes a micro – institutional perspective and investigates the relationship between economic growth and industrial pollution emissions in Vietnam by using panel data for 63 provinces in Vietnam between 2000 and 2013. Chapter 5 (the third essay) pursues the study of the direction of causality and sign (in the panel sense) between EC including coal, oil, and electricity and the GDP for total of 63 provinces in Vietnam. Finally, Chapter 6 offers an integrated summary, the contribution of thesis, and lays out the agenda for future work.

1.2. Economic growth, FDI, environment, and energy consumption

The Renovation (Doi Moi) reform launched in 1986 dramatically transformed Vietnam's war –torn economy. Notably, the country has been successful in curbing an inflation crisis by lowering the rate from 774 per cent in 1986 to 67.5 per cent in 1990 and 4.1 per cent in 2014 according to General Statistic Office of Vietnam, 2015. At the same time, Vietnam has experienced remarkable economic growth, is one of the fastest growing economies in Asia with the growth rate of GDP averaging 6.2 per cent per annum over the 2005-2014 periods (World Bank 2015). This impressive economic performance was largely attributable to the opening up of the economy to foreign markets and investors. FDI, and foreign trade, particularly exports, are considered to be the key driving forces of economic growth in Vietnam over the past few decades. Rapid export driven economic growth enhanced by large investment inflows from abroad has come at a cost. According to Ministry of Natural Resource and Environment (MONRE) report in 2015, the level of environmental pollution in

Vietnam has increased significantly as a result of high energy consumption and economic growth over the past decades. According to Vietnam development report in 2011, the level of emissions per capita in Vietnam remained at about two metric tons of CO_2, ranking 111^{th} in the world, and it is expected to rise dramatically in the coming time. The high CO_2 emissions into the environment recorded on average an increase of approximately 15 per cent annum for the past decades resulting in the acceleration and increase in the production of CO_2 in the country. The major sources include fuel combustion by industry and the power sector, transport domestic and commercial emissions from using coal and biomass.

Likewise, water pollution in river basins such as Cau, Nhue-Day and Dong Nai has reached an alarming level due to the discharge of non-treated or inappropriately treated wastewater from industrial cluster/zones, manufacturing establishments, households, urban services, and mining activities from the riverhead, which contaminates the surface water. The important feature is that these socio-economic activities contribute the most to the growth in industrial zones, economic restructuring, labor restructuring and job creation, factors that drive the national growth. Meanwhile, soil erosion and natural disasters such as floods and droughts are mainly caused by the processing industries using wood materials, power and gas generation. Also, the need to improve agricultural productivity and output requires increasing use of pesticides, fertilizers and growth stimulators. When it comes to solid waste, Vietnam was named among the five countries that dump more plastic into the oceans than the rest of the world combined[1]. Around 28 million tons of solid waste is discharged nationwide each year, and it is estimated that approximately 46 per cent of them is discharged in urban areas, 30 per cent is industrial discharged, and the rest is from agriculture, trade villages and the health sector. In light of these, the rapid increase of CO_2, water pollution, and solid waste is mainly due to the results of human activities due to development and industrialization. The MONRE of Vietnam estimated that pollution costs about 1.5 to 3 per cent of Vietnam's GDP each year.

The rapid economic development together with the urbanization process, industrialization, and population growth has promoted the increasing energy demand for industries,

[1] Vietnam VnExpress: Trash talk: Vietnam slowly sinking under the mountains of waste. https://e.vnexpress.net/projects/vietnam-slowly-sinking-under-mountains-of-waste-3633166/index.html

transportation, and domestic activities. It is estimated that the energy use comparative to GDP growth in Vietnam is twice bigger than that of developed countries. Energy demand tripled over the last decade, and it is likely to triple again over the next decade if economic growth remains robust[1]. In consequence, Vietnam will have to rely increasingly on imported energy, including coal and oil.

The relationship between pollution, energy consumption, and economic growth can be separated into three research clusters in literature. The first research cluster is focused on the relationship between various indicators of environmental degradation and economic growth to examine the validity of the Environmental Kuznets Curve (EKC). Grossman and Krueger (1991) initially developed the EKC which indicates that when a country's income level increases, environmental degradation of the country increases at the first stage of development, then after a certain point it starts to decline.

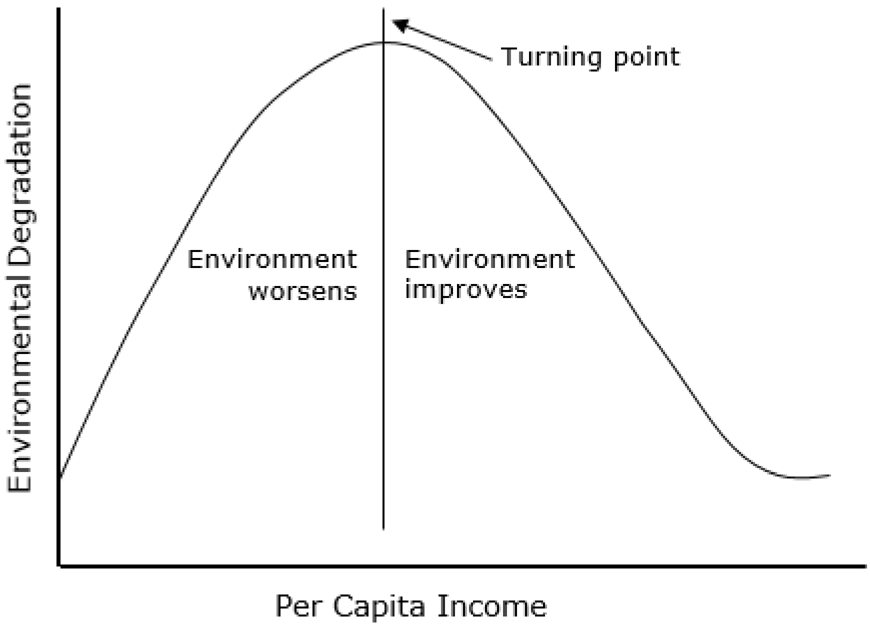


Figure 1.1 Environmental Kuznets curve

The second research cluster investigates the energy-growth nexus, while the third research cluster attempts to analyze the dynamic relationship between pollution indicators, energy consumption, and economic growth. The existing literature on the nexus between energy consumption and economic growth are categorized into four competing useful hypotheses: growth hypothesis, conservation hypothesis, feedback hypothesis, and neutrality hypothesis (Ozturk 2010 and Payne 2010).

[1]Ministry of Industry and Trade: Vietnam energy outlook report 2017.

Growth hypothesis, which suggests that energy consumption, causes economic growth as a complement to other inputs in the production function. Such hypothesis is confirmed by the existence of a unidirectional causality from energy consumption to real GDP. Whereas conservation hypothesis, which testifies that waste policies on energy consumption have not any effect on economic growth. It may be due to little share of energy in the production function. Conservation hypothesis is found when there is unidirectional causality from real GDP to energy consumption.

Feedback hypothesis asserts that energy consumption and economic growth are interdependent. Bidirectional causality between energy consumption and real GDP show such behavior. The impact of energy consumption on economic growth may be more complex with feedback hypothesis. In contrast, neutrality hypothesis proposes that energy consumption and economic growth are independent. Perhaps, energy sector policies have more flexibility when this hypothesis is accepted.

Therefore, in the case of Vietnam, one of the fastest growing economies in Asia thanks to the driving force of FDI inflows, it is very worthy to consider the benefit of FDI to environmental quality, and the existence of EKC as well as the energy-growth nexus.

1.3. Research objectives

Like other emerging economies, Vietnam has experienced rapid economic development due to the opening of the economy to foreign investment as well as the increasing demand for energy consumption; however, besides the gained marvelous achievements in socio-economic developments, Vietnam also has to pay a dear price and face a series of environmental challenges. Therefore, this thesis aims to provide the evidence of economic-growth nexus with the role of FDI and economic growth-energy nexus. To achieve this aim, it is necessary to do the following objectives.

Research objective 1: to determine the impact of economic growth and FDI on CO_2 in Vietnam since the time of renovation to date.

Research objective 2: to evaluate the relationship between economic growth and industrial pollution emissions at the city level in Vietnam.

Research objective 3: to identify the direction of causality between per capita GDP, and energy consumption (including oil, diesel and electricity) in the short and long run.

CHAPTER 2

ECONOMIC GROWTH, FDI, ENVIRONMENT, ENERGY CONUSMPTION IN VIETNAM AND RESEARCH QUESTIONS

2.1 Economic growth and FDI activities

Vietnam was transformed from a poor country with more than 70 per cent of living in hunger and poverty, to a middle income country with GDP per capita of United States Dollar (USD) 2520 in 2015. It has also integrated into the global economy by becoming an active member of international organizations; by the end of 2015 Vietnam has joined 12 bilateral and multilateral free trade agreements (FTAs). Vietnam saw a tremendous increase in GDP growth between the years 1992-1996, averaging at 8.85 per cent before dropping in the 1996-2000 periods due to the Asian financial crisis. The economy recovered after the crisis and economic fluctuated in the 2001-2006 period, reaching a peak of 7.1 per cent in 2007 when Vietnam officially becomes a member of the World Trade Organization (WTO) before slowing down due to the impact of the global financial and economic downturn.

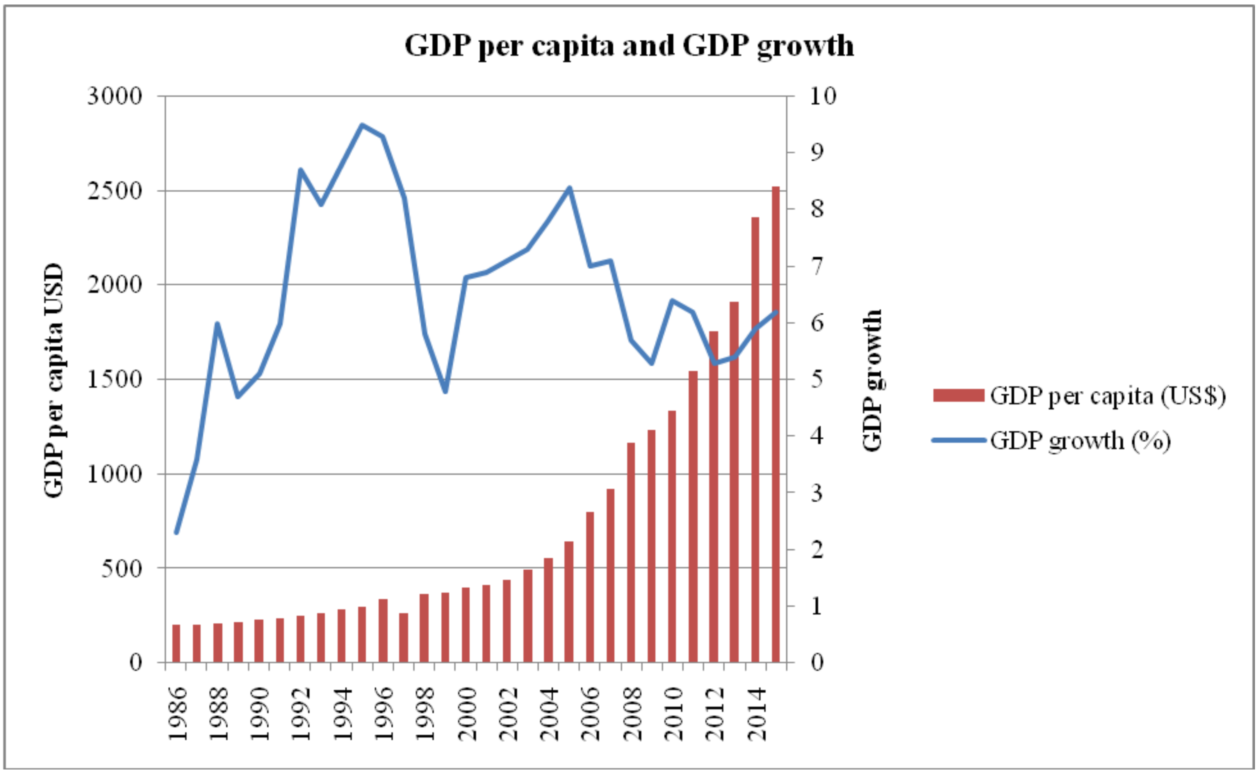


Figure 2.1 GDP per capita and GDP growth during 1986-2015

Source: GSO Vietnam, 2015

After 30 years of opening the economy to attract foreign investment, the inflow of FDI capital to Vietnam has been constantly increasing. Implemented FDI capital reached USD 11 billion in 2010, USD 14.5 billion in 2015 and USD 15.8 billion in 2016, respectively. As of the 2017 year end, Vietnam attracted over 25,000 FDI projects with a total registered capital of over USD 333 billion. So far, 129 countries and territories have invested in Vietnam. FDI projects have been present in 63/63 provinces and cities in 19/21 industries in Vietnam. There have been 129 countries and territories with valid investment projects in Vietnam, of which South Korea takes the lead with a total registered capital of USD 61.51 billion (18.5 per cent of the total investment). Japan ranks second with USD 55.86 billion (16.8 per cent of the total investment), followed by Singapore, Taiwan, British Virgin Islands, and Hong Kong.

Table 2.1 FDI inflows during 1991-2015

Unit: millions USD

Year	Projects	Registered capital	Implemented capital
1991	152	1284.4	428.5
1992	196	2077.6	574.9
1993	274	2829.8	1117.5
1994	372	4262.1	2240.6
1995	415	7925.2	2792
1996	372	9635.3	2938.2
1997	349	5955.6	3277.1
1998	285	4873.4	2372.4
1999	327	2282.5	2528.3
2000	391	2762.8	2398.7
2001	555	3265.7	2225.6
2002	808	2993.4	2884.7
2003	791	3172.7	2723.3
2004	811	4534.3	2708.4
2005	970	684	3300.5
2006	987	12004.5	4100.4
2007	1544	21348.8	8034.1
2008	1171	71726.8	11500.2
2009	1208	23107.5	10000.5
2010	1237	19886.8	11000.3
2011	1186	15598.1	11000.1
2012	1287	16348	10046.6
2013	153	22352.2	115
2014	1843	21921.7	125
2015	212	24115	145
Total	17896	306948.2	100577.9

Source: GSO Vietnam, 2015

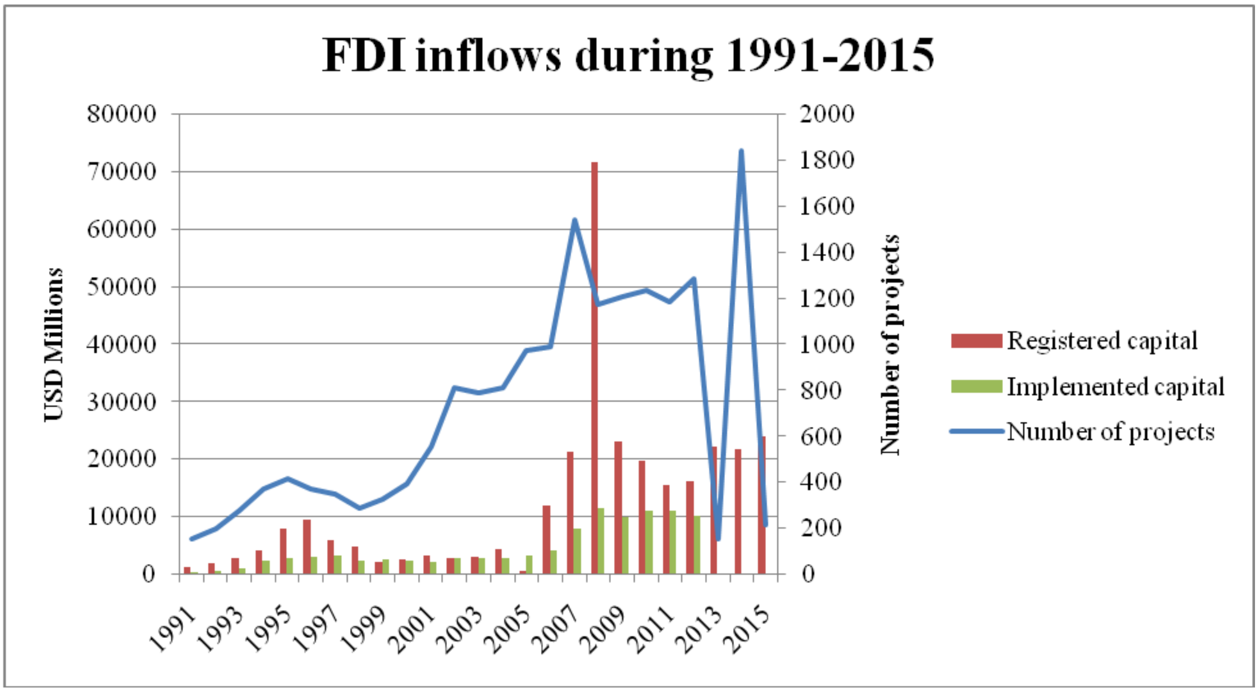


Figure 2.2 FDI inflows during 1991-2015

Source: GSO Vietnam, 2015

Foreign-invested enterprises have made remarkable contributions to the socio-economic development in Vietnam. State budget revenue from the FDI sector has increased steadily. This sector contributed over Vietnam Dong (VND) 83 trillion to the state budget in 2012, over VND 111 trillion in 2013, over VND 123 trillion in 2014, over VND 140 in 2015, and VND 161 trillion in 2016 which doubled that of 2012 (excluding revenue from crude-oil). Currently, FDI accounts for 72 per cent of total export value, about 25 per cent of total capital on social development and 20 per cent of the nationwide GDP.

In 2005-2014, FDI enterprises contributed around 15.1-16.4 per cent to GDP of Vietnam (in 2014, GDP gained around USD 180 billion at current price) and 38 per cent to economic growth (particularly in 2005-2014, GDP growth rate of the whole economy gained around 6.05 per cent, in which FDI enterprises contributed 2.3 per cent percent points to the growth). While FDI enterprises contributed around 23 per cent to social investment, such contribution of FDI enterprises to the growth of the national economy was remarkable. In 10 years, FDI enterprises only increased their contribution rate to the total size of Vietnam economy by 1.2 percent points (on average 0.12 per cent/year). This figure was modest compared with the expected objective. Although FDI enterprises contributed relatively high to Vietnam economy, they have the right to transfer part of the created value (in foreign currency) to their country.

Table 2.2 Contribution rate of FDI enterprises to Vietnam economic growth in 2005-2014

	2005	2014	Value added in 2005-2014
National GDP, price 2010 (billion VND)	1,588.646	2,695.796	1,107.105
FDI sector, price 2010 (billion VND)	24.814	442.441	422.895
Percentage over the total, per cent	-	-	38.19

Source: GSO Vietnam, 2015

In 2014, although FDI enterprises created an inconsiderable number of jobs, only around 3.45 million jobs and accounted for 6.4 per cent of total labors working in economic industries, they contributed around 1/6 national GDP. This contribution is small, but it is very important.

The contribution to total state budget revenue for Vietnamese government had decreased in 2005-2014 (from the rate 33.3 per cent in 2006 to 14 per cent in 2014). FDI enterprises accounted for 16.4 per cent GDP but only contributed 13.9 per cent to total state budget revenue. When it comes to the contribution to the increase in export value of Vietnam, it can be said that this was a remarkable point. FDI enterprises have played a more and more important role in the export and economic open policy in Vietnam. In 2005 FDI enterprises contributed around 57.2 per cent to Vietnam export value; in 2014 they contributed around 62.5 per cent. That means FDI enterprises played a decisive role in the possibility of national economic open and integration of economic globalization. However, they had to bring technology and import materials and rend services (especially foreign logistic transportation service), so the net export value was not high. Although it is surely that the net export value of export products produced by FDI enterprises cannot account for a high percentage in their total export value.

Table 2.3 Percentage of the contribution of FDI enterprises to Vietnam economy in 2005-2014

Unit: per cent

The percentage of contribution to	2005	2010	2014
Job solution	2.7	4.39	6.4
State budget revenue	8.4	11.0	13.9
Export value	57.2	54.2	62.5
Vietnam GDP	15.2	15.2	16.4

Source: GSO Vietnam, 2015

Because of lacking association between core FDI enterprises and domestic enterprises, the involvement of domestic enterprises to value chain is limited. Generally, some FDI enterprises in Vietnam participated in some global value chains such as automobile production, computer, phone, steel refining, visual-audio device production, electronic, etc but basically, those enterprises still depended on their mother enterprises over-sea and they were not indecisive position of the value chain. Thus, their influence on the world was limited.

2.2 Environmental quality in Vietnamese cities

According to a report of the Central Institute for Economic Management (CIEM) - Ministry of Planning and Investment - in 2017, a trend of FDI inflow with environmentally unfriendly consumption of energy natural resources and manpower such as ship repair, exploitation of natural resources without any connection with deep processing, pulp production, chemical production, agricultural products processing, etc. has been observed in Vietnam. Most of the investment projects in Vietnam are in raw production, simple processing, high consumption of power and resources, low technology, high emission, low added value industries and lack of foundation industries such as auxiliary and high-tech industries. Also, heavy industries have left the most significant impacts on the environment, resources, health, safety, and social order, and become “potential” industries causing environmental pollution, and degradation due to their huge amount of waste including wastewater, emissions, and solid waste, a high concentration of pollutants.

Environmental pollution caused by enterprises is mostly due to their outdated technology and equipment, their financial shortage for waste treatment technology and the limited awareness and capacity to prevent, control and protect the environment of enterprises themselves and even local agencies. Many issues have incurred related to environmental protection in works, projects, factories operating in the fields of industrial production such as steel production, paper and pulp production, food production, thermal power, etc with prime examples of environmental pollution incidents and disasters caused by big projects and facilities like Vedan Vietnam Enterprises Co., Ltd (Taiwan) in 2008, Miwon Vietnam Co., Ltd from 2008 to 2014, Formosa Ha Tinh Steel Corporation (Taiwan), Vietnam Lee & Man Paper Manufacturing Limited (Hau Giang province), etc.

In 2015, Vietnam was named among the five countries that dump more plastic into the oceans than the rest of the world combined. Solid waste produced in Vietnam is forecasted to increase by 10 per cent every year. Around 28 million tons of solid waste is discharged nationwide each year, and it is estimated that approximately 46 per cent of them is discharged in urban areas, 30 per cent is industrial discharged, and the rest is from agriculture, trade villages and the health sector. According to the survey of MNORE in 2011, industrial discharged is around 22,440 tons per day; it is around 8.1 million tons per year. Statistically, data reveals that industrial discharged is mainly in the South East and Red River Delta where the locations of the two key economic zones in Vietnam are, 34 per cent and 32 per cent, respectively. The following is North Central Coast and South Central Coast with 16 per cent and Mekong River Delta with 10 per cent. The least discharged regions are Northern midlands and mountain areas and Central Highlands, 6 per cent and 2 per cent, respectively.

Table 2.4 The industrial discharged in six economic zones in Vietnam in 2011

Unit: Tons

Order	Name of economic zones	Industrial discharged	The hazardous industrial discharged
1	Red River Delta	7,250	1,370
2	Northern Midlands and mountain areas	1,310	190
3	North Central Coast and South Central Coast	3,680	1,140
4	Central Highlands	460	65
5	South East	7,570	1,580
6	Mekong river delta	2,170	350

Source: MONRE, 2012

The industrial boom has been accompanied by increased water pollution, partly due to the absence of waste management and control. In 2016, Formosa Ha Tinh Steel Corporation (Taiwan) released large amounts of toxic chemical waste, killing fish along the stretch of coast, causing long term tourism in affected provinces by about 30 per cent. Large amount of wastewater discharged from industrial zones without proper treatment. Currently, of the more than 1 million m^3 of wastewater discharged daily, 70 per cent is discharged directly to the receivers without treatment, leading to widespread surface water pollution. Meanwhile, there remain shortcomings and problems in collecting, sorting and treating solid waste under the environment sanitary standards, especially in the management, transportation, and registration of discharge locations of hazardous waste.

The industrial pollutants concentrated in some regions and sectors. In table 2.5, Red River Delta and South East are the largest industrial output, therefore also the largest pollutant emission.

Table 2.5 National Industrial Output Value (NIOV) and emission by region

Share (per cent) of / **Region**	**NIOV**	**Emitted air pollutants**					**Discharged water pollutants**		
		SO_2	NO_2	CO	VOC	TSP	BOD	TSS	Hazardous chemicals
Red River Delta	26.84	10.65	24.59	28.97	24.96	25.96	13.75	19.47	22.95
Northern Mountains	3.62	2.90	6.53	7.95	3.83	6.27	6.58	5.84	3.85
Central Coasts	9.58	6.18	15.37	12.66	11.23	17.68	9.44	11.68	7.64
Central Highlands	0.87	2.11	1.38	2.04	2.11	1.65	1.9	2.54	1.55
South East	49.55	72.65	37.42	39.40	49.68	32.92	49.21	49.62	54.75
Mekong River Delta	9.54	5.52	14.71	8.98	8.18	15.52	22.16	13.48	12.01

Source: MONRE, 2012

2.3 Energy consumption in Vietnam

Vietnam is endowed with a variety of primary energy resources including coal and peat, oil, natural gas, hydro, and renewable energy and it has generally been an energy self-sufficient economy. The total energy production and consumption in Vietnam during the period of 2001-2011 in Figure 2.3. During this period, the average growth rate of total energy production and consumption were 4.3 per cent per year and 5.8 per cent per year, respectively

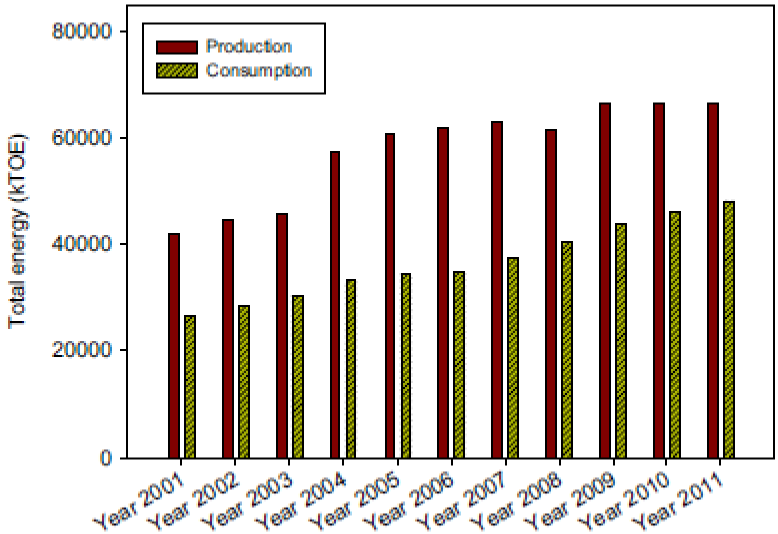


Figure 2.3 Total energy production and consumption in Vietnam during 2001-2011

Source: Vietnam Institute of Energy, 2014

The energy production by the source during the period of 2001-2011 is shown in Figure 2.4. Over this period, natural gas production grew at the highest rate and followed by coal and peat, 14.8 per cent and 10.7 per cent, respectively. The total energy consumption in 2011 was 51,313 kt of oil equivalent (kTOE) in which the largest consumer of energy was the industrial sector, contributing 35.4 per cent to the total energy consumption, followed by the residential (31.8 per cent), transport (21.5 per cent), commercial (3.7 per cent), and agriculture (1.3 per cent) sectors. The most notable here is the considerable growth in energy consumption in the industrial, residential, and transport sectors during this period. The significant increase in total energy consumption has been driven by three key factors: increasing industrialization, increasing household use of modern fuels, especially electricity, and the expansion of motorized transport. These three drivers are also expected to continue accounting for most of the increase in energy demand over the next decade.

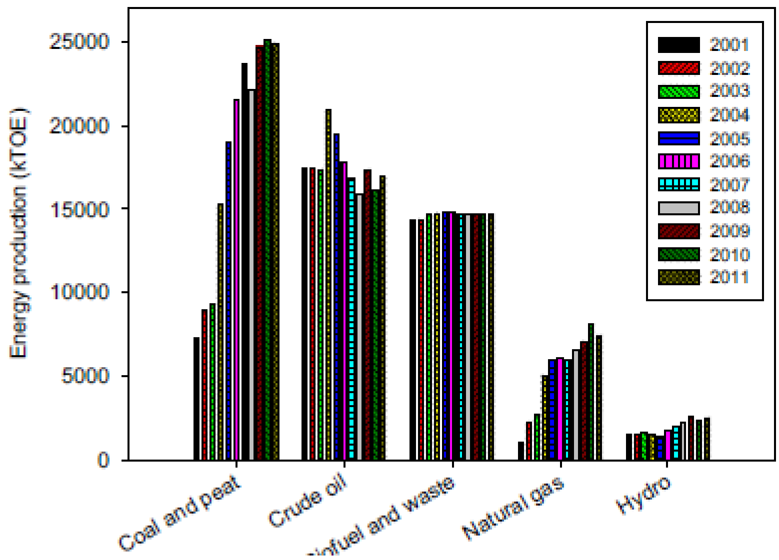


Figure 2.4 Energy production by the source during the period of 2001-2011

Source: Vietnam Institute of Energy, 2014

Industrial growth has been one key driver of Vietnam's increasing energy consumption. Industrial energy consumption grew from 8,536 kTOE in 2001 to 18,181 kTOE in 2011-almost 2.1 times in just 10 years. Between 2001 and 2011, the average growth rate of energy consumption by the industry sector was 7.2 per cent per year. Since the industry is the most energy-intensive main economic sector, the increasing industrialization of Vietnam's economy by itself contributes to the increase in Vietnam's overall energy consumption.

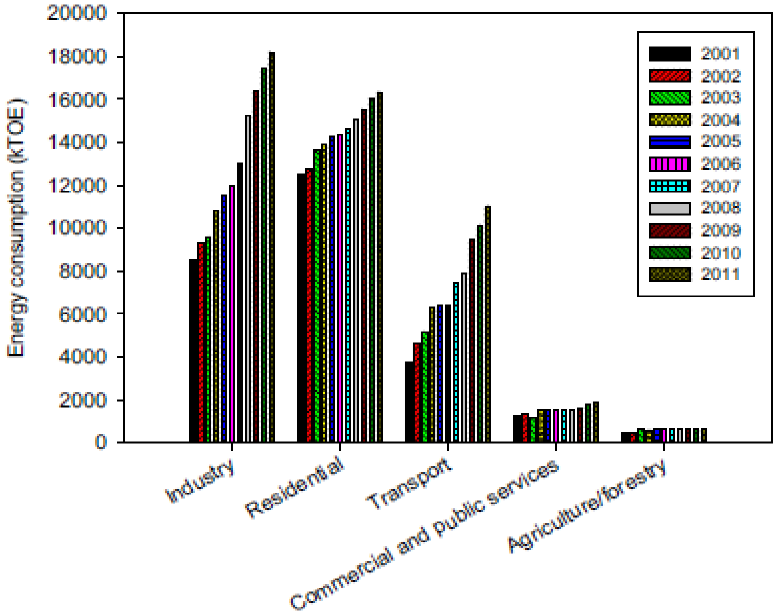


Figure 2.5 Energy consumption by sectors during 2001-2011

Source: Vietnam Institute of Energy, 2014

With the increasing energy demand and recent fluctuations in energy import and export, Vietnam has become a net energy importer since 2015. In 2015, the total primary energy supply of Vietnam was 70,588 kTOE, of which commercial energy accounted for 75.5 per cent and non-commercial energy accounted for 24.5 per cent. The share of noncommercial biomass energy in total primary energy supply decreased significantly from 44.2 per cent in 2000 to 16.9 per cent in 2015. In the whole period between 2001 and 2015, commercial primary energy supply grew by 9.5 per cent per year. This growth rate was higher than the GDP growth rate during the same period, leading to the elasticity coefficient of commercial energy to GDP, greater than 1. Among commercial energies, natural gas had the highest growth rate with 13.4 per cent per year. The growth rate of coal, oil products, and hydropower in the same period was of 12.2 per cent, 6.2 per cent and 27.6 per cent per year, respectively.

Table 2.6 Total primary energy supply during 2000-2015

Unit: kTOE

Energy	2000	2005	2010	2011	2012	2013	2014	2015
Coal	4,372	8,376	14,730	15,605	15,617	17,239	19,957	24,608
Oil	7,197	12,270	17,321	16,052	15,202	14,698	17,700	19,540
Gas	1,441	4,908	8,316	7,560	8,253	8,522	9,124	9,551
Hydro power	1,250	1,413	2,369	3,519	4,540	4,468	5,146	4,827
Non-commercial energy	14,191	14,794	13,890	14,005	14,121	13,673	12,745	11,925
Electricity import		33	399	333	125	200	124	136
Total	29,171	41,794	57,025	57,075	57,857	58,801	64,797	70,588

Source: MONRE, 2015

2.4. Outline of research questions

All three empirical essays that make up this thesis employ data from World Development Indicators, Ministry of Planning and Investment of Vietnam and GSO of Vietnam. The first essay titled *"The impact of foreign direct investment and economic growth on carbon dioxide emissions in Vietnam"*, examines pollution haven hypothesis in Vietnam basing on time series data during the period 1988-2015.

Research question 1: *To what extent do economic growth and FDI cause CO_2 emissions in Vietnam in the short and long run?*

Using the time series data from between 1988 and 2015 by applying the ARDL approach, we find that in the long-run, the causality relationship is found among variables; GDP has a significantly positive impact on CO_2 emission while FDI has a slightly negative effect. However, in the short-run, the causality relationship cannot be found for all variables. The results reveal that the pollution haven hypothesis does not exist in Vietnam since FDI is good for the environment in the long-run.

The second essay *titled "The economic growth and environment: evidence from Vietnamese cities",* we investigate the relationship between economic growth and industrial pollution emissions in Vietnam by using panel data for 63 provinces in Vietnam between 2000 and 2013. We examine three industrial pollution indicators including gaseous, solid waste and liquid waste.

Research question 2: *Do emissions increase along with the development of economic growth in each city in Vietnam? Which economic sector pollutes more in Vietnamese economy?*

We used a panel of 63 Vietnamese cities for 14 years to examine the income-pollution nexus for gaseous, solid and liquid waste. The evidence from the majority of pollutant emissions confirms that at current income levels in Vietnam, economic development will induce more industrial pollution emissions, that is, the net effect of economic growth on environment quality is negative. Notably, the increase in income induces more liquid waste than gaseous and solid waste due to a large amount of wastewater discharged from industrial zones, and manufacturing establishments without proper treatment as well as the subsectors significantly contributed to water pollution.

The third essay titled "*The relationship between economic growth and energy consumption in Vietnam: a panel data analysis of Vietnamese cities"*, examines the direction of causality and sign (in the panel sense) between EC including coal, oil, and electricity and the GDP for total 63 provinces in Vietnam between 2000 and 2013. At the same time, the causality relationship is also investigated among variables in all economic zones in Vietnam.

Research question 3: *Is there a causality relationship between economic growth and energy consumption in Vietnam? To what extent economic growth in Vietnam is driven by energy consumption?*

The results from our empirical tests show that there is a long-run equilibrium relationship among the variables, and the majority of energy consumption variables have a positive sign, indicating that an increase in GDP would lead to greater use of energy. When turning to the city specific coefficients, the relationship between EC and GDP across provinces is positive, and statistically significant; but it changes slightly among cities due to the geographic location, population, and natural resources. This research results suggest that energy consumption is not a limiting factor for Vietnam's economic growth, and it implies that the rise in energy prices can be a good opportunity for the economy to promote substitution and technological innovation.

From the Granger causality test, there is a short-run unidirectional causal relationship running from GDP to energy consumption. This implies that in the short-run, economic growth leads to energy consumption in Vietnam, and energy is only one of the essential inputs to production in Vietnam, supporting the conservation hypothesis. This result is consistent with Quang Canh (2011), Thanh Binh (2011), and contradictory with Tang (2016) for the studies in Vietnamese economy. Overall, the research results support the conservation hypothesis, since a high level of economic growth results in a high level of energy demand, but not vice versa.

CHAPTER 3

THE IMPACT OF FOREIGN DIRECT INVESTMENT AND ECONOMIC GROWTH ON CARBON DIOXIDE EMISSIONS IN VIETNAM

3.1. Introduction

Since the start of renovation (Doi Moi) in 1986, and especially since the global economic integration of the early 1990s, Vietnam has become an attractive destination for FDI; this resulting from the country's governmental policies encouraging FDI, as well as from its geographical position near global supply chains, political and economic stability, and abundant labor resources. According to the GSO of Vietnam 2013, from 1988 to 2012, FDI inflow into Vietnam has followed a long-term upward trend and short-term fluctuations

Table 3.1 FDI inflows during 1991-2017

Unit: millions USD

Year	Projects	Registered capital	Implemented capital	% implemented capital/registered capital
1991	152	1,284.4	428.5	33.4
1992	196	2,077.6	574.9	27.7
1993	274	2,829.8	1,117.5	39.5
1994	372	4,262.1	2,240.6	52.6
1995	415	7,925.2	2,792	35.2
1996	372	9,635.3	2,938.2	30.5
1997	349	5,955.6	3,277.1	55.0
1998	285	4,873.4	2,372.4	48.7
1999	327	2,282.5	2,528.3	110.8
2000	391	2,762.8	2,398.7	86.8
2001	555	3,265.7	2,225.6	68.2
2002	808	2,993.4	2,884.7	96.4
2003	791	3,172.7	2,723.3	85.8
2004	811	4,534.3	2,708.4	59.7
2005	970	6,840	3,300.5	48.3
2006	987	12,004.5	4,100.4	34.2
2007	1544	21,348.8	8,034.1	37.6
2008	1171	71,726.8	11,500.2	16.0
2009	1208	23,107.5	10,000.5	43.3
2010	1237	19,886.8	11,000.3	55.3
2011	1186	15,598.1	11,000.1	70.5
2012	1287	16,348	10,046.6	61.5
2013	1530	22,352.2	11,500	51.4

2014	1843	21,921.7	12,500	57.0
2015	2120	24,115	14,500	60.1
2016	2613	26,890.5	15,800	58.8
2017	2741	37,100.6	17,500	47.2

Source: GSO Vietnam, 2017

The number of investment projects in the industrial, manufacturing is the largest: by 31/12/2017, there are 12,460 industrial projects, which are manufactured to the amount of USD 186,514.2 million accounted for 58.36 per cent of FDI capital, and 2,478 investment projects in the field of scientific expertise and technology projects but the amount of capital is only USD 3,096.3 million (representing 0.97 per cent of total FDI capital). The number of investment projects in the field of water supply, management, and wastewater treatment is very small; there are only 68 FDI projects to invest in this sector with USD 2,338.5 million.

Table 3.2 Structure of FDI by economic activities accumulated by 31/12/2017

Sector	Projects	Total registered capital (million USD)	The rate of capital each sector
Total	24,803	319,613.1	
Agriculture, forestry, and fishing	511	3,521.2	1,10
Mining and quarrying	105	4,876	1,53
Manufacturing, and processing industry	12,460	186,514.2	58,36
Electricity, gas, hot water, steam, and air conditioning	115	20,820.9	6,51
Water supply, management, and wastewater treatment	68	2,338.5	0,73
Construction	1,481	10,846.5	3,39
Wholesale, and retail trade, repair of vehicles	2,805	6,200	1,94
Transportation, warehouse	666	4,646.7	1,45
Accommodation, and food service activities	644	12,004.2	3,76
Information and communication	1,653	3,336.5	1,04
Financial, banking and insurance activities	81	1,487.8	0,47
Real estate activities	639	53,226	16,65
Professional, scientific and technical activities	2,478	3,096.3	0,97
Administrative and support service activities	298	527.1	0,16

Education and training	376	759.9	0,24
Human health and social work activities	134	1,867	0,58
Art and entertainment	133	2,781.6	0,87
Other services activities	156	762.8	0,24

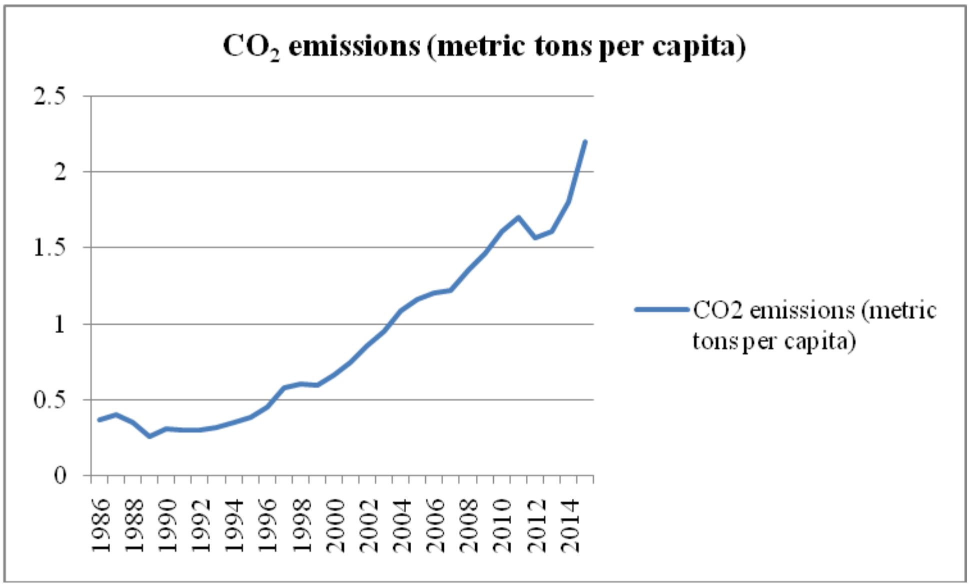
Source: GSO, 2017

The success of Vietnam in attracting FDI has had a positive impact on the country's economic performance; between 2000 and 2012, the contribution of FDI to GDP has followed an increasing trend from 13.3 per cent in 2000 to 18.1 per cent in 2012. Regarding the contribution to investment, in accordance with GSO, over a ten years period of 1995-2004, despite an increase in absolute value, the share of FDI in total investment declined from 30.4 per cent in 1995 to the low percentage of 14.2 per cent in 2004 mainly due to the vigorous expansion of public investment. Subsequently, it bounced back from 14.9 per cent in 2005 with the most recent figure of 23.3 per cent in 2012. Meanwhile, the share of the state sector decreased significantly after 2001 partly due to state-owned enterprises reform in recent years which included streamlining of public investment. At the same time, FDI makes a particularly important contribution to export revenue. In 2011, export by the FDI sector was more than USD 55 billion or a half (49.4 per cent) of the country's total export and there was a rising trend of FDI exports throughout 1995-2012, which rose faster than the export of the domestic invested sector. The exports fell temporarily in 2009 because of a global recession but continued to rise subsequently, reaching the highest rate approximately 70 per cent to Vietnam's export turnover of USD 162.4 billion in 2015. This highlights the fact that FDI activity is a crucial determinant of trade flows and structure in the Vietnamese economy. Also, FDI also contributes to the state coffers. Despite the existence of many incentives in the forms of exemptions, tax reductions and import duties, the contribution of the FDI sector to fiscal revenue was on a rising trend, from 5.2 per cent of the total state revenue in 2000 to 14.10 per cent in 2014.

Vietnam's economic growth in the nearest two decades was closely associated with the inflow and operation of FDI. The long-term rising trends in the contribution of FDI to some macroeconomic aspects including GDP, investment, export, and fiscal revenue are the evidence of the critical importance of FDI sector in Vietnam's economic development. Due to the economic reforms in Vietnam in 1986, the annual growth rate is 8.5 per cent over the decades before the year of 1997; and after the Asian financial crisis in 1997/1998, the growth rate of Vietnam fell from 9.3 per cent in 1996 to 5.8 per cent in 1998 and then 4.8 per cent in 1999. After that it started to move up again in 2000 to 6.7 per cent and went on to achieve 8.5

per cent in the year of 2007. Due to the global financial crisis which started in 2008, it declined to 5.3 per cent in 2009, and the recovery has been witnessed since 2012 with GDP growth gradually increasing and reaching 6 per cent in 2014. Despite the global trade recession and China's economic growth slowing down, which impacted most parts of Southeast Asia, Vietnam proved to be resilient to the turbulence and still scored a growth rate of 6.7 per cent in 2015. In a mere-quarter century Vietnam has raced from the back of the third world economy to middle-income status; however, Vietnam's economic growth has had an outsized environmental impact; between 1991 and 2012, the country's GDP grew by 315 per cent, while its greenhouse gas emissions rose by 937 per cent; hence, there is potential to reduce Vietnam's greenhouse gas emissions relative to GDP[1].

Vietnam's CO_2 emissions have grown by more than 10 per cent in most years after 1990[2]. While at the time before 1990 a clear singular driver of emissions cannot be identified, after 1990 the economic growth and carbon intensity have driven the increase of emissions to approximately equal extents. In 2007, the country's CO_2 emissions per capita were 1.07 tons, nearly 20 per cent of the world average, increasing to more than 100 per cent to around 2.2 tons in 2015. The carbon growth rate was around 83.2 per cent from 1990 to 2010, and the CO_2 emissions are expected to grow rapidly as Vietnam is likely to industrialize and economically utilizes more carbon-intensive fuels, substituting traditional noncommercial fuels including biomass. Therefore, the purpose of this study is to investigate the impact of economic growth and FDI on CO_2 emissions in Vietnam since the time of innovation to date.



[1] World Resources Institute Climate Analysis Indicators Tool (WRI CAIT 2.0, 2016)
[2] International Energy Agency 2012

Figure 3.1 CO_2 emissions per capita in Vietnam during 1986-2015

Source: World Bank 2014, and WRI CAIT 2.0, 2016

Vietnam's international cooperation in responding to climate change

Understanding the negative impacts of climate change, Vietnam actively participates in various activities against the impacts of climate change proposed by the UN. Vietnam has signed the United Nations Framework Convention on Climate Change (UNFCCC) on 11 June 1994, Kyoto Protocol on December 3, 1998, which has been ratified on December 25, 2002.

Vietnam and the EU have signed a Partnership and Cooperation Agreement (PCA) in replacement of the Framework Agreement for Cooperation in 1995. The PCA has officially come into force on June 27, 2012; article 31 of the PCA between Vietnam and the EU affirms that both sides will *"cooperate to accelerate the fight against climate change and its impact on environmental degradation and poverty, promote policies to help mitigate climate change and adapt to the negative effects of climate change, especially the rise of sea levels, and to set their economies on sustainable low-carbon growth paths"*.

On November 03, 2016, the Viet Nam Government has ratified the Paris Agreement of the United Nations Framework Convention on Climate Change (Paris Agreement). The plan outlines systematic tasks and solutions to adapt to climate change, mitigate greenhouse gases, mobilize resources, create transparency of responses and supports, and strengthen state management of climate change. Vietnam plans to reduce 8 per cent of its greenhouse gas emissions by 2030, and is aiming at 25 per cent reduction with adequate support from the international community.

3.2. Literature review

3.2.1. Pollution haven hypothesis, and empirical studies

The pollution haven hypothesis (PHH) was first postulated by Copeland and Taylor (1994) in the context of North-South trade under NAFTA. It was the first paper that links the environmental regulation stringency and trade patterns with the level of pollution in a country.

As stated by the PHH, the migration of the dirty industries from advanced to developing countries takes place through the trade of goods and foreign direct investment (FDI). This phenomenon is driven by the comparative cost advantage enjoyed by the developing countries due to lower pollution controls. The developing countries tend to specialize and export polluted goods and developed countries tend to specialize and export clean goods. Resultantly, the developing countries are becoming the pollution haven for the dirty industries of the advanced countries.

The critics of trade liberalization also argued that the concentration of pollution-intensive industries in poor and developing countries was due to weak environment standards of these countries. They claim that the consumers of the developed world enjoy the pollution-intensive goods at lower prices due to under pricing of environmental resources in developing countries. This phenomenon of the concentration of pollution-intensive industries in poor and developing countries is known as PHH.

The empirical support to the PHH is mixed as Jaffe et al. (1995) and Tobey (1990) did not find any evidence to claim that stringency of environmental regulation of a country had any impact on the trade of pollution-intensive goods. On the other hand, Mani and Wheeler (1998) found temporary evidence in favor of the PHH.

Cole (2004) also found that pollution-intensive industries grew at rapid speed in developing countries in the periods when environmental regulations in OECD countries had been very stringent. Similarly, Frankel and Rose (2005) also found support for the PHH from a city-level study of SO2 concentrations and Cole and Elliott (2005) also supported these results. Nevertheless, Dinda (2004) rejected the PHH stance. He submitted that the polluting industries that tend to locate in the developing countries would also raise the income levels of the host country. Resultantly, these host countries would also start imposing stringent environmental regulations. Therefore, sooner or later there would be no country where polluting industries can be relocated and all countries would be on the same playing level.

The analysis of more recent literature seems to be more supportive of the thesis on the existence of pollution havens. By econometrically the impact of the environmental stringency on the FDI outflow of OECD countries, a significant positive correlation is found. This evidence would support the pollution haven hypothesis as related to the industrial flight dynamic, which indeed corresponds to an increase of FDI outflows when environmental stringency of countries arises (Mihci et al 2005). He (2006) provides convincing evidence of the existence of the pollution haven hypothesis. He observes that the location and composition of the inward stock of Chinese FDI are highly motivated by pursuing a “production platform” with lower compliance costs of pollution regulation. Wenhuda (2007) proves the existence of the hypothesis in question while analyzing the pollution abatement cost savings and FDI inflows to specific “dirty” production sectors in China. Spatareanu (2007) observes how firms in industries with higher abatement costs tend to invest more abroad to avoid high environmental compliance costs. Elliot and Shimamoto (2008) carried to understand whether or not ASEAN countries can be considered pollution havens for Japanese high-polluting industries, indicates the non-existence of the pollution havens hypothesis. Why the literature fails to find more evidence of the pollution havens hypothesis: another study suggests that the lack of a systematic and firm link between industry abatement costs and the FDI outflow from developed countries is due to the fact that most of the studies ignore the role of factor endowments in the decision of MNCs to relocate their activities abroad. By focusing particularly on the link between capital intensity and pollution intensity, it is possible to identify those countries which are more likely to be considered as pollution havens. Hence, after demonstrating the relationship between capital intensity and pollution intensity of US industries and the link between the stringency of countries' environmental regulations and capital abundance, the study econometrically analyzes the determinants of the US multi-sector FDI outflow to Mexico and Brazil and finds the capital sectorial requirement a key determinant for FDI location. It also finds that in the US industry the abatement cost of pollution levels is a significant determinant of its FDI outflow, thus proving the evidence of pollution have effects (Cole and Elliot 2005).

3.2.2. Effects of FDI on the environment, and empirical studies

Grossman and Krueger (1991) described three possible sources of environmental impact from greater openness to trade and foreign investment: A scale effect, a technique effect, and a composition effect.

Scale effect

The scale effect refers to the expansion of economic activity as a result of an increase in foreign investment. If the nature of the economic activity remains unchanged, the total amount of pollution generated must increase, as well as the use of natural resources. "Even if the foreign firms are relatively less polluting across all emissions and/or more concerned about sustainable resource harvesting, the overall quantity of pollution and level of resource degradation increases with a greater level of investment. In addition to pollution, a larger increase in the scale of investment without a larger 'sustainable development' land and resource use planning framework is likely to undermine biodiversity and degrade common access resources such as river and coastlines"[1]. *Ceteris paribus*, the scale effect on environmental quality is expected to be negative.

[1]Zasky (1999), p.3

Composition effect

FDI may have an impact on the environment by changing the industrial structure. Traditional trade theory suggests that countries will specialize in those sectors in which they have a competitive advantage. Foreign investment, to a greater extent, is attracted by such a competitive advantage. "If competitive advantage derives largely from differences in environmental regulation, then the composition effect will be damaging to the environment…On the other hand, if the sources of international comparative advantage are more traditional ones, namely cross-country differences in factor abundance and technology, then the implications of the composition effect for the state of the environment are ambiguous…The net effect of this on the level of pollution is each location will depend upon whether pollution-intensive activities expand or contract in the country that on average has the more stringent pollution controls"[1].

Technique effect

Grossman and Krueger (1991) provided two reasons that pollution per unit of output might fall, especially in developing countries. First, foreign investors may bring newer and better technologies, which tend to be less polluting and use fewer resources. In addition to technology transfer, FDI may also create other positive technological spillovers to national firms through imitation, employment turnover, and supply chain requirements (OECD, 2002). Second, FDI may increase residents' income and then people may have more demand for environmental quality. Thus, there will be more pressure on the government to implement more stringent environmental regulations and stricter enforcement of existing laws.

Empirical studies

Jha (1999) and Zarsky (1999) showed that the effects of FDI on receiving countries can be positive, negative, or neutral. In the case of China, Liang (2006) examined the relationship between the scale of FDI and local air pollution by using the data of more than 260 major cities from 1996 to 2003. He then found evidence that foreign investment has a beneficial effect on the local environment, controlling for industrial output and composition. On the other hand, theoretical literature pointed out that the economic success of the country has been achieved at the expense of their environmental degradation. However, identifying the net effect of FDI on the environment is complex. The OECD (2002) presented two limitations that might explain the difficulties in addressing the net environmental effect of FDI flows.

[1] Grossman and Krueger (1991), p.4

First, it is difficult to separate the environmental effects of domestic economic activity from the effects of foreign affiliate activity. Second, FDI does not occur in a vacuum so environmental effects cannot be analyzed in isolation from other related factors, for example, trade influences the potential market opportunities in a country. In a related study, Zhang (2013) used a panel of 112 Chinese cities over four years from 2001 to 2004 to examine the income-pollution nexus for several water and air pollution indicators. The majority of pollutant emissions confirmed that at current income levels in China, economic development will induce more industrial pollution emissions; whereas EKC was found to exist for wastewater and petroleum-like matter with the estimated turning point is USD 3,605 and USD 4,992 (at 1990 prices), respectively. At the same time, the study also expresses that domestic investments have the strongest positive effects on industrial pollution emissions, while foreign investments have an insignificant effect in almost pollutants (wastewater, COD, CrVI, waste gas, SO_2, soot, and dust), except for positive significance for petroleum-like matter, waste gas and SO_2.

Basing on panel data of 66 less developed countries between 1980 and 1996, Grime and Kentor (2003) argued that heavy dependence on FDI contributes to the growth of CO_2 emission in less developed economies of the globe; however, the domestic investment has no significant effect on CO_2 emissions. Furthermore, the study also suggested that FDI is more concentrated on industries that require more energy; as a result, energy emissions are increased, and therefore, foreign investors prefer to invest in these industries in developing countries where environmental laws are relatively flexible. With the same conclusion, Beak et al (2009) the examined dynamic relationship among the trade, income, and environment for 25 developed and 25 developing countries by using a time series dataset of sulfur emissions (SO_2), income and trade openness and adopt the vector autoregression model. Results suggested that trade and income growth tend to increase environmental quality in various developed countries, whereas they have detrimental effects on environmental quality in most developing countries. Muhammad et al (2011) examined the environmental consequences of economic growth and FDI, basing on data of 110 developing and developed nations in the world by applying pooled regression along with fixed and random effect models, and showed that a consistent rise in FDI is contributing to CO_2 emissions. Additionally, the case of FDI inflows of France, Kheder (2010) considered mutual relationship among the FDI, the environmental regulation and the pollution by using a consistent data set at a disaggregate sector-level, in a mix of developing, transition, emerging, and developed countries for the years from 1999 to 2003; this confirmed the pollution havens and determine their impact on pollution in host countries. The researcher detected a negative influence of the environmental regulation on FDI location, while it took into account the endogeneity of this environmental regulation. In other research, Beak and Koo (2009) investigated the interrelationship among FDI, economic growth and environment in China and India by analyzing the annual time-series data over the period 1980-2007, and the period 1978 to 2007 for China and India respectively by applying ARDL methodology. They found that for China, FDI tends to deteriorate environmental quality in both the short and long-run; and the result is the same for India in the short-run, but in the long-run, FDI is insignificant. For economic growth, it tends to worsen the environment in both the short and long-run.

3.2.3. Empirical studies related to Vietnam

In the case of FDI inflow in Vietnam, there are various studies evaluating the performance of the FDI and its impact on Vietnamese socio-economy (i.e. Freeman, 2002; Phuong Hoa, 2002, 2004; Nguyen et al, 2011; Anh Dao & Thanh Binh, 2013; Bhatt, 2013; Anwar & Nguyen 2010, 2011 and etc); however studies investigating the EKC hypothesis in Vietnam are still far and few in between. To my knowledge, recently, there are two papers of Al-Mulali et al (2015) and Tang et al (2015) that investigate the EKC hypothesis in Vietnam for time series data from 1981 to 2011 and 1976 to 2009, respectively. The first research used ARDL methodology and following the new approach by Narayan and Narayan (2010) for variables including CO_2 emissions, capital, labor force, export, import and electricity consumption; whereas the last one applied the techniques of cointegration and Granger causality for CO_2 emissions, energy consumption, FDI and economic growth. With different methodologies as well as time series data, the results of their studies are contrasting when Al-Mulali et al (2015) state that EKC hypothesis does not exist in Vietnam; while Tang et al (2015) confirmed the existence of EKC hypothesis and assume an inverted U-shaped relationship between CO_2 emissions and economic growth. However, the conclusions of two researches are questionable due to the year of starting in time series data are from 1981 and 1976 respectively, this was not suitable for Vietnamese economy when Vietnam War ended in 1975, and it started innovation since 1986; and especially the law of FDI was enacted at the end of 1987. Therefore, FDI and export in Vietnam only can be significant after those few years. Thus, the author believes that with the time series in this study starting from 1988, it will eliminate that limitation, and the conclusions of paper will probably make a contribution to the literature.

3.3. Methodology

3.3.1. Model specifications

The relationship between CO_2 emissions, FDI and economic growth is given in the empirical model below:

$$\ln CO_{2t} = f(\ln CO_{2t-1}, \ln FDI_t, GDP_t) \quad (1)$$

In the model (1), ln denotes the natural logarithm, t is year of time series, CO_2 is per capita carbon dioxide emissions measured in metric tons, GDP is per capita Gross Domestic Product, and FDI is per capita FDI measured in 2010 of constant US dollar. CO_{2t}, FDI_t, and GDP_t denote the value of each variable in the current period, and CO_{2t-1} denotes the value of CO_2 in the previous period.

ARDL bound cointegration test model for CO_2, FDI, and GDP according to the error-correction version of the ARDL model developed by Pesaran et al (2001) (equation 30):

$$\Delta(\ln CO_{2t}) = \alpha + \sum_{k=1}^{p} \varepsilon_k \Delta(\ln CO_{2t-k}) + \sum_{k=1}^{p} \varphi_k \Delta(\ln FDI_{t-k}) + \sum_{k=1}^{p} \emptyset_k \Delta(\ln GDP_{t-k}) + \delta_1 \ln CO_{2t-1} + \delta_2 \ln FDI_{t-1} + \delta_3 \ln GDP_{t-1} + \nu_t \quad (2)$$

In equation (2), Δ is the difference operator, *k* is lag order, *p* is the optimum lag length, and ν_t is the disturbance term. This methodology solved the non-stationary problem related to the time series data, the bounds test can be used irrespective of whether the variables are pure I(1), I(0) or mutually cointegrated. Besides, the properties of the ARDL approach are more effective in analyzing small samples than other approaches. Another advantage of this model is that the short-run and the long-run effects of the independent variables on the dependent variables are assessed simultaneously to distinguish between the short and long-run effects of the variables.

Equation (2) indicates that CO_2 emissions tend to be influenced and explained by its past values. The structural lags are established by using minimum Akaike's information criteria (AIC) and Schwarz information criterion (SIC). After the regression of Equation (2), the Wald test (*F*-statistic) was computed to differentiate the long-run relationship between the concerned variables. The Wald test can be carried out by imposing restrictions on the estimated long-run coefficients of CO_2 emissions, FDI and GDP. The null and alternative hypotheses are as follows,

H_0: $\delta_1 = \delta_2 = \delta_3 = 0$ (no long-run relationship)

Against the alternative hypothesis,

H_1: $\delta_1 \neq 0$; $\delta_2 \neq 0$; $\delta_3 \neq 0$ (a long-run relationship exists)

The computed F-statistic value will be evaluated with the critical values tabulated in Table CI (iii) of Pesaran et al. (2001). According to these authors, the lower bound critical values assumed that the explanatory variables x_t are integrated of order zero, or I(0), while the upper bound critical values assumed that x_t are integrated of order one, or I(1). Therefore, if the computed F-statistic is smaller than the lower bound value, then the null hypothesis is not rejected and we conclude that there is no long-run relationship between property and its determinants. Conversely, if the computed F-statistic is greater than the upper bound value, then x_t and its determinants share a long-run level relationship. On the other hand, if the computed F-statistic falls between the lower and upper bound values, then the results are inconclusive (Pesaran et al, 2001, p.301).

3.3.2. Data source

This study will use time series data for the period 1988-2015, CO_2 emissions data is extracted from the World Bank, WDI (World Development Indicators), FDI data is collected from Ministry of Planning and Investment of Vietnam and GDP data is collected from General Statistic Office of Vietnam.

3.4. Empirical results

3.4.1. *Unit root tests*

The ARDL modeling starts with unit root tests to check the stationary status of all variables in the model and the order to its integration after differencing. This is to ensure that the variables are not I(2) or I(d) stationarity so as to avoid spurious results and ARDL approach could be applied to the model. The results of unit root tests (t-statistic) of 3 variables in the model under deterministic trend and intercept, and intercept only options are presented in Table3.1. All variables in the model comprise a combination of cointegration I(0) and I(1), hence complied with the unit root test requirement to proceed for bounds testing procedure in the ARDL approach (Pesaran & Pesaran, 2009).

Table 3.3 Unit roots tests using ADF and AIC selection criteria

Var	**With trend and intercept**				**With intercept only**			
	level	**1st Diff**	**2nd Diff**	**I(d)**	**level**	**1st Diff**	**2nd Diff**	**I(d)**
$lnco_2$	-3.85**	-4.88***		I(0)	0.45	-5.2***		I(1)
lngdp	-2.94	-4.81**		I(1)	-1.88	-3.57***		I(1)
lnfdi	-3.65**	-5.82***		I(0)	-5.93***	-5.16***		I(0)

Notes: the null hypothesis is that the time series is non-stationary, or contains a unit root. The asterisks ***, ** and * denote significance at 1, 5 and 10 per cent levels, respectively.

3.4.2. Cointegration results and diagnostic tests

Table 3.2 shows the determination of the lag length (p) of each variable in equation (2). To choose an optimal lag length, we use various system-wise methods such as AIC, SC, FBE, HQ and LR test. The results indicate that the lag length of one year is the best.

Table 3.4 Lag length selection criterions

Lag	Log L	LR	FPE	AIC	SC	HQ
0	37.15379	NA	0.003404	-2.846149	-2.698892	-2.807082
1	45.16671	13.35487*	0.001901*	-3.430559*	-3.234217*	-3.378469*
2	45.74609	0.917356	0.001975	-3.395508	-3.150080	-3.330396
3	46.01263	0.399801	0.002109	-3.334386	-3.039872	-3.256251
4	46.19425	0.257296	0.002273	-3.266187	-2.922588	-3.175030

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5 % level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information citerions

With the selected lag lengths, we then test the existence of a long-run cointegrated relationship among the variables. Specifically, the null hypothesis of no long-run relationship (H_0: $\delta_1 = \delta_2 = \delta_3 = 0$) in equation (2) is tested using an F-test with the critical value tabulated by Pesaran et al (2001). The result shows that with 1 lag (p =1), the calculated F-statistic is 5.02 that is higher than upper critical value of 4.85[1] at 5 per cent for unrestricted model with intercept and no trend; therefore the null hypothesis of no cointegration can be rejected, indicating the existence of a stable long-run relationship among CO_2 emissions, GDP and FDI. At the same time, the diagnostics reveal that the ARDL model of equation (2) is stable (see Table 3, Panel C), supporting the choice of p =1 for this model.

To consider the significance of the lagged level variables in the error correction model in equation (2) explaining Δ $lngdp_t$ and Δ $lnfdi_t$ as long run forcing variables for $\Delta lnco_2$, we back track the dependent variable in the model as per ARDL functions and test for joint

[1] With two regressors and unrestricted intercept and no trend, F-statistic for 5 per cent critical value bounds is (3.79, 4.85), which is taken from Table CI (iii) in Pesaran et al. (2001) on p.300.

significance using F-statistic. Specifically, we change $\Delta lnco_2$ in equation (2) to Δ $lngdp_t$ and Δ $lnfdi_t$ respectively; the results show that the null of no conintegration cannot be rejected. Hence, the results suggest that the variables GDP_t and FDI_t can be treated as the "long-run forcing" variables for the explanation of CO_2.

The results have confirmed the cointegration among variables in the long-run, therefore the author will estimate the reduced-form solution of equation (2) in which first-differenced variables jointly equal zero. In the long run, all variables are statistically significant at the 1 per cent level (Table 3.3, panel A). The long-run elasticity of CO_2 emissions with regarding to GDP is 1.59, meaning that a 1 per cent increase in per capita GDP is associated with a 1.59 per cent increase in per capita CO_2; then the rapid economic growth in Vietnam has a detrimental effect on environmental quality. This suggests that Vietnam has not reached income level high enough to be able to reach the EKC turning points in a development trajectory; therefore the economic growth leads to an increase in the scale of economic activity and consequently, worse environmental quality. This outcome is consistent with Tang et al (2015) and Al-Mulali et al (2015). On the other hand, FDI has a slight negative impact on CO_2 emission (the coefficient is, - 0.078); the increase in FDI inflows will result in decreasing slightly in per capita CO_2 emissions (about 7.8 per cent) in the long run. Our result supports the neo-liberal argument that the influx of FDI is good for reducing CO_2 emissions in Vietnam by transferring environment-friendly technologies and production techniques from developed countries to Vietnam. Besides, the main sources of CO_2 emissions in Vietnam have changed over the time. For the period from 2000 to 2009, the agricultural sector was the leading contributor, followed by the energy sector with 65 million tones and 52.7 million tones of CO_2 discharged to the environment that was accounted for approximately 43 per cent and 35 per cent of total CO_2 emissions, respectively. After 2010, the main causes of CO_2 emissions are from coal fired power plants, and vehicles, with 54 per cent and 13 per cent, respectively. Thus, the pollution haven hypothesis in Vietnam is rejected; this is in line with the findings of Tang et al (2015).

Table 3.5 The long-run and short-run elasticities

Panel A: Normalized cointegrating vector – Long-run elasticities			
Variables	Coefficients	t-statistics	p-values
Constant	-10.5937	-47.90215***	0.0000
lngdp	1.5932	40.3849***	0.0000
lnfdi	-0.0781	-2.8899***	0.008
Panel B: Vector error correction model- Short-run elasticities			
Variables	Coefficients	t-statistics	p-values
Constant	-0.0149	-0.3772	0.7097
Δlnco2	0.3838	2.4465**	0.0233
Δlngdp	1.2205	1.4858	0.1522
Δlnfdi	-0.0094	-0.4161	0.6815
ε_{t-1}	-0.382	-2.2275**	0.037
Panel C: Diagnostic tests			
Serial correlation	[1]0.1752 (0.6166) [2] 1.3879 (0.1940)		
Heteroskedasticity	[1]0.5249 (0.7176) [2] 1.1036 (0.3406)		
Normality	[1] 1.6342 (0.4416) [2] 1.3412 (0.5114)		
RESET	[1] 0.3779 (0.7099) [2] 0.3252 (0.8071)		
CUSUM	[1] stable [2] stable		
CUSUMSQ	[1] stable [2] stable		

Note: The asterisks ***, ** and * denote significance at 1, 5 and 10 per cent levels, respectively. [1] Long-run model, [2] Error correction model

The error-correction model is estimated by the ARDL approach to capture the short run dynamic that may exist between the CO_2 emissions and its main determinants in Vietnam. The results in Panel B reveal that we fail to find any significant evidence about the effect of FDI on CO_2 in the short run; this result is supported by Tang et al (2015) when they could not find any relationship between FDI and CO_2 in the short-run in Vietnam. One of the possible explanations for this insignificance is that it takes time for Vietnam to learn and adapt to the advanced technology and production techniques. Although the result of the relationship between GDP and CO_2 of this paper is contrasting with Tang et al (2015) when they confirmed the existence of an inverted U-shaped relationship between CO_2 emissions and economic growth; however it is consistent with Al-Mulali et al (2015).

The negative coefficient and significance of ε_{t-1} error-correction term (ECT) ensure that the long-run equilibrium can be achieved; the absolute value of ECT indicates the speed of adjustment to equilibrium. The result indicates that ECT is negative and it is significant; hence the speed of adjustment of variables to achieve the long-run equilibrium is approximately 38 per cent in a year. One explanation for this remarkable number is that Vietnamese economy is still in the initial stages of development; therefore to achieve the long-run equilibrium, the variables need to maintain high speed to adjust the equilibrium.

Ultimately, the diagnostic tests on the short-run model have applied, and the model is serially uncorrelated, heteroskedasticity, and normality. Furthermore, the Ramsey Reset test expresses that the model is correctly specified, and the CUSUM and CUSUMSQ tests to the residuals of the ECM model are stable over the sample period.

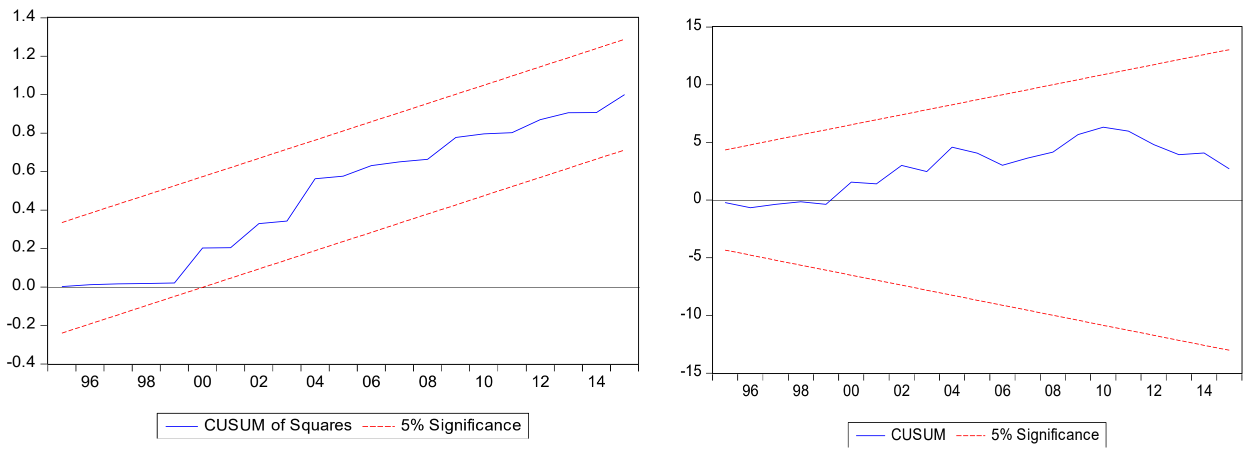


Figure 3.2 The plots of CUSUM and CUSUMSQ statistics

3.5. Conclusion

This paper has estimated the impact of FDI and GDP on CO_2 emissions in Vietnam by using time series data from 1988 to 2015 and employing Bounds Test approach. The analysis demonstrates that in the long-run, the causality relationship is found among variables; GDP has a significantly positive impact on CO_2 emission while FDI has a slightly negative effect. However, in the short-run, the causality relationship cannot be found for all variables. Also the empirical result points out that the variables can achieve the long-run equilibrium if the adjustment speed of them is approximately 38 per cent. The results indicate that Vietnam economic development level has not reached the point where pollution can be reduced by the increase in GDP; at the same time, in the long-run foreign investors in Vietnam, they are supported to enhance the quality of the environment in Vietnam. Thus, the Vietnamese government while offering an inductive business environment to attract FDI should set proper policies on environmental planning and transfer of green technologies to ascertain the commitment of investors to environmental responsibility, energy, and wider sustainability in the country.

However, this study has quite a few limitations which should influence the outcomes, such as a small number of observations, even the ARDL methodology is applied so as to avoid this disadvantage; real per capita FDI is an independent variable whereas it is considered less reliable in the most real economic analysis, and likely the omitted of other variables such as energy consumption (Tang et al. 2016, Al-Mulali et al 2015), factor demand, and technology intensity (Ramstetter et al. 2013). For further research, it should be possible to explore panel estimates across regions in Vietnam by adding such data as well as other waste emissions and ownership data to gain more understanding of the issues.

CHAPTER 4

THE ECONOMIC GROWTH AND WASTE EMISSIONS: EVIDENCE FROM VIETNAMESE CITIES

4.1. Introduction

Over the past three decades since “Doi Moi”, Vietnam has strongly promoted policies towards socio-economic development and poverty alleviation through increased industrialization. The rapid industrialization from the early 1990s until now has been one of the key drivers that transformed Vietnam from a poor to middle-income country (Appendix 4.1). However, besides the gained marvelous achievements in socio-economic developments, Vietnam also has to pay a dear price and face a series of environmental challenges.

According to Vietnam Environment State Report published by MONRE in 2010, it is estimated that the total economic loss resulting from the environmental pollution in Vietnam accounts at least 1.5 per cent to 3 per cent of GDP. Consequently, environmental problems must be identified and solutions put forward for environmental protection in the coming years in order to mobilize all resources necessary to fulfill the goals set in the ***“National strategy on environmental protection to 2020 and vision to 2030”***. Accordingly, the general objectives to 2020 are to control and minimize the increase of environmental pollution, resource deterioration and biodiversity degradation; to further improve quality of the habitat; to raise the capability of responding climate change, striving for sustainable national development. With the visions to 2030 are to prevent and push back environment pollution, resource deterioration and biodiversity degradation; to improve quality of the habitat; to actively respond to climate change; to create fundamental conditions for a green economy, with low waste and low carbon, for the sake of the country’s prosperity and sustainable development.

In this chapter, we examine the relationship between economic growth and the environment in Vietnam. We make three specific contributions to the growth-environment literature. First, we focus on Vietnam given the undeniable strain such a large and rapidly growing economy is placing on the natural environment. Studies investigating these issues in Vietnam are relatively scarce. Second, we concentrate our analysis on Vietnamese cities and examine the city-level characteristics that influence industrial emissions. Lastly, we separate the impact of the state economic sector, non-state economic sector and foreign investment economic sector on waste emissions. We believe the use of city-level variables provides more potential explanatory power than the use of highly aggregated variables reported at the national level.

4.2. Environmental quality and waste emissions by economic sectors in Vietnam

4.2.1. Environmental quality in Vietnam

According to GSO of Vietnam (2015), waste emissions in Vietnam include three majority groups are gaseous waste, solid waste, and liquid waste; meanwhile the quantity of solid waste is always highest in total. In 2000, the quantity of solid waste is 917,981,021 m^3, whereas the volume of gaseous and liquid waste is 67,232,782 m^3, and 52,553,701 m^3, respectively. After 10 years, in 2010, the volume of solid waste and liquid waste increased around 6 times, whereas the quantity of gaseous waste increased approximately 10 times.

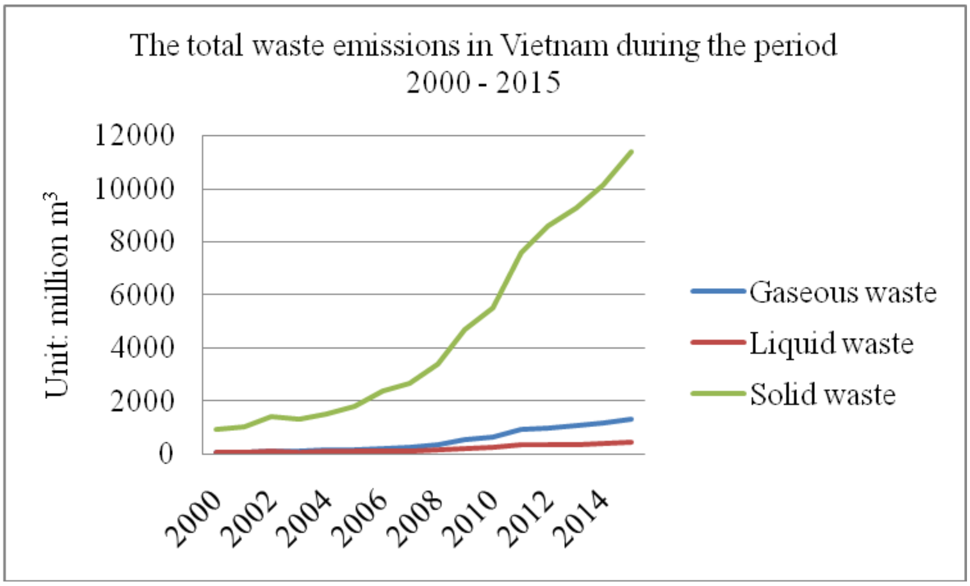


Figure 4.1 The total waste emissions in Vietnam during the period 2000-2015

Source: General Statistical Office of Vietnam (2015)

The MONRE reports that during the period 2011-2015, industrial production generated approximately 5 million tons of solid waste each year. The waste is mainly treated by burying or burning at industrial incinerators. Also, landfills remain the major way of treating waste in Vietnam because of its simplicity and low cost. This allows enterprises to save money on waste treatment, and therefore, cut the production cost. MONRE (2013) stated that Vietnam had 458 solid waste landfills with an area of more than 1 hectare for each. Smaller landfills in localities were not counted. As waste cannot be sorted at source, landfills have to receive a waste of different kinds, from domestic garbage, electronic waste, and industrial solvent to hazardous waste containing mercury, arsenic, cadmium, and lead.

4.2.2. Waste emissions by economic sectors in Vietnam

In Vietnam, after Doi Moi (renovation) in 1986, there are three economic sectors: the state economic sector, the non-state economic sector, and foreign investment economic sector. During the period 2000 and 2009, non-state economic and state economic sector contributed significantly to Vietnam GDP, approximately 46 per cent and 37 per cent respectively; and the rest one was foreign investment. However, after 2009 when Vietnam become an official member of World Trade Organization (WTO), the contribution of each sector to GDP has changed, non-state economic still played a crucial role in GDP, but it decreased slightly around 2 per cent, and state economic sector went down significantly around 8 per cent. Whereas the percentage of foreign investment increased from 15 per cent to 17 per cent, and consumption tax minus subsidies contributed around 10 per cent.

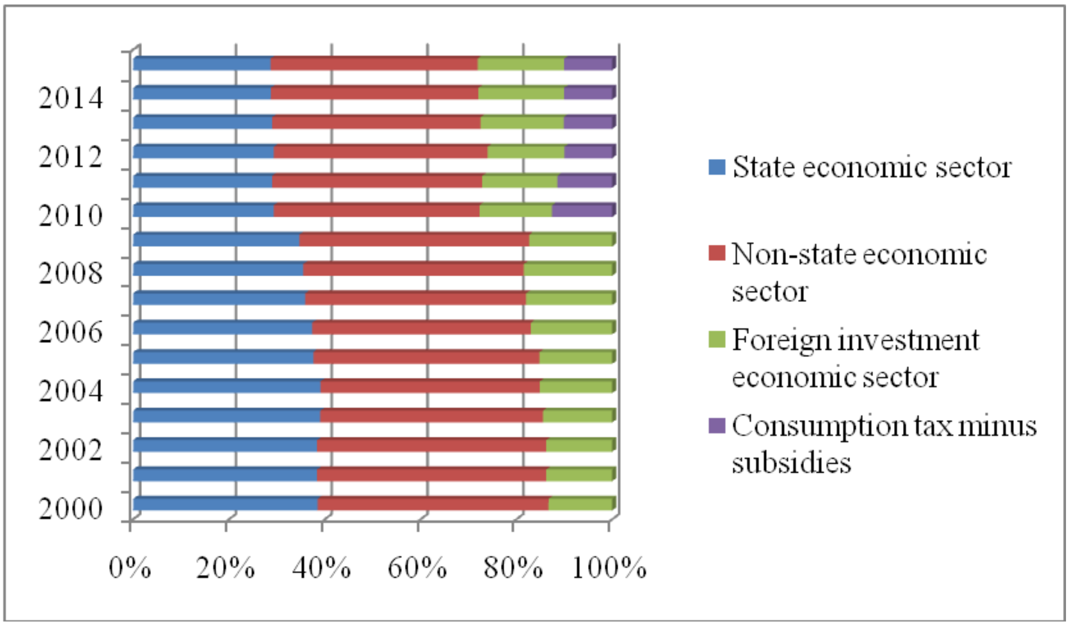


Figure 4.2 The contribution of the economic sectors to GDP from 2000 to 2015

Source: General Statistical Office of Vietnam (2015)

When it comes to waste emissions by economic sector, Figure 4.1, and Figure 4.3 stated that the state economic sector produced mostly solid and gaseous waste in Vietnam during the period 2000 and 2015. Specifically, state economic sector only contributed around 35 per cent of GDP in Vietnam; however, it produced approximately 51 per cent of total gaseous waste and 85 per cent of total solid waste. Meanwhile, the non-state economic sector contributed up to around 40 per cent to GDP; but it only produced around 3 per cent of solid waste, and 22 per cent of gaseous waste. Conversely, the liquid waste generated from the non-economic sector was the biggest number; it was around 48 per cent on average and followed by the state economic sector and foreign investment economic sector, approximately 33 per cent and 18 per cent, respectively.

It is noted from Figure 4.2 that foreign investment produced up to 25 per cent of gaseous waste in total, but it only contributed 16 per cent of GDP (Figure 4.1.)

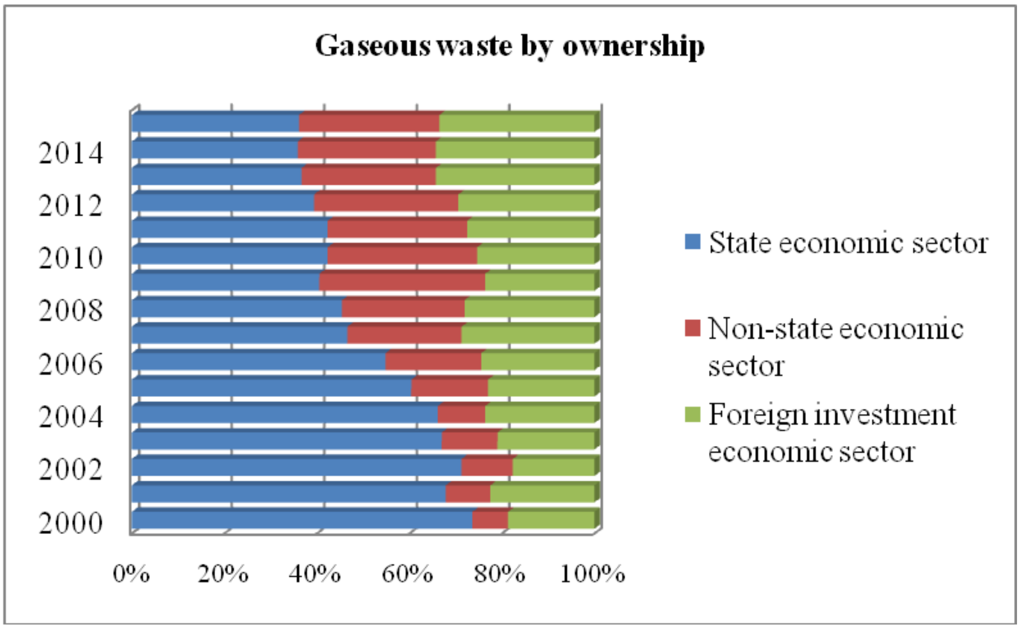


Figure 4.3 Gaseous waste by ownership from 2000 to 2015

Source: General Statistical Office of Vietnam (2015)

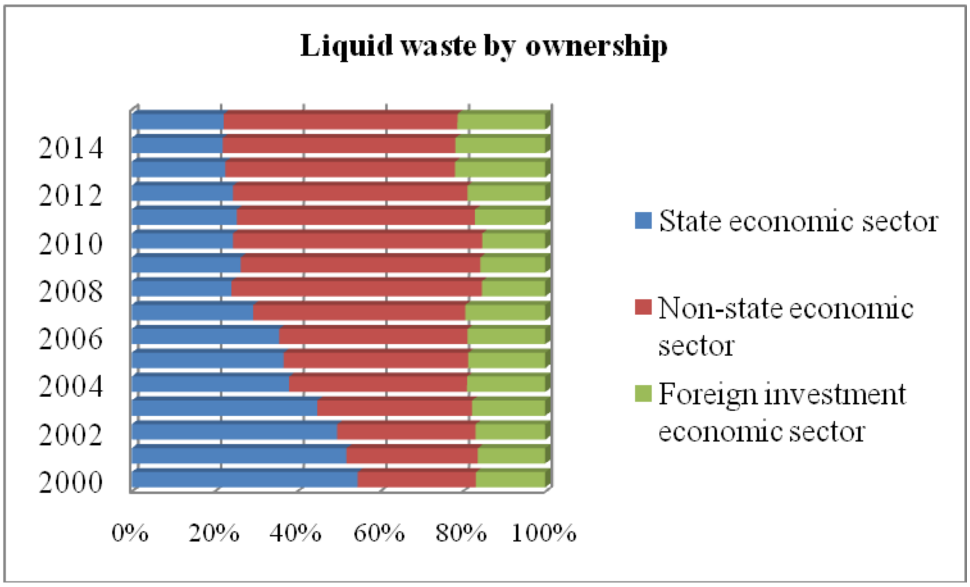


Figure 4.4 Liquid waste by ownership from 2000 to 2015

Source: General Statistical Office of Vietnam (2015)

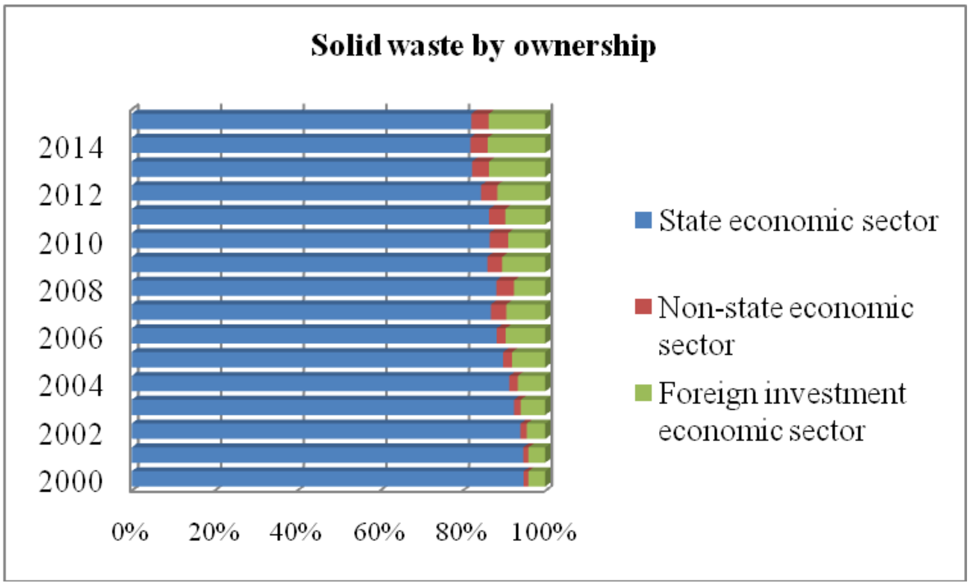


Figure 4.5 Solid waste by ownership from 2000 to 2015

Source: General Statistical Office of Vietnam (2015)

4.3. Literature review

4.3.1. Economic growth and environment

The interaction between environment and economic growth has been a subject of different approaches. The EKC approach analyzes the effects of economic growth on different dimensions of environmental quality. Initiated by Grossman and Krueger (1991), studies in the EKC literature hypothesize that the negative scale effect tends to prevail in the initial states of economic growth, but after a threshold level of development, it should be outweighed by the positive structural and technological effects. Following the paper in 1991, Grossman and Krueger (1995) used a cross country data set covering 58 countries in the1980s and found the support of an inverse U-shape relationship between the income and pollution, i.e. pollution increases with income at low levels of income and decreases at high levels of income, with the turning point for most of the pollutants coming before a country reaches a per capita income of USD 8, 000 (Grossman and Kruger, 1995, p.370).

Since the appearance of EKC literature review, there are two different schools of thought: The first one, supporting the EKC implication that economic growth is ultimately good for environment (Beckerman, 1992; Shafik and Bandyopadhyay, 1992; Grossman and Krueger, 1995; Lomborg, 2001); and the second one, pointing a number of methodological flaws in deriving the EKC (Arrow et al, 1995; Stern et al 1996; Ekins, 1997; Stern, 1998; Suri and Chapman, 1998; Rothman, 1998; Stern and Common, 2001; Cole, 2003, 2004). Since the mid – 1990s, the EKC has been attacked on both empirical and methodological grounds, a trend that has continued in recent years, and the results have been far more ambiguous (Nahman and Antrobus, 2005; Shen, 2006; Beak and Koo, 2009; Mulali et al, 2015; etc). In order to explain for the mixed empirical results in EKC, Nahman and Antrobus (2005) stated that *"in some cases the data does give rise to an EKC-type relationship, in other cases it does not, while in many cases the emergence of an EKC-type relationship depends on the variables included in and the functional form attached to the statistical model, or on the type of model used"* (Nahman and Antrobus 2005, p.110). The critiques of EKC were divided into two groups: Methodology and interpretation of results (Cole, 2003). Due to the collinearity or multicollinearity problems that may arise between GDP and square of GDP in EKC hypothesis when the environmental degradation is a function of GDP and square of GDP, Narayan and Narayan (2010) proposed a new way of testing whether a country or group of countries has reduced CO_2 emissions over time with growth in real per capita GDP. They suggest comparing the short and long-run elasticities, if the long-run income elasticity is smaller than the short-run elasticity, then we can conclude that over time, income leads to less carbon dioxide emissions. The results of panel data of 43 developing countries during period 1980-2004 reveal that only in Middle Eastern and South Asian panels the income elasticity in the long-run is smaller than the short-run, denoting that CO_2 emissions has fallen with a rise in income. Simultaneously, Jaunky (2011) based on the methodology of Narayan and Narayan to test the CO_2 emissions-income nexus for 36 high-income countries for the period 1980-2005, and found that in the long-run, CO_2 emissions have fallen as income rises.

Different studies in the EKC literature employs different indicators such as carbon dioxide (CO_2), sulfur dioxide emissions (SO_2) (Boulatoff and Jenkins, 2010); urban air quality (Esty and Porter, 2005); deforestation (Ehrhardt-Martinez et al., 2002), and waste (Mazzanti et al., 2009). The empirical result is mixed, however. It is not possible to talk about a unique curve for all types of environmental degradation, which raises doubts about the generalize ability of the EKC hypothesis (Ozler and Obach, 2009).

Grossman and Krueger (1991) described three possible sources of environmental impact from economic growth: A scale effect, a technique effect, and composition effect; and, some studies have done to break down these effects. Panayotou (1997) argued that the determinants of environmental quality include: (1) the scale of economic activity (scale effects); (2) the composition of economic activity (composition effects), and (3) the effect of income on the demand and supply of pollution abatement efforts (pure income effects). The scale effect is expected to be a monotonically increasing function of income while the income effect is monotonically the decreasing function of income, all else being equal. The composition effect is likely to be a non-monotonic (inverted –U) function of income. Panayotou (1997) specified a cubic function form for all decomposition effects with other variables including population density, the rate of economic growth and the quality of institutions. The results on ambient SO_2 levels confirmed the expectation of the three effects, and also suggested that policies and institutions can help flatten the EKC and reduce the environmental price of economic growth. De Bruyn et al. (1998) adopted a dynamic model and estimated for three types of emissions (CO_2, NO_x, and SO_2) in four developed countries (Netherlands, UK, US, and Western Germany). They found that these emissions may decline over time, probably due to structural and technological changes.

For individual countries, Vincent et al. (1997) found that suspended particulate matter (SPM) and chemical oxygen demand (COD) increase with income, while biochemical oxygen demand (BOD) decreases with income in Malaysia; whereas Carson et al (1997) found that all major air pollutants declined with increasing levels of income across 50 US states. In China, Shen (2006) used a simultaneous equation model to examine the existence of the EKC relationship between per capita income and per capita pollution emissions. Shen (2006) tested two air pollutants (SO_2 and dust fall) and three water pollutants (COD, arsenic, and cadmium) from 1993 to 2002 in 31 Chinese provinces and municipalities. The results suggested an EKC relationship for all water pollutants, while SO_2 showed a U-shaped relationship with income levels and dust fall has no significant relationship with income levels. Besides, government expenditure on pollution abatement had a significant, and negative, effect on pollution; while the net effect of secondary industries on pollution emissions were all positive and significant. In a related paper, Zhang (2013) used a panel of 112 Chinese cities over four years from 2001 to 2004 to examine the income-pollution nexus for several water and air pollution indicators. The majority of pollutant emissions confirmed that at current income levels in China, economic development will induce more industrial pollution emissions; whereas EKC was found to exist for wastewater and petroleum-like matter with the estimated turning point is USD 3,605 and USD 4,992 (at 1990 prices), respectively. Therefore, environmental policy and industrial structure both play important roles in determining water and air pollution levels in China.

4.3.2. Ownership and environment

The literature on state-owned enterprises and privatization emphasizes that the lack of clearly defined property rights in state-owned enterprises leads state-owned enterprise managers to have weaker incentives to pursue profit and efficiency than those in privately owned firms including multinational corporations. Hence state-owned enterprises are often expected to be relatively inefficient compared to private firms. Moreover, governments have often established state-owned enterprises in imperfectly competitive or highly regulated industries, where the lack of competition further weakens the pressure to instill efficiency. Dunning (1988) asserted that a firm must first have “ownership advantages” as would be afforded by the possession of relatively large amounts of intangible assets, as well as “location advantages” and “internalization advantages” before investing in a foreign country. And if multinational corporations have relatively large amounts of knowledge-based, intangible assets, they will tend to be relatively efficient producers compared to non-multinational corporations, at least in some respect. And this relatively high efficiency could involve multinational corporations becoming more energy efficient and/or polluting less as part of efforts to facilitate increased demand among consumers and minimize production costs related to energy and pollution abatement needs. It is logical to expect that multinational corporations are relatively efficient producers and consumers of goods and services that promote energy efficiency and pollution reduction when multinational corporations tend to be relatively R&D and patent-intensive and because technologies for clean energy and pollution control usually require relatively sophisticated technological inputs. Cole et al. (2006) suggest that Japanese firms with FDI tend to have better environmental performance (pollute less and manage emissions better) than firms without FDI is consistent with the notion that MNCs are both better able to and more highly motivated to pollute less than other firms.

In Vietnam, state-owned enterprises are expected to be more responsive to the public or government needs that private firms and the government has emphasized how state-owned enterprises should play leading roles in industry and that private firms should seek to cooperate with state-owned enterprises (Vu 2005, pp. 304-306). Thus, if the government puts a priority on low pollution and/or abatement of emissions, then it is reasonable to expect that SOEs might be more motivated to pollute less and abate more than private firms. However, it is difficult to argue convincingly that the Vietnamese government has put a high priority on pollution reduction or abatement in the last decade, for example, or that the government has emphasized energy efficiency or low pollution when operating its SOEs. Thus, if the SOEs in Vietnam pollute relatively little, it is probably more related to differences in technical characteristics of the firms and the fact that the Vietnamese government chooses to own SOEs that are often relatively sophisticated technologically compared to private firms. As in the comparison of MNCs and non-MNCs, the fact that one group possesses more technology-related assets than the other is the key, differentiating characteristic.

4.3.3. Literature review on Vietnam

As Vietnam has become another successful Asian transition economy in terms of growth performance, the consequences of economic development on the environment have examined accordingly. To our knowledge, there are quite a few researches that investigate the EKC hypothesis in Vietnam basing on time series data and CO_2 emissions variables for pollution have done with mixed results. Pham (2017) examined the relationship between foreign direct investment economic growth, and CO_2 emissions basing on time series data from 1988 to 2015, and revealed that pollution haven hypothesis does not exist in Vietnam; it is consistent with the outcomes of Al-Mulali et al (2015) and Dinh et al (2012). However, Tang and Tan (2015) confirmed the existence of EKC hypothesis and assumed an inverted U-shaped relationship between CO_2 emissions and economic growth.

For panel data study, there is only one study of Ramstetter (2011) that investigated the ownership and pollution in Vietnam's manufacturing firms in 2002 and 2004. For this research, the simple descriptive statistics suggest that multinational corporations (MNCs) tended to have relatively low propensities in a few industries while state-owned enterprises (SOEs) tended to have relatively high ratios in a few more industries. After accounting for the influences of other factor demands and technology intensity, the outcomes demonstrate SOEs tended to have relatively high emission propensities in several cases and that MNCs also had relatively high emission propensities in a few cases. However, in most industry-year combinations, it was difficult to find statistically significant differences in emission propensities. Due to the absence of statistical studies in examining economic growth and pollution in Vietnam, especially at the city-level characteristics; this study, therefore, aims to at least partially fill this gap in the literature by examining the extent to which economic growth influences industrial pollution emissions in Vietnam using data for 63 cities between 2000 and 2013. Also, we examine three industrial pollution indicators including gaseous, solid waste and liquid waste; as well as separate the impact of the state economic sector, non-state economic sector, and foreign investment economic sector on waste emissions in Vietnam.

4.4. Methodology

4.4.1. Model specifications

To investigate the relationship between economic growth and environment, we start by estimating the following reduced-form equation for the emission of industrial pollutants:

$$\ln Epc_{it} = \gamma_i + \theta_t + \beta_1 \ln GDP_{it} + \varepsilon \quad (1)$$

$$\ln Epc_{it} = \gamma_i + \theta_t + \beta_1 \ln GDP_{it} + \beta_2 (\ln GDP_{it})^2 + \varepsilon \quad (2)$$

$$\ln Epc_{it} = \gamma_i + \theta_t + \beta_1 \ln GDP_{it} + \beta_2 (\ln GDP_{it})^2 + \beta_3 (\ln GDP_{it})^3 + \varepsilon \quad (3)$$

Where Epc denotes per capita emissions including liquid waste, gaseous waste, and solid waste; γ is city-specific intercepts, θ_t is time-specific intercepts, GDP presents per capita income, ε is the error term. Subscripts *i* and *t* represent city and year, respectively.

We include per capita income (GDP), and then add its quadratic term (GDP^2) and finally the cubic term (GDP^3). If linear regression is considered, we expect a positive relationship between income and pollution at current economic development levels in Vietnam. If a quadratic function is estimated, we expect a standard EKC relationship (inverted-U) between income and pollution, which is $\beta_1 > 0$ and $\beta_2 < 0$. Following Grossman and Krueger (1995), we expect negative β_1 and β_3 and a positive β_2 in the cubic functions.

To avoid the problem that the model is whether the unobserved individual-specific effects and time effects, we estimate two-way fixed effects and random effects error component models. For our fixed effects models, we initially use the within regression estimator, which is a pooled ordinary least square (OLS) estimator based on time – demeaned variables, or uses the time variation in both dependent and independent variables within each cross-sectional observation (Wooldridge, 2000). For the random effects models, we choose the generalized least square (GLS) estimator, which produces a matrix-weighted average of the between and within estimator results.

The equations are estimated using two alternative functional forms in logs to reduce the positive skewness of all the dependent and independent variables. We estimated both fixed and random effects models. Hausman specification tests were performed to discover whether the random effects model was appropriate and suggest that the random effects estimator was not efficient and therefore we focused on the fixed effects model results. Time dummy variables are included for all estimations.

When we perform the diagnostic test (heteroskedasticity and cross-sectional correlation across panels) of the fixed effects model for the equation (1), (2), and (3) for all three kinds of waste emissions, the results reveal that the fixed effects models have cross-sectional dependence, except for the model of equation (1), and (2) of liquid waste. At the same time, the residuals of all models are heteroskedastic; therefore the results of the fixed effects model are not reliable. (Appendix 4.4)

To correct the problems of autocorrelation and heteroskedastic of the fixed effects model, we employed Feasible Generalised Least Square (FGLS) methodology. For the FGLS methodology, the models are homoskedastic, and there is no autocorrelation; hence the results are reliable. The FGLS estimation results are reported in Table 4.2.

At the same time, we want to separate the impact of foreign owned firms on emission wastes from that of domestically owned firms including state owned enterprises and private enterprises. We therefore require a variable that captures the scale of activity of such firms within the city. While direct measures of FDI inflows, turnover of the state economic sector and the non-state economic sector are not available in each city, we are only able to decompose GDP of Vietnam into three components: the contribution of state economic sector, non-state economic sector and foreign investment economic sector (Figure 4.1). Thus, we have the following model:

$$\ln waste_t = \lambda_1 + \lambda_2 \ln GDP_{(state)t} + \lambda_3 \ln GDP_{(nonstate)t} + \lambda_4 \ln GDP_{(fdi)t} + \nu_t \qquad (4)$$

Where waste denote waste emissions including liquid waste, gaseous waste, and solid waste, t is time series from 2000 to 2015; $GDP_{(state)}$, $GDP_{(nonstate)}$, $GDP_{(fdi)}$ present the rate of state economic sector, non-state economic sector and foreign investment economic sector to GDP, and ν_t is error term.

4.4.2. Data description

The panel data for 63 provinces in Vietnam from 2000 to 2013 are extracted from the statistical yearbooks of GSO of Vietnam that will be used in this research. All the values of per capita GDP are adjusted to 2010 prices using GDP deflator. Emissions data are reported in terms of total emissions for a large selection of key enterprises in each city; however the number of selected enterprises and the proportion of enterprises vary across cities. Such data cannot provide information of total industrial pollution emissions at the city-level; therefore General Statistics Office of Vietnam had to convert available pollution emissions of selected enterprises to the emissions of all the enterprises in the city. Total emissions are then scaled by the population to form per capita emissions. Although, some limitations exist in the emissions data; but it is the only available source to arrive at the total industrial pollution emissions in each city in Vietnam. Appendix 4.2 and 4.3 provide summary statistics and a correlation matrix of variables, respectively.

The data for liquid waste, gaseous waste, and solid waste, and GDP by economic sector including state, non-state, and foreign investment are extracted from statistical yearbooks of GSO of Vietnam from 2000 to 2015.

4.5. Empirical results

In Table 4.2, columns 1, 4, 7 and 2, 5, 8 provide linear and quadratic specifications of the simple relationship between income and emissions with no further controls. The quadratic specification (columns 2, 5, and 8) provides a direct test of the EKC hypothesis. Columns 3, 6 and 9 illustrate the results of cubic functions.

Gaseous waste

Column 1 for gaseous waste shows a statistically significant and positive relationship between income and emissions of gaseous. It confirms our expectation that economic growth induces more gaseous waste pollution at current income levels for all cities in Vietnam. The income elasticity is approximately 0.364, indicating that a 1 per cent increase in per capita income will increase per capita emissions of gaseous by 0.364 per cent. It is consistent with the findings in Shen (2006) and Zhang (2013).

When a quadratic specification is considered, we could not find an inverted -U shaped the relationship between income and per capita emissions. The relationship between quadratic income and gaseous waste per capita is significant at 1 per cent but it is positive, indicating that economic growth is increasing environmental pollution levels in Vietnam, and most Vietnamese cities are on the up sloping part of the curve; however there is a decrease slightly when a 1 per cent increase in per capita income only results in going up of gaseous waste by 0.23 per cent approximately.

Column 3 shows the result of cubic relationship, the sign of income elastic is positive (0.223) and significant at 1 per cent; it confirms that the increase in income still induces more gaseous waste in Vietnam.

Solid waste

The result of solid waste in column 4 is almost the same result of gaseous waste in column 1 when a 1 per cent increase in per capita income will increase per capita of solid waste by 0.347 per cent. Thus, economic growth causes the rise of gaseous and solid waste at the same rate at the provincial level in Vietnam. For the consideration of the quadratic specification, the income elastic is negative (- 0.294) but it is insignificant; therefore it could not provide evidence of an inverted -U EKC relationship.

Column 6 provides the results to support the conclusion of economic development which leads to the growth of gaseous and solid waste at the same level, around 22 per cent.

Liquid waste

In respect to liquid waste, the coefficient of linear specification indicates that economic growth induces more liquid waste than gaseous and solid waste, a 1 per cent in per capita income causes approximate 0.4 per cent in liquid waste (0.364, and 0.347 per cent for gaseous and solid waste, respectively). It is supported by the results of Zhang (2013).

An inverted – U shaped relationship between income and per capita emissions does not exist here when the elastic of quadratic function is significant but it is positive (0.203). The coefficients of per capita income and quadratic per capita income are around 20 per cent; indicating that at higher income levels, the increase in pollution emissions is still the same.

The result of the cubic function is positive and significant at 1 per cent level. It is 0.159 and smaller than the coefficients of a linear and quadratic function (0.397, and 0.203 respectively); hence the increase in income level will decrease liquid waste significantly.

Table 4.2 Fixed effects model results

	Gaseous waste			Solid waste			Liquid waste		
Variables	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
GDP	0.364	0.159	0.078	0.347	0.374	0.294	0.397	0.217	0.160
	(11.61)***	(2.38)**	(1.15)	(7.19)***	(3.62)***	(2.78)***	(3.432)***	(3.31)***	(2.38)**
GDP^2		0.2327	0.143		-0.294	-1.118		0.203	0.1397
		(3.5)***	(2.10)**		(0.29)	(1.11)		(3.10)***	(2.06)**
GDP^3			0.223			0.221			0.159
			(4.89)***			(3.09)***			(3.51)***
Constant	3.621	3.467	3.164	3.324	3.343	3.044	3.432	3.299	3.082
	(19.85)***	(18.59)***	(16.30)***	(11.81)***	(11.55)***	(10.02)***	(19.10)***	(17.93)***	(15.99)***
EKC		No			No			No	
Observations	869	869	869	818	818	818	869	869	869

Notes: Absolute value of z-statistics in parentheses. All variables are in logs. The asterisks ***, ** and * denote significance at 1, 5 and 10 per cent levels, respectively.

The results of equation (4) are reported in Table 4.3. For gaseous waste, the outcome of the state economic sector and foreign sector are positive and significant at 1 per cent level; at the same time, it reveals that the state economic sector produces more gaseous waste than the foreign economic sector when the coefficient of the state economic sector is greater than the foreign direct investments' one, 1,547.578, and 1,134.035, respectively. The coefficient of the non-state economic sector is positive, but it is insignificant.

Table 4.3 OLS results

Variables	Gaseous waste	Liquid waste	Solid waste
State economic sector	1547.578	189.286	99.787
	(4.366)***	(3.368)***	(4.965)***
Non-state economic sector	224.932	40.680	4.661
	(-1.414)	(1.613)	(0.517)
Foreign sector	1134.035	102.033	16.162
	(6.488)***	(3.681)***	(1.630)
Constant	-857511	-58888	926677.2
	(-0.523)	(-2.263)**	(0.099)
R^2	0.998	0.996	0.996

Notes: Absolute value of t-statistics in parentheses. All variables are in logs. The asterisks ***, ** and * denote significance at 1, 5 and 10 per cent levels, respectively.

In respect to liquid waste, and solid waste, the results of the non-state economic sector are the same as the outcome of gaseous waste. This result suggests that the non-state economic sector produces less waste emissions in Vietnam than the state economic sector and foreign investment economic sector. The coefficients of the state economic sector and foreign investment are positive and significant. It reveals that 1 per cent increase in GDP from the state economic sector and foreign investment economic sector will lead to 189.286 and 102.033 units of liquid waste accordingly. At the same time, the coefficient of the state economic sector in solid waste is positive significantly, 1 per cent growth in GDP from the state economic sector will increase around 100 units of solid waste; whereas the result of the foreign investment economic sector is insignificant in this group of waste.

The regression model results reveal that the state economic sector in Vietnam produces more waste emissions than the foreign investment economic sector between 2000 and 2015. The result of the non-state economic sector is inconclusive. This outcome is consistent with Ramstetter (2011).

Ultimately, the diagnostic tests on the OLS models of gaseous waste, solid waste and liquid waste are applied, and the models are serially uncorrelated, heteroskedasticity, and normally distributed. Thus, the results are reliable and can be applied for policy implications. (The detail results in Appendix 4.5)

4.6. Conclusion

In this paper, we used a panel of 63 Vietnamese cities over 14 years to examine the income-pollution nexus for gaseous, solid and liquid waste; at the same time we investigate the impact of state economic sector, non-state economic sector, and foreign investment economic sector on waste emissions during the period between 2000 and 2015.

The evidence from the majority of pollutant emissions confirms that at current income levels in Vietnam, economic development will induce more industrial pollution emissions, that is, the net effect of economic growth on environment quality is negative. Notably, the increase in income induces more liquid waste than gaseous and solid waste due to a large amount of waste water discharged from industrial zones, and manufacturing establishments without proper treatment as well as the subsectors significantly contributed in water pollution[1] Besides, the environmental Kuznets curve is not found to exist in Vietnam at the provincial level, indicating that Vietnamese economy is still at the initial stages of development. It is consistent with the finding of Pham (2017), Al-Mulali et al (2015), and Dinh et al (2012) for the studies of Vietnam; and Matthew et al (2011) for the case of China.

In respect to the impact of economic sectors on waste emissions, the results suggest that the state economic sector tended to have relatively more high waste emissions in all kind of wastes, and the foreign investment economic sector also had relatively high waste emissions in gaseous and liquid waste; whereas the outcome for the non-state sector is insignificant in all kind of wastes.

The largely positive relationship between income and emissions suggests that the increased stringency and enforcement of environmental regulations are crucial to alleviate pressure on the natural environment in Vietnam. For further research, it should be possible to explore panel estimates across regions in Vietnam by adding other variables such as energy

[1] INVEN-2: Mitigation of environmental impacts related to foreign direct investment in Vietnam, p.55

consumption (Tang et al. 2015, Al-Mulali et al 2015), factor demand, and technology intensity (Ramstetter et al. 2013) as well as other waste emissions and ownership data to gain more understanding of the issues.

Appendix 4.1 Economic growth and social welfare gain

Year	GDP growth (per cent)	GDP per capita (USD)	Year	GDP growth (per cent)	GDP per capita (USD)
1986	2.3	202	2001	6.9	416
1987	3.6	205	2002	7.1	441
1988	6	211	2003	7.3	492
1989	4.7	220	2004	7.8	558
1990	5.1	227	2005	8.4	642
1991	6	235	2006	7	797
1992	8.7	251	2007	7.1	919
1993	8.1	266	2008	5.7	1,165
1994	8.8	285	2009	5.3	1,232
1995	9.5	301	2010	6.4	1,334
1996	9.3	337	2011	6.2	1,543
1997	8.2	261	2012	5.3	1,755
1998	5.8	365	2013	5.4	1,909
1999	4.8	374	2014	5.9	2,357
2000	6.8	402	2015	6.2	2,520

Source: Vietnam, General Statistics Office yearbook 1994-2015

Appendix 4.2 Descriptive statistics of variables

Variable	Obs.	Mean	Std.Dev.	Min	Max
Gas waste (m3 per 1000 persons)	869	3029.732	9370.590	18.703	56242.244
Liquid waste (m3 per 1000 persons)	869	1208.997	10316.069	2.263	61898.683
Solid waste (tons per 1000 persons)	818	21253.046	71439.703	1.491	428639.715
GDP (billion VND per 1000 persons)	882	18.474	37.307	1.949	225.792

Source: The statistical results from Stata 12

Appendix 4.3 Correlations of the variables

	Gas waste	Liquid waste	Solid waste	GDP	GDP^2	GDP^3
Gas waste	1.0000					
Liquid waste	-0.0515	1.0000				
Solid waste	0.1786	-0.1393	1.0000			
GDP	0.0805	-0.0792	0.1470	1.0000		
GDP^2	0.0970	-0.0545	0.1127	0.8663	1.0000	
GDP^3	0.0616	0.0289	0.0334	0.6151	0.5867	1.0000

Source: The statistical results from Stata 12

Appendix 4.4 Diagnostic tests for the fixed effects models of all waste emissions According to the equation (1), (2), and (3)

1. Gaseous waste

```
. xtreg  lngas lngdp, fe

Fixed-effects (within) regression               Number of obs      =       882
Group variable: province                        Number of groups   =        63

R-sq:  within  = 0.0832                         Obs per group: min =        14
       between = 0.4947                                        avg =      14.0
       overall = 0.1326                                        max =        14

                                                F(1,818)           =     74.22
corr(u_i, Xb)  = 0.2076                         Prob > F           =    0.0000

------------------------------------------------------------------------------
       lngas |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lngdp |   .2983946   .0346352     8.62   0.000     .2304103    .3663788
       _cons |   3.995565    .200564    19.92   0.000     3.601885    4.389246
-------------+----------------------------------------------------------------
     sigma_u |    .378232
     sigma_e |  1.0793911
         rho |  .10936058   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(62, 818) =     1.64             Prob > F = 0.0017
```

Pesaran test for autocorrelation:

```
. xtcsd, pesaran abs


Pesaran's test of cross sectional independence =     2.553, Pr = 0.0107

Average absolute value of the off-diagonal elements =     0.309

.
```

Ho: there is no cross sectional dependence

H1: there is cross-sectional dependence

Pr=0.01, which is less than 5 per cent, therefore we reject Ho, accept H1; it means that the model has cross-sectional dependence or autocorrelation; hence the model is not desirable.

Heteroskedasticity test:

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (63)  =      350.41
Prob>chi2 =       0.0000
```

Ho: residuals are homoskedastic

H1: residuals are heteroskedastic

Prob>chi2 equals 0 per cent, which is less than 5 per cent; therefore we reject Ho, and accept H1; it means that the residuals of model are heteroskedastic, it is not desirable model.

```
. xtreg  lngas lngdp  lngdp2, fe

Fixed-effects (within) regression               Number of obs      =       882
Group variable: province                        Number of groups   =        63

R-sq:  within  = 0.0880                         Obs per group: min =        14
       between = 0.5947                                        avg =      14.0
       overall = 0.1443                                        max =        14

                                                F(2,817)           =     39.42
corr(u_i, Xb)  = 0.2492                         Prob > F           =    0.0000

------------------------------------------------------------------------------
       lngas |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lngdp |   .1497833   .0794659     1.88   0.060    -.0061982    .3057647
      lngdp2 |   .1627258   .0783507     2.08   0.038     .0089334    .3165183
       _cons |   3.915185   .2038664    19.20   0.000     3.515021    4.315348
-------------+----------------------------------------------------------------
     sigma_u |   .3666063
     sigma_e |  1.0772116
         rho |  .10380116   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(62, 817) =     1.52              Prob > F = 0.0076

. xtcsd, pesaran abs


Pesaran's test of cross sectional independence =     2.220, Pr = 0.0264

Average absolute value of the off-diagonal elements =     0.307

.
```

Ho: there is no cross sectional dependence

H1: there is cross-sectional dependence

Pr = 0.02, which is less than 5 per cent, therefore we reject Ho, accept H1; it means that the model has cross-sectional dependence or autocorrelation; hence the model is not desirable.

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (63)  =      309.94
Prob>chi2 =       0.0000
```

Ho: residuals are homoskedastic

H1: residuals are heteroskedastic

Prob>chi2 equals 0 per cent, which is less than 5 per cent; therefore we reject Ho, and accept H1; it means that the residuals of model are heteroskedastic, it is not desirable model.

```
. xtreg  lngas lngdp  lngdp2  lngdp3, fe

Fixed-effects (within) regression               Number of obs      =       882
Group variable: province                        Number of groups   =        63

R-sq:  within  = 0.1037                         Obs per group: min =        14
       between = 0.6752                                        avg =      14.0
       overall = 0.1671                                        max =        14

                                                F(3,816)           =     31.46
corr(u_i, Xb)  = 0.2751                         Prob > F           =    0.0000

------------------------------------------------------------------------------
       lngas |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lngdp |   .0623664   .0821558     0.76   0.448    -.0988952     .223628
      lngdp2 |   .1143371    .078771     1.45   0.147    -.0402806    .2689548
      lngdp3 |   .1802296   .0477166     3.78   0.000     .0865679    .2738913
       _cons |   3.662195   .2130346    17.19   0.000     3.244035    4.080356
-------------+----------------------------------------------------------------
     sigma_u |  .34874541
     sigma_e |  1.0685708
         rho |  .09626161   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(62, 816) =     1.38             Prob > F = 0.0318


. xtcsd, pesaran abs


Pesaran's test of cross sectional independence =     2.714, Pr = 0.0066

Average absolute value of the off-diagonal elements =     0.305
```

Ho: there is no cross sectional dependence

H1: there is cross-sectional dependence

Pr = 0.006, which is less than 5 per cent, therefore we reject Ho, accept H1; it means that the model has cross-sectional dependence or autocorrelation; hence the model is not desirable.

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (63)  =      313.88
Prob>chi2 =       0.0000
```

Ho: residuals are homoskedastic

H1: residuals are heteroskedastic

Prob>chi2 equals 0 per cent, which is less than 5 per cent; therefore we reject Ho, and accept H1; it means that the residuals of model are heteroskedastic, it is not desirable model.

2. Solid waste

```
. xtreg  lnsolid lngdp, fe

Fixed-effects (within) regression               Number of obs      =       882
Group variable: province                        Number of groups   =        63

R-sq:  within  = 0.0222                         Obs per group: min =        14
       between = 0.1775                                        avg =      14.0
       overall = 0.0554                                        max =        14

                                                F(1,818)           =     18.56
corr(u_i, Xb)  = 0.1731                         Prob > F           =    0.0000

------------------------------------------------------------------------------
     lnsolid |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lngdp |    .144256   .0334867     4.31   0.000     .0785261     .209986
       _cons |   4.483686   .1939134    23.12   0.000      4.10306    4.864313
-------------+----------------------------------------------------------------
     sigma_u |  1.4040072
     sigma_e |   1.043599
         rho |  .64412429   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(62, 818) =    24.58             Prob > F = 0.0000
```

```
. xtcsd, pesaran abs


Pesaran's test of cross sectional independence =     2.584, Pr = 0.0098

Average absolute value of the off-diagonal elements =     0.301

.
```

Ho: there is no cross sectional dependence

H1: there is cross-sectional dependence

Pr = 0.009, which is less than per cent, therefore we reject Ho, accept H1; it means that the model has cross-sectional dependence or autocorrelation; hence the model is not desirable.

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (63)  =      313.88
Prob>chi2 =       0.0000
```

Ho: residuals are homoskedastic

H1: residuals are heteroskedastic

Prob>chi2 equals 0 per cent, which is less than 5 per cent; therefore we reject Ho, and accept H1; it means that the residuals of model are heteroskedastic, it is not desirable model.

```
. xtreg  lnsolid lngdp  lngdp2, fe

Fixed-effects (within) regression               Number of obs      =       882
Group variable: province                        Number of groups   =        63

R-sq:  within  = 0.0249                         Obs per group: min =        14
       between = 0.1423                                        avg =      14.0
       overall = 0.0470                                        max =        14

                                                F(2,817)           =     10.42
corr(u_i, Xb)  = 0.1440                         Prob > F           =    0.0000

------------------------------------------------------------------------------
     lnsolid |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lngdp |   .0403002   .0769275     0.52   0.601    -.1106986     .191299
      lngdp2 |   .1138292   .0758479     1.50   0.134    -.0350505    .2627089
       _cons |   4.427459   .1973541    22.43   0.000     4.040078     4.81484
-------------+----------------------------------------------------------------
     sigma_u |  1.4078903
     sigma_e |  1.0428011
         rho |  .64573952   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(62, 817) =    24.65             Prob > F = 0.0000

.
```

```
. xtcsd, pesaran abs

Pesaran's test of cross sectional independence =     2.284, Pr = 0.0224

Average absolute value of the off-diagonal elements =     0.300

.
```

Ho: there is no cross sectional dependence

H1: there is cross-sectional dependence

Pr = 0.02, which is less than 5 per cent, therefore we reject Ho, accept H1; it means that the model has cross-sectional dependence or autocorrelation; hence the model is not desirable.

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (63)  =    2.0e+06
Prob>chi2 =      0.0000
```

Ho: residuals are homoskedastic

H1: residuals are heteroskedastic

Prob>chi2 equals 0 per cent, which is less than 5 per cent; therefore we reject Ho, and accept H1; it means that the residuals of model are heteroskedastic, it is not desirable model.

```
. xtreg  lnsolid lngdp  lngdp2  lngdp3, fe

Fixed-effects (within) regression               Number of obs      =       882
Group variable: province                        Number of groups   =        63

R-sq:  within  = 0.0423                         Obs per group: min =        14
       between = 0.1196                                        avg =      14.0
       overall = 0.0517                                        max =        14

                                                F(3,816)           =     12.01
corr(u_i, Xb)  = 0.1199                         Prob > F           =    0.0000

------------------------------------------------------------------------------
     lnsolid |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lngdp |  -.0459672   .0795042    -0.58   0.563    -.2020239    .1100896
      lngdp2 |   .0660768   .0762286     0.87   0.386    -.0835505     .215704
      lngdp3 |   .1778596   .0461765     3.85   0.000     .0872209    .2684983
       _cons |   4.177796   .2061588    20.26   0.000     3.773132     4.58246
-------------+----------------------------------------------------------------
     sigma_u |  1.4047102
     sigma_e |  1.0340818
         rho |  .64854149   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(62, 816) =    24.90             Prob > F = 0.0000

. xtcsd, pesaran abs


Pesaran's test of cross sectional independence =     3.552, Pr = 0.0004

Average absolute value of the off-diagonal elements =     0.290

.
```

Ho: there is no cross sectional dependence

H1: there is cross-sectional dependence

Pr = 0.000, which is less than 5 per cent, therefore we reject Ho, accept H1; it means that the model has cross-sectional dependence or autocorrelation; hence the model is not desirable.

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (63)  =    11035.87
Prob>chi2 =      0.0000
```

Ho: residuals are homoskedastic

H1: residuals are heteroskedastic

Prob>chi2 equals 0 per cent, which is less than 5 per cent; therefore we reject Ho, and accept H1; it means that the residuals of model are heteroskedastic, it is not desirable model.

2. Liquid waste

```
. xtreg  lnliquid lngdp, fe

Fixed-effects (within) regression               Number of obs      =       882
Group variable: province                        Number of groups   =        63

R-sq:  within  = 0.1124                         Obs per group: min =        14
       between = 0.4420                                        avg =      14.0
       overall = 0.1578                                        max =        14

                                                F(1,818)           =    103.62
corr(u_i, Xb)  = 0.1601                         Prob > F           =    0.0000

------------------------------------------------------------------------------
    lnliquid |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lngdp |   .3449775     .03389    10.18   0.000      .278456     .411499
       _cons |   3.730281   .1962487    19.01   0.000      3.34507    4.115491
-------------+----------------------------------------------------------------
     sigma_u |  .38948933
     sigma_e |   1.056167
         rho |  .11971517   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(62, 818) =     1.86              Prob > F = 0.0001

. xtcsd, pesaran abs


Pesaran's test of cross sectional independence =     1.815, Pr = 0.0696

Average absolute value of the off-diagonal elements =     0.309

.
```

Ho: there is no cross sectional dependence

H1: there is cross-sectional dependence

Pr = 0.06, which is greater than 5 per cent, therefore we cannot reject Ho, we accept it; it means that the model has no cross-sectional dependence or autocorrelation; hence the model is desirable.

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (63)  =    5421.28
Prob>chi2 =      0.0000
```

Ho: residuals are homoskedastic

H1: residuals are heteroskedastic

Prob>chi2 equals 0 per cent, which is less than 5 per cent; therefore we reject Ho, and accept H1; it means that the residuals of model are heteroskedastic, it is not desirable model.

```
. xtreg  lnliquid lngdp  lngdp2, fe

Fixed-effects (within) regression               Number of obs      =       882
Group variable: province                        Number of groups   =        63

R-sq:  within  = 0.1165                         Obs per group: min =        14
       between = 0.5036                                        avg =      14.0
       overall = 0.1667                                        max =        14

                                                F(2,817)           =     53.87
corr(u_i, Xb)  = 0.1898                         Prob > F           =    0.0000

------------------------------------------------------------------------------
    lnliquid |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lngdp |   .2088717   .0777816     2.69   0.007     .0561964    .3615469
      lngdp2 |   .1490327     .07669     1.94   0.052       -.0015    .2995654
       _cons |   3.656664   .1995453    18.32   0.000     3.264982    4.048345
-------------+----------------------------------------------------------------
     sigma_u |  .38108964
     sigma_e |  1.0543791
         rho |  .11554153   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(62, 817) =     1.76              Prob > F = 0.0004
```

```
. xtcsd, pesaran abs

Pesaran's test of cross sectional independence =     1.840, Pr = 0.0658

Average absolute value of the off-diagonal elements =     0.307

.
```

Ho: there is no cross sectional dependence

H1: there is cross-sectional dependence

Pr = 0.06, which is greater than 5 per cent, therefore we cannot reject Ho, we accept it; it means that the model has no cross-sectional dependence or autocorrelation; hence the model is desirable.

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (63)  =    6589.59
Prob>chi2 =      0.0000
```

Ho: residuals are homoskedastic

H1: residuals are heteroskedastic

Prob>chi2 equals 0 per cent, which is less than 5 per cent; therefore we reject Ho, and accept H1; it means that the residuals of model are heteroskedastic, it is not desirable model.

```
. xtreg  lnliquid lngdp  lngdp2  lngdp3, fe

Fixed-effects (within) regression               Number of obs      =       882
Group variable: province                        Number of groups   =        63

R-sq:  within  = 0.1240                         Obs per group: min =        14
       between = 0.5465                                        avg =      14.0
       overall = 0.1782                                        max =        14

                                                F(3,816)           =     38.49
corr(u_i, Xb)  = 0.2053                         Prob > F           =    0.0000
```

lnliquid	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lngdp	.1489207	.0807715	1.84	0.066	-.0096237	.3074652
lngdp2	.1158474	.0774438	1.50	0.135	-.036165	.2678599
lngdp3	.1236023	.0469126	2.63	0.009	.0315188	.2156859
_cons	3.483162	.2094451	16.63	0.000	3.072048	3.894277
sigma_u	.37175565					
sigma_e	1.0505658					
rho	.11128375	(fraction of variance due to u_i)				

```
F test that all u_i=0:     F(62, 816) =     1.68             Prob > F = 0.0012
```

```
. xtcsd, pesaran abs

Pesaran's test of cross sectional independence =     2.129, Pr = 0.0333

Average absolute value of the off-diagonal elements =     0.310
```

Ho: there is no cross sectional dependence

H1: there is cross-sectional dependence

Pr = 0.03, which is greater than 5 per cent, therefore we cannot reject Ho, we accept it; it means that the model has no cross-sectional dependence or autocorrelation; hence the model is desirable.

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (63)  =     2514.88
Prob>chi2 =      0.0000
```

Ho: residuals are homoskedastic

H1: residuals are heteroskedastic

Prob>chi2 equals 0 per cent, which is less than 5 per cent; therefore we reject Ho, and accept H1; it means that the residuals of model are heteroskedastic, it is not desirable model.

Appendix 4.5 OLS results and the features of a good regression model

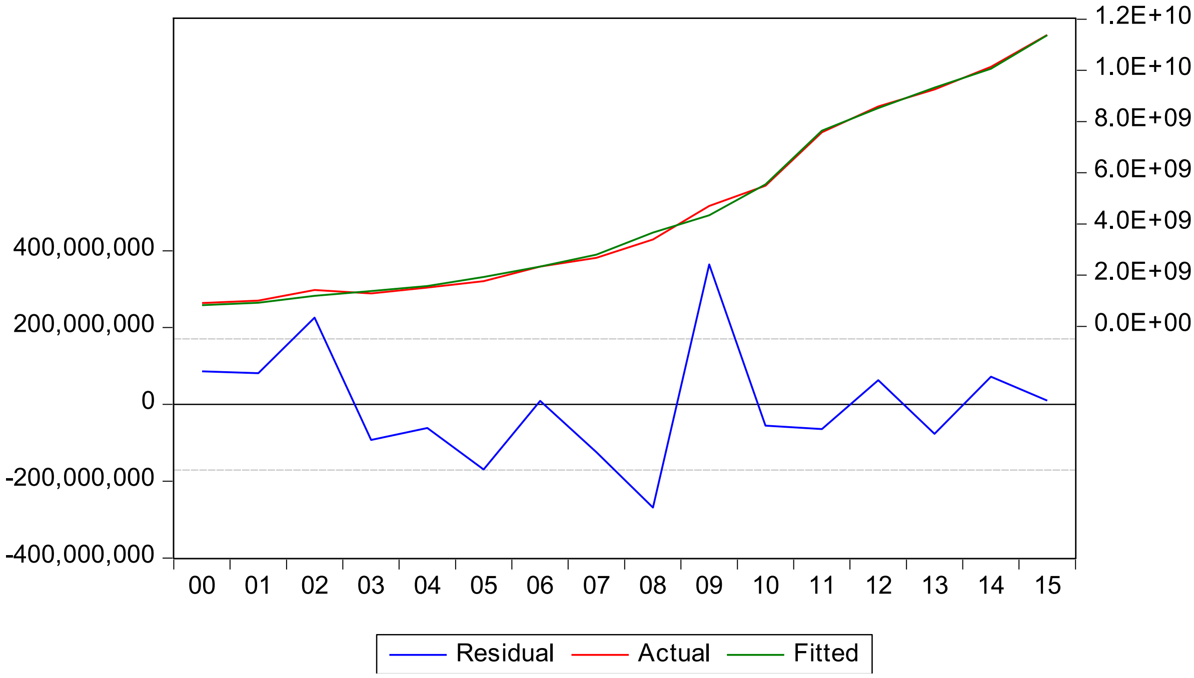
1. The model of gaseous waste

Dependent Variable: GASEOUS_WASTE
Method: Least Squares
Date: 06/18/19 Time: 14:20
Sample: 2000 2015
Included observations: 16

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-85751198	1.64E+08	-0.522686	0.6107
GIPFI	1134.035	174.7856	6.488150	0.0000
GIPNONSTATE	224.9325	158.9709	1.414929	0.1825
GIPSTATE	1547.578	354.4450	4.366200	0.0009

R-squared	0.998248	Mean dependent var	4.59E+09
Adjusted R-squared	0.997810	S.D. dependent var	3.64E+09
S.E. of regression	1.71E+08	Akaike info criterion	40.95939
Sum squared resid	3.49E+17	Schwarz criterion	41.15253
Log likelihood	-323.6751	Hannan-Quinn criter.	40.96928
F-statistic	2279.367	Durbin-Watson stat	2.418474
Prob(F-statistic)	0.000000		

The actual, fitted, residual graph



- Serial correlation

Ho: residuals are not serially correlated

Alternative: residuals are serially correlated

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.324489	Prob. F(2,10)	0.7302
Obs*R-squared	0.975083	Prob. Chi-Square(2)	0.6141

Pro.Chi-square is 61 per cent, which is more than 5 per cent; we cannot reject Ho, we accept it; therefore the model does not have serial correlation.

- Heteroskedasticity test:

Ho: residuals are heteroscedastic, which is homoscedastic

Alternative: residuals are heteroscedastic

Heteroskedasticity Test: Breusch-Pagan-Godfrey

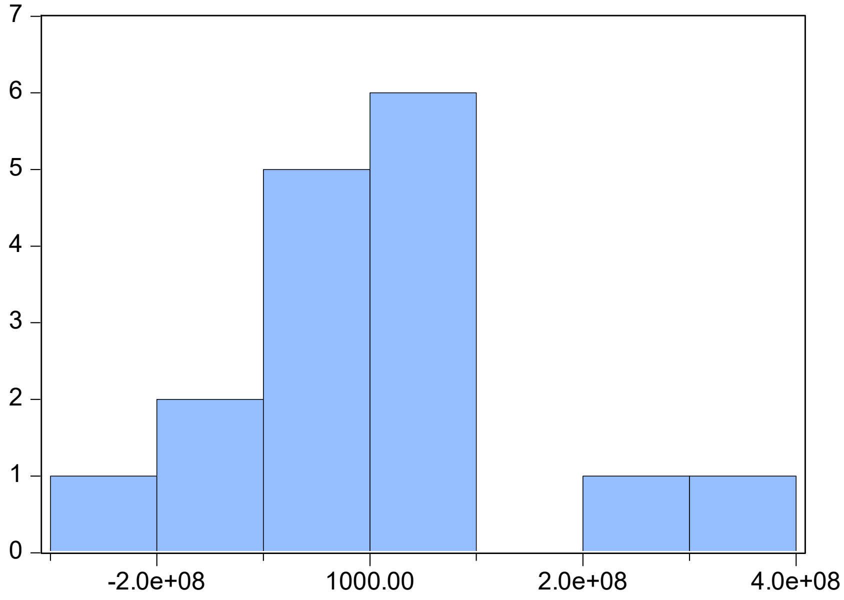
F-statistic	2.224763	Prob. F(3,12)	0.1379
Obs*R-squared	5.718484	Prob. Chi-Square(3)	0.1261
Scaled explained SS	4.056043	Prob. Chi-Square(3)	0.2555

Prob.Chi-square is 12 per cent, which is more than 5 per cent, we cannot reject Ho, we accept it; hence the model is homoscedastic.

- Normally distributed test

Ho: residuals are normally distributed

Alternative: residuals are not normally distributed



Series: Residuals	
Sample 2000 2015	
Observations 16	
Mean	-4.17e-07
Median	-23206832
Maximum	3.65e+08
Minimum	-2.69e+08
Std. Dev.	1.53e+08
Skewness	0.653907
Kurtosis	3.521907
Jarque-Bera	1.321845
Probability	0.516375

Jarque-Bera is 1.32, and probability is 51 per cent, which is more than 5 per cent, we cannot reject Ho, we accept it; therefore residuals are normally distributed.

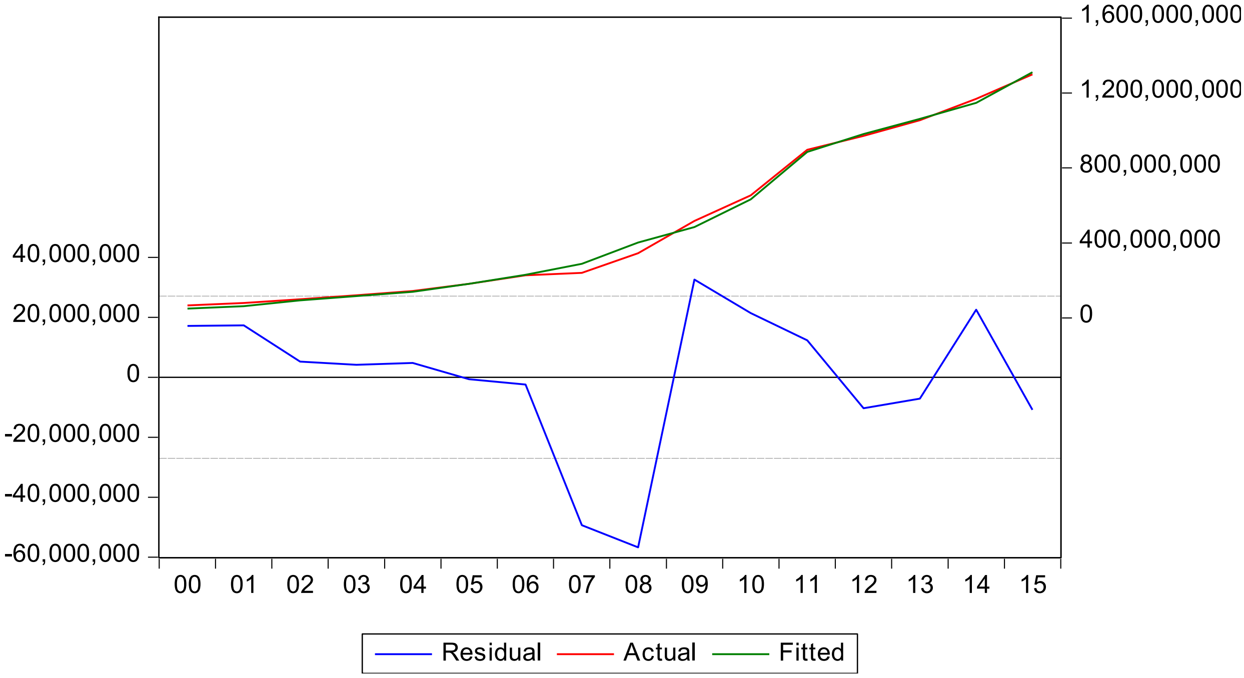
2. The model of liquid waste

Dependent Variable: LIQUID_WASTE
Method: Least Squares
Date: 06/18/19 Time: 23:55
Sample: 2000 2015
Included observations: 16

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-58888426	26013370	-2.263775	0.0429
GIPFI	102.0331	27.71426	3.681611	0.0031
GIPNONSTATE	40.68005	25.20667	1.613861	0.1325
GIPSTATE	189.2869	56.20132	3.368015	0.0056

R-squared	0.996934	Mean dependent var	5.04E+08
Adjusted R-squared	0.996167	S.D. dependent var	4.37E+08
S.E. of regression	27044176	Akaike info criterion	37.27616
Sum squared resid	8.78E+15	Schwarz criterion	37.46931
Log likelihood	-294.2093	Hannan-Quinn criter.	37.28605
F-statistic	1300.621	Durbin-Watson stat	1.498450
Prob(F-statistic)	0.000000		

The actual, fitted, residual graph



- Serial correlation

Ho: residuals are not serially correlated

Alternative: residuals are serially correlated

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.273566	Prob. F(2,10)	0.3216
Obs*R-squared	3.248083	Prob. Chi-Square(2)	0.1971

Pro.Chi-square is 19 per cent, which is more than 5 per cent; we cannot reject Ho, we accept it; therefore the model does not have serial correlation.

- Heteroskedasticity test:

Ho: residuals are heteroscedastic, which is homoscedastic

Alternative: residuals are heteroscedastic

Heteroskedasticity Test: Breusch-Pagan-Godfrey

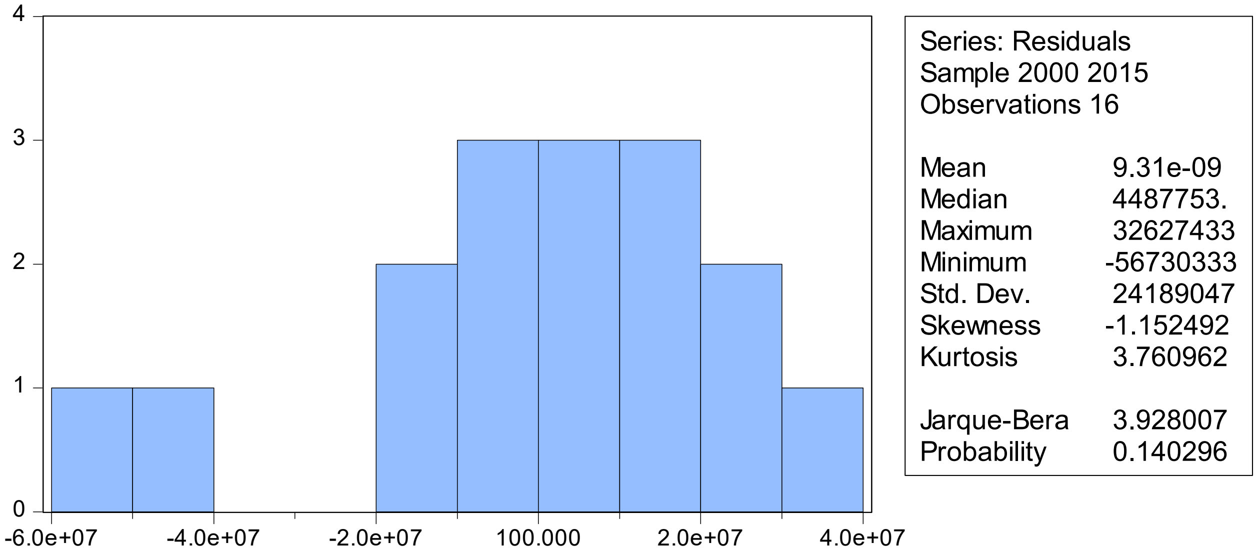
F-statistic	3.186702	Prob. F(3,12)	0.0629
Obs*R-squared	7.094663	Prob. Chi-Square(3)	0.0689
Scaled explained SS	5.509151	Prob. Chi-Square(3)	0.1381

Prob.Chi-square is 7 per cent, which is more than 5 per cent, we cannot reject Ho, we accept it; hence the model is homoscedastic.

- Normally distributed test

Ho: residuals are normally distributed

Alternative: residuals are not normally distributed



Jarque-Bera is 3.92, and probability is 51 per cent, which is more than 5 per cent, we cannot reject Ho, we accept it; therefore residuals are normally distributed.

3. The model of solid waste

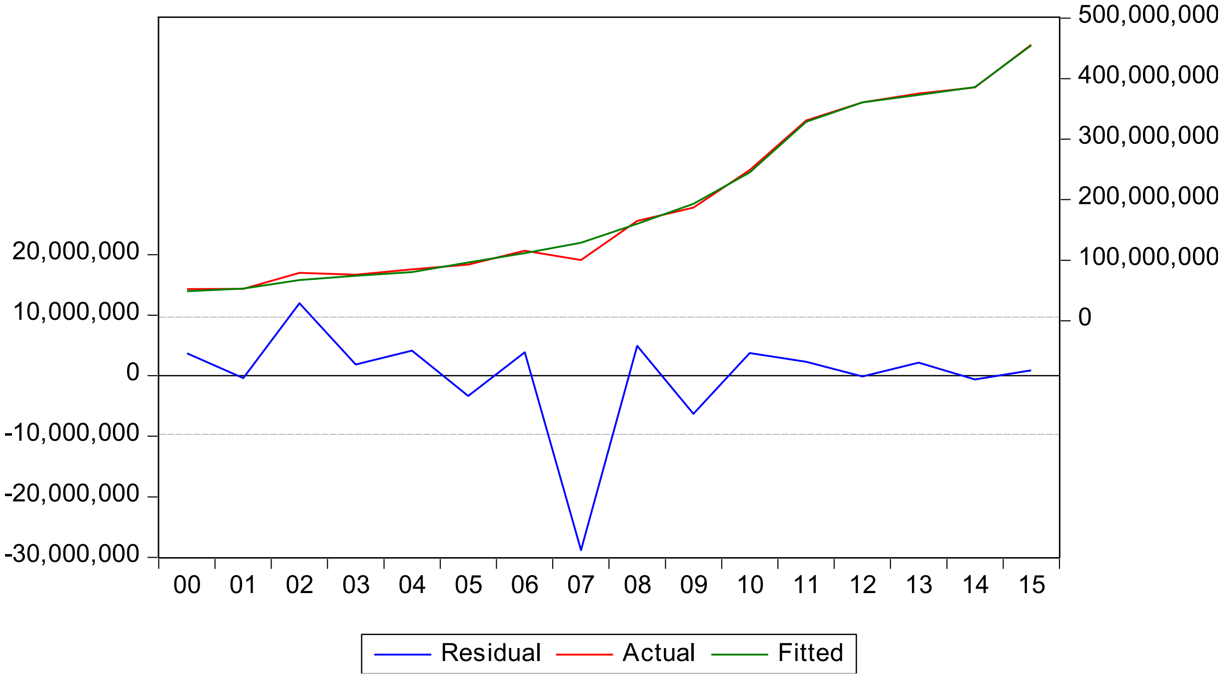
Dependent Variable: SOLID_WASTE
Method: Least Squares
Date: 06/18/19 Time: 23:59
Sample: 2000 2015
Included observations: 16

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	926677.2	9301727.	0.099624	0.9223
GIPFI	16.16205	9.909922	1.630896	0.1289
GIPNONSTATE	4.661282	9.013270	0.517158	0.6144
GIPSTATE	99.78714	20.09618	4.965478	0.0003

R-squared	0.996162	Mean dependent var	1.98E+08
Adjusted R-squared	0.995203	S.D. dependent var	1.40E+08
S.E. of regression	9670318.	Akaike info criterion	35.21934
Sum squared resid	1.12E+15	Schwarz criterion	35.41249

Log likelihood	-277.7547	Hannan-Quinn criter.	35.22923
F-statistic	1038.229	Durbin-Watson stat	2.531567
Prob(F-statistic)	0.000000		

The actual, fitted, residual graph



➢ Serial correlation

Ho: residuals are not serially correlated

Alternative: residuals are serially correlated

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.042906	Prob. F(2,10)	0.3878
Obs*R-squared	2.761337	Prob. Chi-Square(2)	0.2514

Pro.Chi-square is 25 per cent, which is more than 5 per cent, we cannot reject Ho, we accept it; therefore the model does not have serial correlation.

➢ Heteroskedasticity test:

Ho: residuals are heteroscedastic, which is homoscedastic

Alternative: residuals are heteroscedastic

Heteroskedasticity Test: Breusch-Pagan-Godfrey

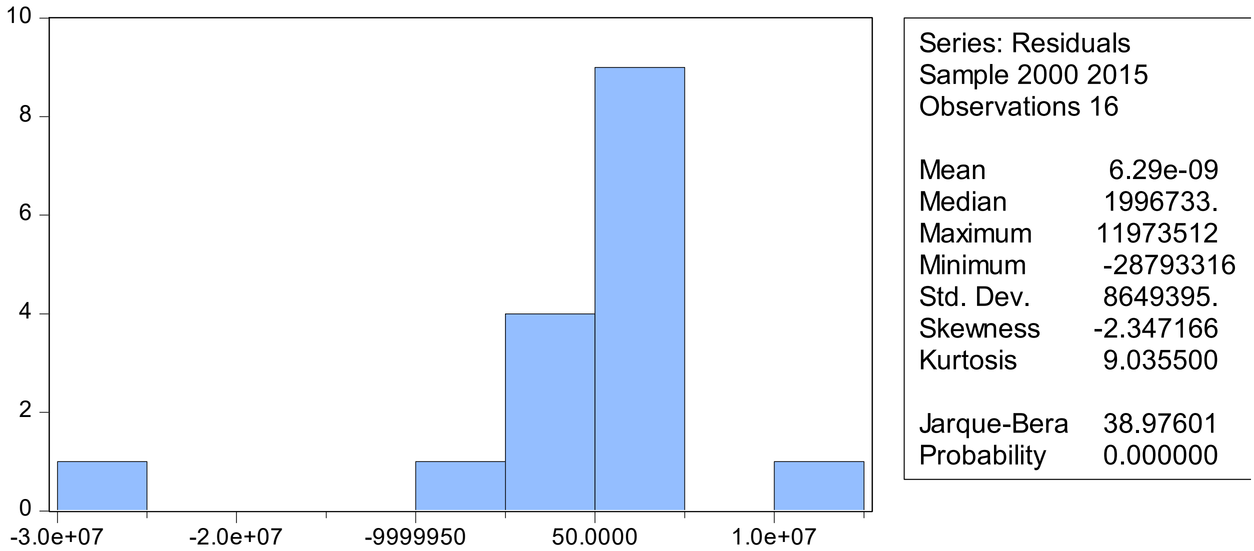
F-statistic	0.159423	Prob. F(3,12)	0.9216
Obs*R-squared	0.613251	Prob. Chi-Square(3)	0.8934
Scaled explained SS	1.385938	Prob. Chi-Square(3)	0.7088

Prob.Chi-square is 89 per cent, which is more than 5 per cent, we cannot reject Ho, we accept it; hence the model is homoscedastic.

- Normally distributed test

Ho: residuals are normally distributed

Alternative: residuals are not normally distributed



Jarque-Bera is 38.9, and probability is 0 per cent, which is less than 5 per cent, we can reject Ho, we accept alternative hypothesis; therefore residuals are not normally distributed.

CHAPTER 5

THE RELATIONSHIP BETWEEN ECONOMIC GROWTH AND ENERGY CONSUMPTION IN VIETNAM: A PANEL DATA ANALYSIS OF VIETNAMESE CITIES

5.1. Introduction

In 1986, after domestic policies proved ineffective in stimulating economic growth, the Sixth Congress of the Communist Party of Vietnam cast off the Soviet model of central economic planning, and Vietnam began to embark upon reforms transitioning it to a social oriented market economy. The end of the Vietnam-Cambodian conflict in the early 1990s accelerated this process. As Vietnam devalued its currency and decontrolled most prices, a U.S. trade embargo was lifted, the country re-established formal relations with China and member countries of the Association of Southeast Asian nations, and it obtained access to concessional international finance.

Those actions bore fruit, Vietnam, now a nation of 97 million people (based on the latest United Nations estimates), has for the past 15 years seen dizzying GDP growth at an average annual rate of 7%. In 2011, despite the global economic slowdown, the country recorded a 6.5% of GDP increase, making the 35th largest economy in the world, according to Goldman Sachs. However, like other countries in the world, this growth is usually accompanied by a significant increase in energy consumption (EC) and environmental problems. Over the past decades, the consumption of energy in Vietnam increased tremendously under the rapid development of the Vietnamese economy towards industrialization and economic reform in catching – up with the global economy. The per capita energy consumption in Vietnam also increased by 9.3% per annum from 1990 to 2007; besides, the total energy consumption in Vietnam is projected to increase from 55.6 Mtoe in 2007 to 146 Mtoe in 2025. Industrial growth has been one key driver of Vietnam's increasing energy consumption. This impressive performance has sparked the interest among economists and policymakers to investigate whether energy consumption is the cause or effect of economic growth in Vietnam as it had direct implications on the formulation of economic and environmental policies.

5.2. Literature review

Recently, Ozturk (2010) and Payne (2010) devoted their efforts in reviewing the existing literature on the nexus between energy consumption and economic growth and also provided the following four competing useful hypotheses.

(i) No causality between energy consumption and economic growth reveals the existence of a neutrality hypothesis, stating that both energy usage and economic output are not mutually associated with each other. This further indicates that the adoption of energy conservation policies related to energy usage to reduce CO_2 emissions will not undermine the pace of economic growth. The studies support this hypothesis such as Huang et al (2008) for low income countries, Masih et al (1996) for Malaysia, Singapore and Philippine, Soyta et al (2003) for Argentina.

(ii) The growth hypothesis, which indicates the unidirectional Granger causality running from energy consumption to economic growth, suggests that a country may pursue any energy conservation policy for reducing environmental pollution that will adversely affect the pace of economic growth. In this sense, it is suggested in the literature that energy reduction policy for the sake of reducing environmental pollution should be discouraged and new sources of less consuming and lower pollution energy must be explored in order to increase the pace of economic growth. Adegboye et al (2017) for Nigeria, Lee et al (2008) for 16 Asian countries, Lee (2005) for 18 developing countries, Lau et al (2011) for 18 Asian countries, have the findings that are consistent with this hypothesis.

(iii) If Granger causality running from economic growth to energy consumption claims the existence of a conservation hypothesis, it indicates that any adoption of energy conservation policy reducing environmental pollution would not harm economic growth because the economic growth of a country is not associated with energy consumption. Shahbaz et al (2012) for Pakistan, Thanh Binh (2011) for Vietnam, Huang et al (2008) for middle income and rich income countries, these papers reveal the evidence of this conclusion.

(iv) The feedback hypothesis exists based on the existence of bidirectional causality between energy consumption and economic growth, which argues that a rise in economic growth leads to a rise in demand for energy and therefore using energy stimulates output in the economy. Accordingly, a country's pursuit of energy conservation policy to reduce environmental pollution will have a detrimental effect on economic growth. The following studies are consistent with this hypothesis: Huang et al (2008) for middle income and rich income countries, Chang et al (2013) for Vietnam, Cheng and

Lai (1997) for Taiwan, Saatci M and Dumrul (2013) for Turkey, Abbasian et al (2010) for Iran.

Against the above hypotheses, there are also various existing empirical studies on the relationship among energy, consumption and economic growth that reveal mixed or inconclusive findings due to the result of various possibilities of methodological difference and the time periods, time series, and panel data used along with the country characteristics (Soytas et al 2003a, 2003b; Lee 2006, Chiou-Wei et al 2008 etc).

Literature review on Vietnam

For the Vietnamese economy, to best of our knowledge, the empirical papers by Thanh Binh (2011), Quang Canh (2011), Loi (2012) and Tang et al (2016) appear to be the only published works that examined the energy-growth nexus in Vietnam. Based on the bivariate regression model, Quang Canh (2011) investigated the causality relationship between electricity consumption and economic growth in Vietnam during the period of 1975-2010. Loi (2012) on the other hand, examined the Granger causality relationship between energy consumption, GDP and trade in Vietnam for the period 1986-2006. Quang Canh (2011) and Loi (2012) pointed to the evidence that there is a cointegration relationship between GDP and energy consumption, coupled with a long-run causality relationship that is running from GDP to energy consumption in Vietnam. Likewise, Thanh Binh (2011) also found evidence of uni-directional Granger causality running from economic growth to energy consumption in Vietnam; however, energy consumption and economic growth are not cointegrated.

In contrast, Tang et al (2016) analyze the relationship between energy consumption and economic growth in Vietnam using the neoclassical Solow growth framework for the 1971-2011 periods. The results confirm the existence of cointegration among the variables. In particular, energy consumption, FDI and capital stock were found to positively influence economic growth in Vietnam. The Granger causality test revealed unidirectional causality running from energy consumption to economic growth; hence, Vietnam is an energy-dependent economy and any energy or environment policy drawn up in an attempt to conserve energy will jeopardize the process of economic development in Vietnam.

Also, there are some multi-country researches which contain Vietnam as well. Among them, the works of Chotanawat et al (2008) for over 100 countries, included Vietnamese data during 1971-2010, Chang et al (2013) for 12 Asian countries included Vietnamese data over

1970-2010, Anwar et al (2014) for 15 Asian countries included Vietnamese data for the period of 1980-2011. However, the different results are captured due to the different methods of causality study and the sensitiveness of the sample period. Chotanawat et al (2008) found that energy consumption and economic are not cointegrated, but there is evidence of Granger causality running from energy consumption to economic growth; whereas Anwar et al (2014) showed the evidence of the cointegration between energy consumption and economic growth, however there is no evidence of Granger causality running from outputs to energy consumption and vice versa. Surprisingly, Chang et al (2013) revealed the outcome of the feedback hypothesis for Vietnam.

This paper contributes to energy economics literature and difference from the above papers for Vietnamese economy in at least a few ways. First, this study analyzes the relationship between economic growth and energy consumption in Vietnam using panel data for total of 63 provinces in Vietnam, for the period from 2000 to 2013. Last, energy consumption includes the three most used energy that is, coal, diesel, and electricity. Thus, it is strongly believed that the findings of this study would be a reliable and suitable basis for policymaking. The rest of this paper is organized as follows. Section 5.3 discusses the theoretical framework, data, and methodology in this study. The results and conclusions are presented in Section 5.4 and 5.5, respectively.

5.3. Methodology and data

5.3.1. Data sources

Annual data from 2000 to 2013 for all 63 provinces in Vietnam were utilized for the study. The energy consumption including coal, diesel and electricity, GDP, and population were obtained from the statistical yearbooks of General Statistics Office of Vietnam. Energy consumption data are reported in terms of total energy consumption for a large selection of key enterprises in each city; however, the number of selected enterprises and the proportion of enterprises vary across cities. Such data cannot provide the information of total energy consumption at the city-level; therefore General Statistics Office of Vietnam had to convert available energy consumption of selected enterprises to the energy consumption of all the enterprises in each city. In this study, we assumed that energy consumption per unit of industrial product is the same among cities, and total energy consumption included the most used energy: coal, diesel and electricity. Total energy consumption is then scaled by the population to form per capita energy consumption. Although, some limitations exist in the emissions data; but it is only available source to arrive at the total energy consumption in each city in Vietnam.

In this study, per capita total energy consumption is expressed in terms of millions Vietnam dong, and real per capita GDP is expressed in constant 2000 billion Vietnam dong; whereas per capita coal is tons, per capita diesel is 1,000 litters, and per capita electricity is 1,000 kWh. All variables are transformed into natural logarithms to reduce hetetoskedasticty.

Vietnam is composed of 63 provinces and five centrally – governed cities, which stand on the same administrative level as provinces (namely Hanoi, Ho Chi Minh City, Can Tho, Da Nang, and Hai Phong). The General Statistics Office of Vietnam further groups these provinces and cities into 6 regions: Northern midlands and mountain areas, Red river delta, North Central Coast and South Central Coast, Central Highlands, South East, and Mekong river delta. In this study, we also estimate the relationship between total energy consumption (including coal, diesel, and electricity) and economic growth in all regions.

5.3.2. Methodology

5.3.2.1. Panel unit roots

We apply Levin et al (1993) (LLC), lm et al (1997) (IPS), Maddala and Wu (1999) (MW, ADF) and Maddala and Wu (1999) (MW, PP) panel unit root tests to check the stationarity properties of the variables. These tests apply to a balanced panel but the LLC can be considered a pooled panel unit root test, IPS represents a heterogeneous panel test and MW panel unit root test is a non-parametric test.

5.3.2.2. Panel Cointegration

We then proceed to examine whether there exists any long-run equilibrium relationship between the variables under investigation. We resort to Pedroni (1999, 2001, and 2004) and Kao (1999) panel cointegration tests.

Pedroni (1999) uses the following cointegration equation:

$$GDP_{i,t} = \alpha_i+\beta_{1i}EC_{1i,t}+\ldots+\beta_{mi}EC_{mi,t}+\mu_{it} \qquad (1)$$

Where GDP is real per capita GDP and EC is per capita energy consumption including coal, diesel and electricity; subscripts *i* and *t* represent city and year, respectively. GDP and EC are assumed to be integrated of order one. The specific intercept term α_i and slope coefficients β_{1i}, β_{2i},..,β_{mi} vary across individual members of the panel. Pedroni (1999, 2004) proposed seven different statistics to test for cointegration relationship in a heterogeneous panel. These tests are corrected for bias introduced by potentially endogenous regressors. In the presence of cross-sectional dependence, Pedroni suggests the inclusion of common time dummies to eliminate this effect. Pedroni considers seven different statistics, four of which are based on pooling the residuals of the regression along the within-dimension (panel test) of the panel. The other three are based on pooling the residuals of the regression along the between-dimension (group test) of the panel. The within-dimension tests take into account common time factors and allow for heterogeneity across individuals. The between-dimension tests are the group-mean cointegration tests, which allow for the heterogeneity of parameters across individuals.

Kao (1999) proposed Dickey Fuller (DF) and ADF-type test for ε_{it}, where the null is specified as no cointegration.

5.3.2.3. Panel Fully Modified OLS (FMOLS) Estimates

If all the variables are cointegrated, the next step is to estimate the associated long-run cointegration parameters. In the presence of cointegration, the OLS estimator is known to yield biased and inconsistent results. For this reason, several estimators have been proposed. For example, Kao and Chiang (2000) argue that their parametric panel dynamic OLS (DOLS) estimator (that pools the data along the within the dimension of the panel) is promising in small samples and performs well in general in cointegrated panels. However, the panel DOLS of Kao and Chiang (2000) does not consider the importance of cross-sectional heterogeneity in the alternative hypothesis. To allow for cross-sectional heterogeneity in the alternative hypothesis, endogeneity, and serial correlation problems to obtain consistent and asymptotically unbiased estimates of the cointegrating vectors, Pedroni (2000, 2001) proposed the group mean fully modified OLS (FMOLS) estimator for cointegrated panels (Appendix 5.1).

5.3.2.4. Panel VECM causality

We estimate a panel based vector error correction model (VECM) with a dynamic error correction term based on the analysis in Holtz-Eakin et al (1988, 1989). The following VECM models are used to test the causality relation between variables:

$$\Delta GDP_{it} = \pi_{1j} + \sum_{p=1}^{m} \pi_{11ip}\, \Delta GDP_{it-p} + \sum_{p=1}^{m} \pi_{12ip}\, \Delta EC_{it-p} + \mu_{1i} ECT_{it-1} + \upsilon_{1it} \qquad (2)$$

$$\Delta EC_{it} = \pi_{2j} + \sum_{p=1}^{m} \pi_{21ip}\, \Delta EC_{it-p} + \sum_{p=1}^{m} \pi_{22ip}\, \Delta GDP_{it-p} + \mu_{2i} ECT_{it-1} + \upsilon_{2it} \qquad (3)$$

Where Δ is the lag operator and p denotes the lag length. The specification in Equation (2) allows for testing the causality direction. For example, in the short-run, the EC does not

Granger cause GDP where H_0: π_{12ip}= 0 for all i and p, while μ_{1i} = 0 in equation (2). The rejection implies that EC→GDP, supporting the growth hypothesis. Similar analogous restrictions and testing procedures can be applied in testing the hypothesis that GDP does not Granger cause movement in EC, where the null hypothesis H_0: π_{22ip} = 0 for all i and p, while μ_{2i} = 0 in equation (3).

Similarly, we estimate a panel based vector error correction model for GDP, and coal, diesel, and electricity.

$$\Delta GDP_{it} = \pi_{3j} + \sum_{p=1}^{m} \pi_{31ip} \Delta GDP_{it-p} + \sum_{p=1}^{m} \pi_{32ip} \Delta EC_{(C)it-p} + \sum_{p=1}^{m} \pi_{33ip} \Delta EC_{(D)it-p} + \sum_{p=1}^{m} \pi_{34ip} \Delta EC_{(E)it-p} + \mu_{3i} ECT_{it-1} + \upsilon_{3it} \quad (4)$$

$$\Delta EC_{(C)it} = \pi_{4j} + \sum_{p=1}^{m} \pi_{41ip} \Delta EC_{(C)it-p} + \sum_{p=1}^{m} \pi_{42ip} \Delta GDP_{it-p} + \sum_{p=1}^{m} \pi_{43ip} \Delta EC_{(D)it-p} + \sum_{p=1}^{m} \pi_{44ip} \Delta EC_{(E)it-p} + \mu_{4i} ECT_{it-1} + \upsilon_{4it} \quad (5)$$

$$\Delta EC_{(D)it} = \pi_{5j} + \sum_{p=1}^{m} \pi_{51ip} \Delta EC_{(D)it-p} + \sum_{p=1}^{m} \pi_{52ip} \Delta GDP_{it-p} + \sum_{p=1}^{m} \pi_{53ip} \Delta EC_{(C)it-p} + \sum_{p=1}^{m} \pi_{54ip} \Delta EC_{(E)it-p} + \mu_{5i} ECT_{it-1} + \upsilon_{5it} \quad (6)$$

$$\Delta EC_{(E)it} = \pi_{6j} + \sum_{p=1}^{m} \pi_{61ip} \Delta EC_{(E)it-p} + \sum_{p=1}^{m} \pi_{62ip} \Delta GDP_{it-p} + \sum_{p=1}^{m} \pi_{63ip} \Delta EC_{(C)it-p} + \sum_{p=1}^{m} \pi_{64ip} \Delta EC_{(D)it-p} + \mu_{6i} ECT_{it-1} + \upsilon_{6it} \quad (7)$$

Subscripts *C, D* and *E* represent coal, diesel and electricity, respectively.

5.4. Empirical results and discussion

5.4.1. Panel unit root results

Appendix 5.2 presents the estimated results of unit root tests at level and first difference. These results are calculated by applying panel unit root tests: LLC, LM, ADF, and PP on each selected variable without trend, with trend and without trend and intercept. Our empirical findings illustrate that all variables (without trend and intercept) are non-stationary in their level form. However, all the series are stationary at first difference. Thus, we reject the null hypothesis of non-stationary at 1 per cent level of significance and conclude that all series are integrated of order one I (1) in the panel of 63 provinces in Vietnam.

5.4.2. Panel cointegration results

From the panel cointegration results in Table 5.1, we find pretty strong evidence to reject the null hypothesis of no cointegration for four statistics out of seven statistics provided by Pedroni (1999, 2001, and 2004). For Kao (1999) panel cointegration tests, we reject the null hypothesis of no cointegration using the ADF-type statistics; this suggests that the variables in the model for all Vietnamese cities are cointegrated and move together in the long-run. Thus we find that GDP and coal, diesel, and electricity are cointegrated in the panel setting for the same period.

At the same time, the causality relationship between per capita GDP and total energy (including coal, diesel, and electricity) is also estimated. The result of panel cointegration is reported in Table 5.2, and it illustrates that per capita GDP and total energy are cointegrated in the panel for the period from 2000 to 2013.

Table 5.1 Panel Cointegration Tests Results for GDP and coal, diesel, electricity

A: Pedroni Residual Cointegration test

	Panel cointegration statistics (within-dimension)				**Group mean panel cointegrationsatistics (between-dimension)**		
Test	Panel v-Statistic	Panel rho-Statistic	Panel PP-Statistic	Panel ADF-Statistic	Group rho-Statistic	Group PP-Statistic	Group ADF-Statistic
Statistic	-4.4443	0.4295	-6.3246	-5.4999	2.6217	-12.4895	-8.7501
P-value	1.0000	0.6662	0.0000	0.0000	0.9956	0.0000	0.0000

B: Kao Residual Cointegration test

Test	ADF
Statistic	-4.7378
P-value	0.0000

Note: Probability values are in parenthesis

Table 5.2 Panel Cointegration Test Results for GDP and EC

A: Pedroni Residual Cointegration test							
	Panel cointegration statistics (within-dimension)				**Group mean panel cointegrationsatistics (between-dimension)**		
Test	Panel v-Statistic	Panel rho-Statistic	Panel PP-Statistic	Panel ADF-Statistic	Group rho-Statistic	Group PP-Statistic	Group ADF-Statistic
Statistic	1.787365	-5.690924	-8.44526	-5.805833	-3.1009	-9.176	-5.8497
P-value	0.0369	0.0000	0.0000	0.0000	0.0654	0.0000	0.0000
B: Kao Residual Cointegration test							
Test	ADF						
Statistic	-3.3223						
P-value	0.0004						

Note: Probability values are in parenthesis

5.4.3. Panel FMOLS Estimates

Having established cointegration in the long-run, we estimate the long-run parameters of the model by using the FMOLS technique. The FMOLS corrects the standard OLS for the bias induced by endogeneity and serial correlation of the regressors (Lee, 2005). The elasticity of energy consumption is important for understanding the past and assessing future economic dynamics. It represents the weights with which the marginal relative changes of the energy consumption contributes to the relative change of output (Lee et al., 2008).

Table 5.3 FMOLS estimates

No	Provinces	Coal	Diesel	Electricity	Total energy
	Panel estimates	0.1783(8.7313)***	0.3382(10.5720)***	0.142(20.1374)***	0.4671(487.3372)***
1	Ba Ria Vung Tau	-0.0786(-0.4589)	1.4435(7.4867)***	-0.3247(-6.0604)***	0.6300(33.0145)***
2	Ho Chi Minh	-0.2819(-1.4025)	0.9024(3.8501)***	0.1942(3.4974)***	0.5135(92.2315)***
3	Binh Duong	0.1294(3.9260)***	0.3226(8.9776)***	0.1524(13.3251)***	0.4717(193.1977)***
4	Ha Noi	-0.0919(-0.394)	0.7606(3.3551)***	0.0432(0.5535)	0.4654(49.9587)***
5	Bac Ninh	0.1682(1.3601)	-0.2187(-1.4964)	0.4881(7.5238)***	0.4465(60.9784)***
6	Quang Ninh	0.1238(1.6336)	0.3890(3.9159)***	0.1407(6.4727)***	0.4826(318.1029)***
7	Da Nang	-0.1644(-1.2911)	0.7063(4.5604)***	0.1872(5.3370)***	0.4672(122.1337)***
8	Vinh Phuc	-0.0273(-0.2902)	0.1522(1.1293)	0.4413(15.1612)***	0.4609(44.7192)***
9	Can Tho	0.1348(0.5580)	-0.1414(-0.3751)	0.4996(9.7409)****	0.4730(38.6694)***
10	Hai Phong	-0.2345(-2.4996)**	0.7698(6.3679)***	0.2107(9.2318)***	0.4595(190.1404)***
11	Dong Nai	-0.0205(-0.4603)	0.2567(4.6668))***	0.2497(18.6532)***	0.4099(162.1899)***
12	Kien Giang	-0.2149(-1.2236)	1.1019(4.1135)***	0.1470(3.4660)***	0.5350(112.6909)***
13	Khanh Hoa	-0.085(-0.6178)	0.7502(4.0431)***	0.1086(2.7955)**	0.4636(105.4278)***

14	Tay Ninh	0.1537(4.0215)***	0.2065(3.7635)***	0.2534(24.8967)***	0.4751(108.1320)***
15	Long An	0.0557(0.5583)	0.5867(4.2334)***	0.0567(1.5695)	0.4489(121.0336)***
16	Hai Duong	0.3788(3.5743)***	0.2988(1.8418)*	-0.0524(-1.4233)	0.4619(72.2656)***
17	Lam Dong	0.3470(2.2094)**	0.1877(0.7969)	0.1728(3.7412)***	0.5390(150.3794)***
18	Binh Phuoc	-0.0088(-0.1232)	0.5077(4.9829)***	0.2333(11.3798)***	0.4800(155.4657)***
19	Hung Yen	0.3099(4.6418)***	0.1079(1.1297)	0.1141(4.2358)***	0.4343(387.0595)***
20	Tien Giang	0.0998(0.7428)	0.7637(3.4491)***	-0.025(-0.5904)*	0.4836(89.3027)***
21	Vinh Long	0.1304(0.3801)	0.4313(0.8607)	0.1743(1.8566)*	0.4904(85.5610)***
22	Quang Ngai	0.7716(6.3212)***	-0.6200(-3.5318)***	0.1127(2.1439)*	0.4001(98.0547)***
23	Thai Nguyen	-0.1936(-0.9235)	0.7245(2.5819)**	0.2002(3.6713)***	0.4274(116.1701)***
24	Hoa Binh	0.8822(1.6943)	-0.2787(-0.3383)	-0.0776(-0.3729)	0.5388(28.7859)***
25	An Giang	-0.3462(-2.7925)**	1.3684(7.1706)***	0.060(2.0936)*	0.4873(86.7323)***
26	Lao Cai	0.3139(4.8038)***	-0.039(-0.3863)	0.2342(12.7922)***	0.4518(99.9559)***
27	Bac Lieu	0.1061(0.7140)	0.7072(2.8889)**	0.0928(1.5953)	0.5166(77.8947)***
28	Binh Dinh	-0.051(-0.4028)	0.8053(4.1027)***	0.0706(2.1421)*	0.4591(130.6454)***
29	Ca Mau	-0.0197(-0.3179)	0.4319(4.8619)***	0.2156(14.0934)***	0.4233(118.5482)***
30	Ben Tre	-0.0852(-0.6663)	1.2334(5.3874)***	-0.0618(-1.9230)*	0.4957(71.1050)***
31	Gia Lai	-0.0071(-0.0351)	0.6427(2.1448)*	0.1686(3.00489)**	0.4766(109.4069)***
32	Soc Trang	0.2587(2.1305)**	0.4150(2.1109)**	0.0714(1.6223)	0.4866(216.0657)***
33	Binh Thuan	0.2483(2.4691)**	0.1095(0.6891)	0.2424(8.9455)***	0.4760(103.0554)***
34	Hue	-0.1927(-1.4243)	0.9318(4.2844)***	0.1318(3.4874)***	0.4534(116.4920)***
35	Phu Tho	0.0672(0.5497)	0.6545(3.5770)**	0.01453(0.4512)	0.4362(85.5264)***
36	Ninh Binh	0.1219(1.2571)	-0.1151(-0.8299)	0.4165(12.6555)***	0.4060(41.1442)***
37	Quang Nam	-0.0809(-1.3031)	0.6280(5.9710)***	0.2018(10.1982)***	0.4467(124.6739)***
38	Lang Son	0.9606(3.7843)***	-0.7261(-1.7052)	0.0708(0.6233)	0.5343(61.8495)***
39	Thai Binh	-0.1096(-0.77413)	1.1338(4.3030)***	-0.0274(-0.5776)	0.4623(93.4218)***
40	Dak Nong	0.5214(2.1188)*	-0.358(-1.1050)	0.2295(2.5856)**	0.4483(27.5354)***
41	Quang Tri	0.6266(1.8726)*	-0.3465(-0.7345)	0.1282(1.1507)	0.4591(68.4512)***
42	Ha Nam	-0.0083(0.0658)	0.4803(2.4422)**	0.1802(4.1556)***	0.4201(102.0650)***
43	Hau Giang	0.2423(1.7232)	0.2988(1.2253)	0.0812(1.5563)	0.4437(171.5863)***
44	Ninh Thuan	0.4906(1.7009)	0.1701(0.3843)	-0.0271(-0.2490)	0.4710(57.2512)***
45	Phu Yen	-0.0229(-0.1307)	0.6366(2.2399)**	0.1841(3.6683)***	0.4638(111.6279)***
46	Bac Giang	0.3231(2.2285)**	0.5681(2.1550)*	-0.1264(-2.2478)**	0.4566(53.4740)***
47	Tra Vinh	0.1559(1.4716)	0.5683(2.9425)**	0.0778(2.7491)**	0.4790(262.9061)***
48	Nghe An	0.4323(2.0445)**	0.1041(0.2973)	0.0405(0.6010)	0.4558(92.8386)***
49	Dak Lak	0.7008(7.9374)***	-1.0611(-10.4504)***	0.4668(14.5001)***	0.4063(23.6832)***
50	Nam Dinh	0.1657(0.8603)	0.6895(2.0700)*	-0.0502(-0.8510)*	0.4507(66.7026)***
51	Quang Binh	0.276(0.9384)	0.2361(0.5152)	0.1193(1.4435)	0.4543(87.9402)***
52	Dong Thap	-0.1724(-1.74948)	0.3776(2.4996)**	0.3930(15.5775)***	0.4017(32.9560)***
53	Kon Tum	-0.147(-0.5360)	0.553(1.4189)	0.3143(3.5589)***	0.4311(51.7688)***
54	Tuyen Quang	0.5423(3.3865)***	0.0628(0.1966)	0.0251(0.3856)	0.5038(94.8432)***
55	Thanh Hoa	-0.0872(-0.5420)	0.9240(3.1162)**	0.0657(1.1858)	0.4464(88.6668)***
56	Ha Tinh	0.4143(2.0961)*	0.0393(0.1061)	0.127(1.4355)	0.4715(62.6756)***
57	Bac Kan	0.9688(4.3913)***	-0.7805(-2.0961)**	0.0671(0.6707)	0.5180(71.4758)***
58	Dien Bien	0.9245(4.0788)***	-0.6048(-1.7274)	-0.0127(-0.1300)	0.4844(64.1203)***
59	Yen Bai	0.1673(0.7683)	0.4178(1.040)	0.1481(2.0601)**	0.4593(93.0919)***
60	Cao Bang	0.2798(1.4908)	0.5108(1.4313)	-0.004(-0.0742)	0.4674(82.9077)***
61	Son La	0.4690(3.9261)***	-0.2819(-1.3229)	0.2599(5.5348)***	0.4794(58.6568)***
62	Ha Giang	0.5109(2.1022)*	-0.2529(-0.5122)	0.1623(1.7706)	0.4470(55.2358)***
63	Lai Chau	0.1578(1.6106)	-0.4676(-2.1363)**	0.5959(7.5914)***	0.4377(17.9014)***

Note: The values in parentheses are the t-statistics. Asterisks ***, ** and * denote significance at 1, 5 and 10 per cent levels, respectively. The order of provinces is basing on the level of per capita GDP, from high to low.

Table 5.3 reports the results of the long-run estimates for 63 provinces in Vietnam and the panel estimates based on Pedroni's group mean FMOLS estimator. The panel results of the regression equation with real per capita GDP as the dependent variable illustrate that the coefficient of total energy is positive and statistically significant at 1 per cent significance level. A one per cent increase in energy consumption leads to around 0.47 per cent increase in real per capita GDP. Specifically, a 1 per cent increase in coal, diesel and electricity consumption will result in rising proximately 0.18, 0.34 and 0.14 per cent in real per capita GDP, respectively. These outcomes show that diesel usage contributes to the increase of outputs in Vietnam more than coal and electricity, and, more energy results in greater outputs in Vietnam. This is supported by Lee (2005), Narayan and Smyth (2008), Lee and Chang (2008), and Ozturk (2010).

At the city level, for total energy, all coefficients are positive and significant at 1% level, and they range from 0.4001 (Quang Ngai) to 0.6300 (Ba Ria Vung Tau). The results indicate a positive and significant relationship between EC and real per capita GDP in all cities in Vietnam. Specifically, Ba Ria Vung Tau has the highest per capita GDP in Vietnam because it is the largest exploitation of petroleum in Vietnam; therefore energy consumption here causes economic growth significantly. In contrast, energy consumption contributes the least to the economic growth in Quang Ngai province. When it comes to industrial cities, say, Ho Chi Minh, Binh Duong, Ha Noi, Bac Ninh, Quang Ninh, Da Nang, Vinh Phuc, Can Tho, and Hai Phong are the group of cities which have the highest per capita GDP, energy consumption only causes from 44 to 51 per cent the increase in outputs. Interestingly, Dong Nai is one of the highest income provinces in Vietnam, but the coefficient of energy consumption is in the lowest group, the coefficient is 0.4099. Thus, it is suggested that the relationship between EC and GDP across provinces is statistically significant, but it changes slightly among cities due to the geographic location, population, and natural resources.

For the usage of coal, 21 out of 63 cities have the positive and significant coefficients of coal: they range from 0.9688 (Bac Kan) to 0.1294 (Binh Duong). The elasticity estimates are 0.9688, 0.9606, 0.9245, 0.8822, and 0.7716 for Bac Kan, Lang Son, Dien Bien, and Quang Ngai respectively. Bac Kan, and Dien Bien are two of the poorest provinces in Vietnam; hence coal is the most crucial energy, and it contributes to the increase in economic growth significantly. The coefficients of Hai Phong and An Giang are negative and significant at 5 per cent level; however, their coefficients for other energy are positive and significant, and they are very high for diesel, they are 0.7698 and 1.3684, for Hai Phong and An Giang, respectively; whereas for electricity they are significant and very small. It can be seen that two third of coal coefficients are not significant, and it can be explained that coal is an important input source for coal power plants to generate electricity. Currently, Vietnam has 20 coal power plants in operation, accounting for about 35 per cent of the country's total electricity generation, whereas electricity is also examined as a dependent variable as coal in the same model.

From the results in Table 5.3, it reveals that diesel causes an increase in Vietnamese provinces' economy when 34 elasticity estimates are positive and statistically significant. They are range from 1.4435 (Ba Ria Vung Tau) to 0.0265 (Tay Ninh). Besides, the coefficients are very high as 1.3684, 1.2234, 1.1338, and 1.1019 for An Giang, Ben Tre, Thai Binh, and Kien Giang respectively. These results suggest that diesel contributes most to Ba Ria Vung Tau, An Giang, Ben Tre, Thai Binh and Kien Giang. Meanwhile, the coefficients of Dak Lak, Bac Kan, Quang Ngai, and Lai Chau are negative and significant; it suggests that in these provinces, they are reducing to consume diesel energy in production.

For electricity, 36 out of 63 coefficients are positive and significant; it reveals that electricity stimulates economic growth in majority cities in Vietnam. The highest coefficient is 0.5959 for Lai Chau province, indicating electricity contributes most to Lai Chau's outputs. It is notable that Lai Chau province has long been the poorest city, and it is the most sparsely populated in Vietnam; hence electricity plays a crucial role in economic growth in this city. The coefficients of Ba Ria Vung Tau, Bac Giang, Ben Tre, and Tien Giang are negative and statistically significant, it suggests that electricity causes economic growth negatively in these cities.

The results for economic zones are presented in Table 5.4. It shows that energy consumption contributes to around 60 per cent of outputs in all regions with the coefficients ranging from 0.5810 (Central Highlands) to 0.6419 (Northern Midlands and mountain areas). In Northern midlands and mountain areas, energy consumption contributes most to its output whereas this region has seven lowest GDP provinces in Vietnam. The elasticity estimates for Red River Delta and Central Highlands are the lowest, 0.5862 and 0.5810, respectively; meanwhile, the coefficients for North Central Coast and South Central Coast, South East, and Mekong River Delta are around 0.62. These results are consistent with the findings at the city level: there is a positive relationship between EC and GDP among regions, but the results are mixed.

Table 5.4 FMOLS estimates for 6 economic zones

No	Provinces	Coal	Diesel	Electricity	Energy consumption
1	Red River Delta	0.012(0.1041)	0.6074(4.7926)***	0.1494(4.1894)***	0.5862(156.6569)***
2	Northern Midlands and mountain areas	-0.2648(-1.1132)	1.1996(4.1825)***	0.0885(1.3625)	0.6419(80.3159)***
3	North Central Coast and South Central Coast	-0.1183(-1.1529)	0.9149(7.6985)***	0.0923(3.1305)*	0.6141(102.0433)***
4	Central Highlands	-0.1441(-0.4018)	0.6329(1.5114)	0.3459(3.3452)***	0.5810(108.1364)***
5	South East	-0.1629(-1.867)*	1.1321(12.0013)***	-0.0518(-1.9291)*	0.6215(55.3949)***
6	Mekong River Delta	-0.2209(-1.9677)*	1.05566(7.8378)***	0.1078(5258)***	0.6277(113.0477)***

Note: the values in parentheses are the t-statistics. Asterisks ***, ** and * denote significance at 1, 5 and 10 per cent levels, respectively. The results of unit root test and panel cointegration for 6 economic zones at Appendix 5.3 and 5.4.

For coal, all elasticity estimates are negative except for Red River Delta; however, it is only significant at 10 per cent for South East and Mekong River Delta. This result reveals that the demand for coal is decreasing in provinces in South East and Mekong River Delta, and they are switching to use cleaner energy instead of using traditional energy, which causes high pollution in Vietnam.

For diesel, only the coefficient off Central Highland is insignificant, others are positive and significant at 1 per cent, and range from 0.6074 (Red River Delta) to 1.1321 (South East). In Northern Midlands and Mountain Areas, Mekong River Delta, and South East, using diesel contribute more than 100 per cent in GDP; whereas it only accounts for 60 per cent, 63 per cent, and 91 per cent in Red River Delta, Central Highlands and North Central Coast and South Central Coast.

The last energy group is electricity, the coefficient of Northern Midlands and Mountain areas is positive and insignificant, whereas the coefficient of it in diesel is very high (1.1996, significant at 5 per cent), and in coal is statistically negative insignificant. Thus in this region, the most used energy is diesel, and it contributes more than 100 per cent to the increase of GDP. The same pattern can be seen in South East region, and they are decreasing the demand for coal and electricity.

The opposing pattern is in Central Highlands, when electricity contributes to around 35 per cent of outputs, and the coefficients of coal and diesel are insignificant statistically. The coefficients of other regions are 10 per cent approximately, and significant at 1 per cent, indicating that electricity results in increasing around 10 per cent of per capita GDP.

5.4.4. Panel Granger Causality Test Results

Once the long-run estimates have been determined, we turn to the causality linkages. The empirical results presented in Table 5.5 show that for the model in equation (4), the coefficient of the lagged error-correction term (ECT) is negative and significant at 1 per cent level but with a relatively low speed of adjustment to long-run equilibrium. The negative error correction term confirms the existence of the long-run Granger causality running from coal, diesel and electricity to outputs. With the respect to short-run causality tests, the results of the Wald test reveal that there is no Granger causality running from coal, diesel, and electricity to GDP in the short–run.

From equation (5), ECT is positive and significant at 1 per cent level which suggests that income growth does not respond to coal, and there is no long run causality from income growth, diesel, and electricity to coal. Over the short period, there is evidence of Granger causality running from income, and diesel to coal.

The significant and negative ECT in the model of equation (6) confirms the presence of long-run causality running from income growth, coal, and electricity to diesel. In the short–run, all coefficients are significant at 1 per cent level and indicate that GDP Granger causes diesel, coal Granger causes diesel, and electricity Granger causes diesel.

In the last equation, both the long-run and short-run coefficients are significant, thus indicating the acceptance of Granger causality running from income growth, coal, and diesel to electricity.

The results of equations 5, 6, and 7 illustrate that energy consumption is determined by economic growth in Vietnam, which supports the conservation hypothesis; hence, energy conservation policy will have little effect on economic growth. This pattern is similar to results from developing economies (Cheng and Lai, 1997; Ozturk, 2010, Khanh Toan et al 2009). This result can be explained that like other low income countries, the recent economic growth in Vietnam has resulted in an expansion in commercial and industrial sectors where energy is a fundamental input. Also, higher disposable income increases the demand electronic devices for entertainment and comfort for households.

Table 5.5 Panel Granger Causality test results

Dependent variables	Source of causation (independent variables) Δlnpcgdp Short run	Δlnpccoal	Δlnpcdiesel	Δlnpcelectricity	ECT Long run
Δlnpcgdp	-	-0.0286	0.0356	0.0043	-0.0009***
		[-1.4378]	[1.4689]	[0.3450]	[-3.8506]
Δlnpccoal	0.3478**	-	-0.3502***	-0.0292	0.2520***
	[2.2481]		[-3.5192]	[-0.5776]	[8.7916]
Δlnpcdiesel	0.5269***	-0.2012***	-	-0.1837***	-0.0192***
	[4.0373]	[-2.9101]		[-4.3083]	[-4.6666]
Δlnpcelectricity	0.7489***	-0.9080***	0.491***	-	-0.3267***
	[5.6186]	[-12.8568]	[5.7278]		[-16.4674]

Note: Wald F-statistics reported for short-run changes in the independent variables. ECT represents the coefficient of the error correction term. Values in [ ] are t-ratios. The asterisks ***, ** and * denote significance at 1, 5 and 10 per cent levels, respectively.

Table 5.6 reports the estimation of per capita GDP and total energy consumption. The ECT is negative and significant at 1 per cent level in GDP equation, indicating that there is long run causality from energy consumption to GDP and the speed of adjustment to long-run equilibrium is very slow (around 5 per cent). Since the estimated coefficients of the explanatory variables are statistically insignificant; hence there is no short-run causality linkage from energy consumption to outputs. The reason would be that Vietnam has been in its early period of development, and most people have had relatively low income, therefore individuals or households try to secure their basic needs rather than consume energy-intensive goods at least in the short-run. Besides, the energy market in Vietnam is monopolistic, dominated by state-owned enterprises, and the prices are artificially set at a low level.

In the EC equation, ECT is negative, but it is insignificant statistically; therefore there is no long-run causality from GDP to EC; but there is short-run causality from GDP to EC, indicating that energy consumption is determined by economic growth. This supports the above results when each kind of energy consumption is estimated separately.

Table 5.6 Panel Granger Causality test results for total EC and GDP

Source of causation (independent variables)			
Dependent variables	Δlnpcgdp Short run	Δlnpcec	ECT Long run
Δlnpcgdp	-	0.0016	-0.0518***
	-	[0.1712]	[-7.2836]
Δlnpcec	0.6253***	-	-0.0149
	[4.4156]	-	[-1.1432]

Note: Wald F-statistics reported for short-run changes in the independent variables. ECT represents the coefficient of the error correction term. Values in [ ] are t-ratios. The asterisks ***, ** and * denote significance at 1, 5 and 10 per cent levels, respectively.

The results of Granger causality tests of 6 economic zones are shown in Table 5.7 and 5.8.

In Table 5.7, for the model in equation (4) and (5), the error correction term doesn't support the existence of the long-run Granger causality running from independent variables to dependent ones in the long-run. Besides, the Wald test also states that there is no Granger causality running from coal, diesel, electricity to GDP; and outputs, diesel, electricity to coal in the short-run.

In the model of equation (6), ECT is negative and significant at 10 per cent level, which suggests that there is long-run Granger causality running from economic growth, coal, and electricity to diesel. By contrast, there is no evidence of Granger causality among them over the short period.

The outcomes of the last equation are similar to the ones of panel results when they state that there is Granger causality running from income growth, coal, diesel to electricity either in the long-run or short-run.

Table 5.7 Panel Granger Causality test results for 6 economic zones

Dependent variables	Source of causation (independent variables)				
	Δlnpcgdp Short run	Δlnpccoal	Δlnpcdiesel	Δlnpcelectricity	ECT Long run
Δlnpcgdp	-	-0.0027	-0.0216	0.0102	0.0005
		[-0.0681]	[-0.4249]	[0.4100]	[0.5984]
Δlnpccoal	0.9018	-	-0.3842	0.0218	0.2723***
	[1.2065]		[-1.2946]	[0.1499]	[2.9741]
Δlnpcdiesel	0.8306	-0.2354	-	-0.1649	-0.0265*
	[1.4870]	[-1.3461]		[-1.5194]	[-1.9174]
Δlnpcelectricity	0.9729*	-0.9573***	0.0008**	-	-0.3741***
	[1.8976]	[-7.2525]	[3.3639]		[-8.1591]

Note: Wald F-statistics reported with respect to short-run changes in the independent variables. ECT represents the coefficient of the error correction term. Values in [ ] are t-ratios. The asterisks ***, ** and * denote significance at 1, 5 and 10 per cent levels, respectively.

Table 5.8 reports the estimation of per capita GDP and total energy consumption. For the GDP equation, the empirical results reveal that there is no Granger causality from energy consumption to economic growth neither in the long-run nor the short-run. However, the Granger causality is confirmed running from GDP to energy consumption in both the long-run and short-run. This is consistent with the panel result and it supports the conservation hypothesis.

Table 5.8 Panel Granger Causality test results for total EC and GDP in 6 economic zones

Dependent variables	Source of causation (independent variables)		
	Δlnpcgdp Short run	Δlnpcec	ECT Long run
Δlnpcgdp	-	-0.0047	-0.0196
	-	[-0.1918]	[-1.2047]
Δlnpcec	1.2059**	-	-0.1203*
	[2.0328]	-	[-2.6772]

Note: Wald F-statistics reported with respect to short-run changes in the independent variables. ECT represents the coefficient of the error correction term. Values in [ ] are t-ratios The asterisks ***, ** and * denote significance at 1, 5 and 10 per cent levels, respectively.

In general, from the panel results of FMOLS test and panel Granger causality tests, energy consumption brings a positive impact on GDP in the long-run, and in the short-run, economic growth causality causes energy consumption. This indicates that energy is a force for economic growth in the long-run, but in the short-run, energy is fundamentally driven by economic growth. This pattern is similar to results from developing countries (Ang, 2008, and Ozturk, 2010).

5.5. Concluding remarks

Using panel estimation for 63 provinces in Vietnam, this chapter empirically examines the relationship between total energy consumption including coal, diesel, and electricity and GDP. We find that the variables were in a stationary fashion in their first differences or were in an I(1) process. The panel cointegration results reveal a long-run equilibrium relationship among the variables, and it indicates that the increase in energy consumption leads to an increase in real per capita GDP (around 0.47 per cent accordingly). Also, diesel usage contributes more to Vietnamese output than coal and electricity.

When turning to the city-specific coefficients, the relationship between EC and GDP across provinces is positive and statistically significant; but it varies slightly among cities due to the geographic location, population, and natural resources. Energy consumption contributes the most to economic growth in the city that has the highest per capita income in Vietnam (Ba Ria Vung Tau), whereas it contributes the least to the city has the middle-income in Vietnam (Quang Ngai). In respect to each kind of energy consumption, in industrial cities[1] (the top of first 11 cities in Table 5.3), diesel and electricity contribute significantly to economic growth, whereas in the low-income cities[2] (the top of the last 10 cities in Table 5.3), the usage of coal leads to the increase in output notably.

The results of economic zones are consistent with the findings at the city-level when the relationship between EC and GDP over the total of six economic zones is positive and statistically significant. Besides, the usage of diesel and electricity results in the increase in output in all economic zones except for Northern Midlands and mountain areas and Central Highlands; while coal causes the economic growth negatively in South East and Mekong

[1] Ba Ria Vung Tau, Ho Chi Minh, Binh Duong, Ha Noi, Bac Ninh, Quang Ninh, Da Nang, Vinh Phuc, Can Tho, Hai Phong, Dong Nai.

[2] Kon Tum, Tuyen Quang, Thanh Hoa, Ha Tinh, Bac Kan, Dien Bien, Yen Bai, Cao Bang, Son La, Ha Giang, Lai Chau.

River Delta. These research results suggest that the demand for coal is decreasing, and they are switching to use cleaner energy for production in Vietnam.

From the Granger causality tests, there is a short-run unidirectional causal relationship running from GDP to energy consumption. This implies that in the short–run, economic growth leads to energy consumption in Vietnam, and energy is only one of the essential inputs to production in Vietnam, supporting the conservation hypothesis. This result is consistent with Quang Canh (2011), Thanh Binh (2011), and contradictory with Tang (2016) for the studies in Vietnamese economy. The results are mixed for these studies because they use different methodologies, variables as well as time series of variables in each research.

The research results support the conservation hypothesis, since a high level of economic growth results in a high level of energy demand, but not vice versa. Thus, for the policy perspective, the Vietnamese government can pursue the conservation energy policies that aim at curtailing energy use for environmental-friendly development purposes. At the same time, the market competitiveness of the traditional energy market and renewable energies could be gradually established, and improve alternative sources of energy or renewable energy such as hydropower, forest and biomass power, wind and solar power, and geothermal power. These suggestions in line with the National Plan for Environment and Sustainable Development which aims to develop the eco-friendly energy sector in Vietnam.

This study just focuses on the bivariate causality tests for energy consumption (coal, diesel, and electricity) and economic growth for 63 provinces in Vietnam during the period from 2000 to 2013. Further studies can be done by using longer time series, including more types of energy, and using either multivariate models for total energy or bivariate models for disaggregated energy consumption in industrial, residential, transport sectors.

Appendix 5.1 Fully Modified OLS Estimates

Following Pedroni (2001), the FMOLS technique generates consistent estimates in small samples and does not suffer from large size distortions in the presence of endogeneity and heterogeneous dynamics. The panel FMOLS estimator of coefficient β is defined as:

$\hat{\beta} = N^{-1}\sum_{i=1}^{N}(\sum_{t=1}^{T}(y_{it}-\bar{y})^{2})^{-1}(\sum_{t=1}^{T}(y_{it}-\bar{y})z_{it}^{*} - T\hat{\eta}_{i}$ (5)

Where $z_{it}^{*} = (z_{it} - \bar{z}) - \frac{\widehat{L_{21i}}}{\widehat{L_{22i}}}\Delta y_{it}$, $\hat{\eta}_{i} = \hat{\Gamma}_{21i} + \hat{\Omega}^{0}_{21i} - \frac{\widehat{L_{21i}}}{\widehat{L_{22i}}}(\hat{\Gamma}_{22i} + \hat{\Omega}^{0}_{22i})$ and $\hat{L}_{i}$ is a lower triangular decomposition of $\hat{\Omega}^{0}_{i}$. The associated t-statistics give:

$t_{\widehat{\beta^{*}}} = N^{-1/2}\sum_{i=1}^{N} t_{\widehat{\beta^{*}}}, i$ where $t_{\widehat{\beta^{*}}}, i = (\hat{\beta}^{*}_{i} - \beta_{0})\,[\hat{\Omega}^{-1}_{11i}\sum_{t=1}^{T}(y_{it}-\bar{y})^{2}]^{1/2}$

.

Appendix 5.2 Panel unit root test results

Variables	At level						At first difference					
	without trend	P-value	with trend	P-value	None	P-value	without trend	P-value	with trend	P-value	None	P-value
LLC test												
Lnpcgdp	-5.2929	0.0000	2.62792	0.9957	35.6176	1.0000	-13.3769	0.0000	-15.2517	0.0000	-5.1831	0.0000
Lnpccoal	-13.0374	0.0000	-0.91561	0.1799	12.0912	1.0000	-20.9569	0.0000	-29.918	0.0000	-18.6355	0.0000
Lnpcdiesel	-5.86627	0.0000	0.88398	0.8116	13.3046	1.0000	-19.2483	0.0000	-17.9885	0.0000	-17.5637	0.0000
Lnpcelectricity	-5.60241	0.0000	-6.52916	0.0000	25.9589	1.0000	-27.4478	0.0000	-22.9338	0.0000	-7.71016	0.0000
Lnpcec	-14.103	0.0000	8.19972	1.0000	20.1922	1.0000	-17.9095	0.0000	-23.3579	0.0000	-8.84995	0.0000
Im, Pesaran and Shin W-stat												
lnpcgdp	5.24783	1.0000	4.81927	1.0000			-8.84209	0.0000	-6.04334	0.0000		
lnpccoal	-4.82903	0.0000	8.54622	1.0000			-16.4893	0.0000	-22.9104	0.0000		
lnpcdiesel	-0.84299	0.1996	1.83840	0.9670			-19.8213	0.0000	-20.5063	0.0000		
lnpcelectricity	2.83352	0.9977	-1.84543	0.0325			-22.7641	0.0000	-17.9888	0.0000		
lnpcec	-3.68979	0.0001	11.4239	1.0000			-17.0695	0.0000	-22.5398	0.0000		
ADF - Fisher Chi-square												
lnpcgdp	72.9861	1.0000	85.6449	0.9977	12.3960	1.0000	301.239	0.0000	234.047	0.0000	193.088	0.0001
lnpccoal	184.727	0.0005	42.9294	1.0000	19.6504	1.0000	499.883	0.0000	601.457	0.0000	499.232	0.0000
lnpcdiesel	141.046	0.1700	188.561	0.0003	55.7466	1.0000	610.601	0.0000	559.950	0.0000	453.768	0.0000
lnpcelectricity	61.3189	1.0000	157.076	0.0316	11.1856	1.0000	654.756	0.0000	508.138	0.0000	215.622	0.0000
lnpcec	165.320	0.0108	67.9562	1.0000	57.8794	1.0000	574.477	0.0000	626.158	0.0000	257.923	0.0000
PP - Fisher Chi-square												
lnpcgdp	57.0448	1.0000	91.1221	0.9917	2.49014	1.0000	336.314	0.0000	279.002	0.0000	215.856	0.0000
lnpccoal	328.777	0.0000	64.8364	1.0000	7.11376	1.0000	586.849	0.0000	926.511	0.0000	756.685	0.0000
lnpcdiesel	167.761	0.0076	252.366	0.0000	8.63389	1.0000	821.480	0.0000	763.668	0.0000	891.430	0.0000
lnpcelectricity	46.2088	1.0000	166.999	0.0085	0.76227	1.0000	812.034	0.0000	779.158	0.0000	579.350	0.0000
lnpcec	173.189	0.0034	130.039	0.3845	1.96616	1.0000	804.595	0.0000	1025.67	0.0000	671.399	0.0000

Appendix 5.3 Panel unit root test results for 6 economic zones

Variables	At level						At first difference					
	without trend	P-value	with trend	P-value	None	P-value	without trend	P-value	with trend	P-value	None	P-value
LLC test												
lnpcgdp	-1.03469	0.1504	1.47507	0.9299	18.3298	1.0000	-3.95008	0.0000	-4.2421	0.0000	-1.56448	0.0589
lnpccoal	-4.32618	0.0000	-0.28389	0.3882	4.09107	1.0000	-4.14669	0.0000	-7.74171	0.0000	-5.53895	0.0000
lnpcdiesel	-2.18515	0.0144	-0.70214	0.2413	6.26918	1.0000	-6.73494	0.0000	-6.01374	0.0000	-6.45931	0.0000
lnpcelectricity	-2.59774	0.0047	-0.96292	0.1678	9.70947	1.0000	-8.39302	0.0000	-8.25103	0.0000	-1.7532	0.0398
lnpcec	-5.22543	0.0000	3.85924	0.9999	6.27014	1.0000	-3.92299	0.0000	-10.5234	0.0000	-2.06368	0.0195
Im, Pesaran and Shin W-stat												
lnpcgdp	2.02635	0.9786	1.41776	0.9219			-3.2968	0.0005	-1.56488	0.0588		
lnpccoal	-1.79572	0.0363	3.05917	0.9989			-2.68861	0.0036	-5.09181	0.0000		
lnpcdiesel	-0.29575	0.3837	0.36052	0.6408			-5.81645	0.0000	-4.25965	0.0000		
lnpcelectricity	0.62640	0.7345	0.07746	0.5309			-6.81306	0.0000	-5.71291	0.0000		
lnpcec	-1.47867	0.0696	4.19241	1.0000			-3.3925	0.0003	-7.91184	0.0000		
ADF - Fisher Chi-square												
lnpcgdp	3.11231	0.9947	4.47255	0.9733	0.04723	1.0000	30.7527	0.0021	18.7813	0.0939	17.0253	0.1486
lnpccoal	19.2725	0.0822	2.35620	0.9986	1.12623	1.0000	28.3783	0.0049	43.4917	0.0000	44.7432	0.0000
lnpcdiesel	10.3278	0.5872	9.77662	0.6356	0.89195	1.0000	50.7674	0.0000	37.9390	0.0002	65.9727	0.0000
lnpcelectricity	5.81116	0.9253	10.2448	0.5945	0.02674	1.0000	59.5060	0.0000	48.6572	0.0000	12.7332	0.3887
lnpcec	18.2329	0.1088	2.12549	0.9992	0.90682	1.0000	35.2416	0.0004	62.7923	0.0000	14.3103	0.2813
PP - Fisher Chi-square												
lnpcgdp	3.11384	0.9947	5.00230	0.9579	0.07199	1.0000	31.5790	0.0016	19.9355	0.0683	18.9474	0.0898
lnpccoal	30.2906	0.0025	2.95153	0.9959	0.54479	1.0000	38.8893	0.0001	62.9225	0.0000	57.4118	0.0000
lnpcdiesel	18.0605	0.1139	11.4143	0.4938	0.51722	1.0000	48.9164	0.0000	39.7248	0.0001	64.3104	0.0000
lnpcelectricity	5.99574	0.9163	10.0681	0.6100	0.03156	1.0000	70.9279	0.0000	72.8067	0.0000	41.9299	0.0000
lnpcec	17.3520	0.1368	5.62386	0.9338	0.09903	1.0000	55.7597	0.0000	72.1845	0.0000	46.6072	0.0000

Appendix 5.4 Panel Cointegration Tests Results for 6 economic zones

A: Pedroni Residual Cointegration test

	Panel cointegration statistics (within-dimension)				**Group mean panel cointegration satistics (between-dimension)**		
Test	Panel v-Statistic	Panel rho-Statistic	Panel PP-Statistic	Panel ADF-Statistic	Group rho-Statistic	Group PP-Statistic	Group ADF-Statistic
Statistic	-1.693871	-0.522619	-2.691377	-1.669943	0.966252	-2.962261	-2.572379
P-value	0.9549	0.3006	0.0036	0.0475	0.8330	0.0015	0.0051

B: Kao Residual Cointegration test

Test	ADF
Statistic	-2.015454
P-value	0.0219

Note: Probability values are in parenthesis

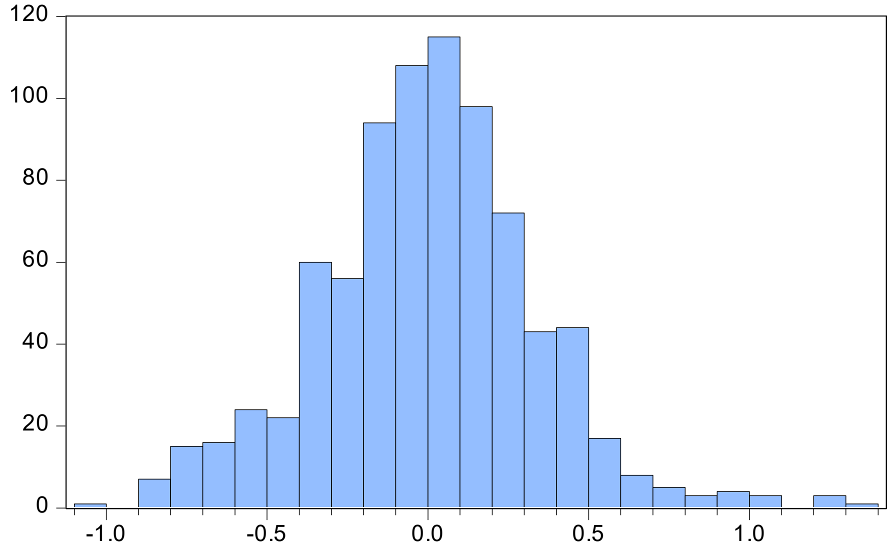
Appendix 5.5 FMOLS diagnostic tests for the panel

- **Autocorrelation test**

Date: 12/10/18 Time: 12:14
Sample: 2001 2013
Included observations: 819

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
.|******|	.|******|	1	0.815	0.815	545.91	0.000
.|***** |	.|* |	2	0.731	0.199	985.72	0.000
.|***** |	.| |	3	0.632	-0.024	1314.6	0.000
.|**** |	.| |	4	0.548	-0.015	1562.4	0.000
.|**** |	.| |	5	0.485	0.029	1756.3	0.000
.|*** |	.| |	6	0.417	-0.023	1899.9	0.000
.|*** |	.| |	7	0.358	-0.016	2006.3	0.000
.|** |	.| |	8	0.302	-0.021	2081.7	0.000
.|** |	.| |	9	0.257	0.003	2136.3	0.000
.|* |	*| |	10	0.194	-0.074	2167.4	0.000
.|* |	.| |	11	0.144	-0.028	2184.7	0.000
.| |	*| |	12	0.057	-0.145	2187.4	0.000

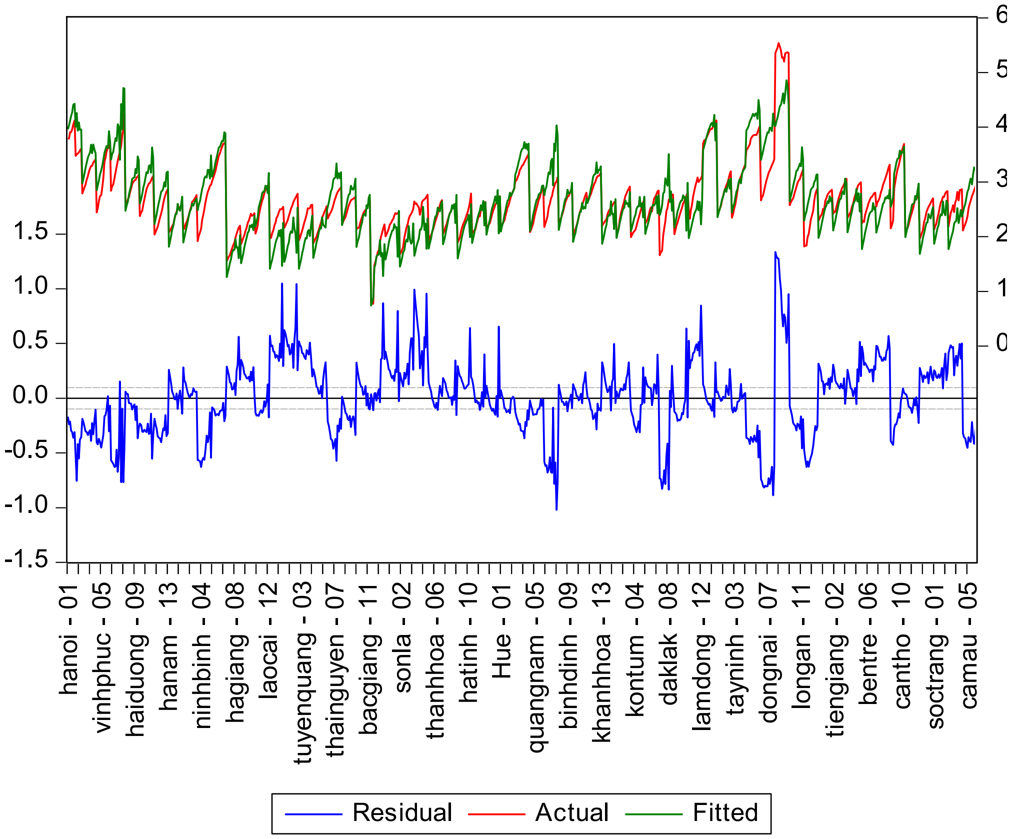
- **Normally distributed test**



Series: Residuals
Sample 2001 2013
Observations 819

Mean	0.001758
Median	0.006558
Maximum	1.335114
Minimum	-1.021808
Std. Dev.	0.340271
Skewness	0.203935
Kurtosis	4.048739
Jarque-Bera	43.20947
Probability	0.000000

➢ **The actual, fitted, residual graph**



CHAPTER 6

CONCLUSIONS

This thesis includes three empirical chapters. The first two studies examine the relationship between economic growth, FDI, and the environment in Vietnam from different perspectives and using different methodologies. The last investigate the economic growth-energy nexus. In this chapter, we provide a brief view of the empirical results in chapters 3-5, the contributions and limitations. The rest part of this chapter discusses plans for further research.

6.1. Summary of results

Chapter 3 estimated the impact of FDI and GDP on CO_2 emissions in Vietnam by using time series data from 1988 to 2015 and employing the Bounds Test approach. The analysis demonstrates that in the long-run, the causality relationship is found among variables; GDP has a significantly positive impact on CO_2 emission while FDI has a slightly negative effect. However, in the short-run, the causality relationship cannot be found for all variables. The results indicate that Vietnam economic development level has not reached the point where pollution can be reduced by the increase in GDP; at the same time, in the long-run foreign investors in Vietnam are supported to enhance the quality of environment in Vietnam.

In chapter 4, we investigate the relationship between economic growth and industrial pollution emissions in Vietnam by using panel data for 63 provinces in Vietnam between 2000 and 2013. We examine three industrial pollution indicators including gaseous, solid waste and liquid waste. The evidence from the majority of pollutant emissions confirms that at current income levels in Vietnam, economic development will induce more industrial pollution emissions, that is, the net effect of economic growth on environment quality is negative. Notably, the increase in income induces more liquid waste than gaseous and solid waste due to a large amount of wastewater discharged from industrial zones, and manufacturing establishments without proper treatment as well as the subsectors significantly contributed in water pollution. Besides, the environmental Kuznets curve is not found to exist in Vietnam at the provincial level, indicating that Vietnamese economy is still at the initial stages of development.

Chapter 5 empirically examines the direction of causality and sign (in the panel sense) between energy consumption including coal, oil, and electricity and GDP for total of 63 provinces in Vietnam between 2000 and 2013. The panel outcomes indicate that an increase in GDP would lead to greater use of energy. When turning to the provincial results, the relationship between EC and GDP across provinces is positive, and statistically significant; but it changes slightly among cities due to the geographic location, population, and natural resources. Also, Granger causality tests show that economic growth leads to energy consumption in Vietnam, and energy is only one of the essential inputs to production in Vietnam, supporting the conservation hypothesis.

Chapters 4 and 5 make two major contributions to the current literature. First, chapter four considers the effects of economic growth on various environmental indicators using Vietnamese city level data, and the results are broadly robust across pollutants. Second, chapter five examines economic growth-energy nexus at the provincial level, and energy consumption includes the most three usage energy are coal, diesel, and electricity. We believe the use of city-level variables provides more potential explanatory power than the use of highly aggregated variables reported at the national level.

6.2. The contribution of the thesis

As a whole, this thesis makes several important contributions to the literature on economic growth, foreign investment, environment, and energy consumption. First, it demonstrates that in an emerging economy like Vietnam, the pollution haven hypothesis does not exist since FDI is good for the environment, whereas economic growth causes pollution in the long-run. Second, at the city level, it shows that industrial pollution indicators including gaseous, solid waste and liquid waste increase with the rise in economic growth at current income levels in Vietnam. Third, the thesis demonstrates that energy consumption brings a positive impact on GDP, and diesel use has a bigger impact than coal and electricity consumption on economic growth. At the same time, it also indicates that energy consumption is determined by economic growth in the short-run, and it supports conservation hypothesis in Vietnam.

All in all, the findings of this thesis provide important policy implications to both central and local governments in Vietnam. To alleviate the pressure on the natural environment, the government has to enforce environmental protection at the earlier stage of development, through the improvement of environmental regulations at every administrative level. Also, the government has to promote the structural changes of the Vietnamese industry from manufacturing to service sectors, in order to reduce the industrial pollution emissions. Finally, the local government is recommended to promote environmental technology transfer of foreign firms to domestics firms and increase the absorptive capacity of local firms by increasing the investment in, for example, R&D and education.

For energy consumption, a high level of economic growth results in a high level of energy demand, but not vice versa. Thus, the Vietnamese government can pursue the conservation energy policies that aim at curtailing energy use for environmental friendly development purposes.

6.3. Further research

To improve the thesis chapters, we plan to add more variables and construct a panel for a longer time period; therefore, we will be able to establish a dynamic model.

In terms of the first essay, it should be possible to add more variables like export, factor demand, and technology intensity as well as separate the impact of foreign investments and domestic investments. At the same time, other air pollution indicators such as nitrogen dioxide (NO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_x), etc should be included in order to measure the quality of air pollution in Vietnam. A further improvement for the second essay is to include the explanatory variables of foreign investment and domestic investment in each province for the aim of separating the impact of foreign owned firms on pollution from that of domestically owned firms. At the same time, a simultaneous equations model should be developed, in which the pollution emissions are determined by regulations, technology, and industrial composition. In this case, we can estimate the scale effects, technique effects and composition effects caused by economic growth and foreign investment. Therefore, a major task is to find out valid measurements for regulations and technology at the city level.

For the last essay, further studies can be done by using longer time series, including more types of energy consumption, and using either multivariate models for total energy or bivariate models for disaggregated energy consumption in industrial, residential, transport sectors.

In terms of new research based on this thesis, the following topics can be considered as noteworthy in the area of economic growth, FDI, the environment, and energy consumption. This thesis considers the relationship between economic growth and the environment from regional dimensions. It is possible to investigate some interesting questions relating to the environment using Vietnamese firm-level data than aggregated regional data. A problem we faced was that the current widely used firm-level databases do not provide any environmental information. Recently, MONRE has reported the names of enterprises, which have emitted excessive water and air pollutants above the national standards in recent years and are forced to make changes within a certain period. It is likely to link this information with a commonly used firm-level database and employ a Probit model to examine the factors that may affect the differences in environmental performance, including endogenous drivers such as firm size and ownership, and exogenous drivers such as industry, market and regulatory forces.

BIBLIOGRAPHY

1. Abbasian, E., Nazai, M., & Basrindoost., M. (2010). Energy Consumption and Economic Growth in the Iranian Economy: Testing the Causality Relationship. *Middle-East Journal of Scientific Research*, *5*(5), 374-381.
2. ADB, & ADBI. (2012). Policies and Practices for Low – Carbon Green Growth in Asia Highlights. Retrieved from http://www.adb.org
3. Anh Dao, T.T, & Thanh Binh, D.T. (2013). FDI and growth in Vietnam: a critical survey. *Journal of Economics and Development*, *15*(3), 91-116.
4. Al-Mulali, U., Saboori, B., & Ozturk, I. (2015). Investigating the environmental Kuznets curve hypothesis in Vietnam. *Energy Policy*, *76*, 123-131.
5. Anwar, S., & Nguyen, L.P. (2010). Foreign Direct Investment and economic growth in Vietnam. *Asia Pacific Business Review*, *16*(1-2), 183-202. doi:10.1080/10438590802511031
6. Anwar, S., & Nguyen, L.P. (2011). Foreign Direct Investment and trade: The case of Vietnam. *Research in International Business and Finance*, *25*, 39-52.
7. Anwar, S., & Nasreen, S. (2014). Causal relationship between trade openness, economic growth and energy consumption: A panel data analysis of Asian countries. *Energy Policy*, *69*, 82-91.
8. Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C.S., Jansson, B.O., Levin, S.Maler, K.G., Perrings, C., & Pinmetal, D. 1995. Economic Growth, Carrying Capacity and the Environment. *Ecological Economics*, *15*(2), 91-95.
9. Asici, A.A. (2013). Economic growth and its impact on environment: A panel data analysis. *Ecological Indicators*, *24*, 324-333.
10. Beak, J., Cho, Y.S., & Koo, W.W. (2009). The environmental of consequences of globalization: A country – Specific Time – Series Analysis. *Ecological Economics*, *68*(8-9), 2255 – 2264.DOI: 10.1016/j.ecolecon.2009.02.021
11. Beak, J., & Koo, W.W. (2009). A dynamic approach to FDI-environment nexus: The case of China and India. *Journal of International Economic Studies*, *13*(2), 87-108.
12. Beckerman, W.1992. Economic growth and the Environment: Whose Growth? Whose Envrionment? *World Development*, *20*(4), 481-496.
13. Bhatt, P.R. (2013). Causal relationship between exports, FDI and income: the case of Vietnam. *Applied Econometrics and International Development*, *13*(1), 162-176.

14. Brown, S., Nguyen, M.H., & Tran, T.T. (2016). INVEN-2 Mitigation of environmental impacts related to foreign direct investments (FDIs) in Vietnam. MUTRAP EU – VIETNAM, 1-81.
15. Boulatoff, C., & Jenkins, M., (2010). Long – term nexus between openness, income and environmental quality. *International Advances in Economic Research*, *16*(4), 410-418.
16. Carson, R., Jeon, Y., & Mc Cubbin, D. (1997). The relationship between Air Pollution Emissions and Incomes: US Data. *Environment and Development Economics*, *2*(4), 433-450.
17. Chang, T., Chu, H.P., & Chen W.Y. (2013) Energy consumption and economic growth in 12 Asian countries: panel data analysis. *Applied Economics Letters*, *20*, 282-287.
18. Chotanawat, J., Hunt, L.C., & Pierse, R. (2008). Does energy consumption cause economic growth? Evidence from a systematic study of over 100 countries. *Journal of Business and Economic Statistics*, *10*, 237-250.
19. Cheng, B.S., & Lai, T.W. (1997). An investigation of co-integration and causality between energy consumption and economic activity in Taiwan. *Energy Economics*, *19*, 435-444.
20. Chiou-Wei, S.Z., Chen, C.F., & Zhu, Z. (2008). Economic growth and energy consumption: evidence from linear and nonlinear Granger causality. *Energy Economics*, *30*, 3063-3076.
21. Cole, M.A. (2003). Development, Trade, and the Environment: How Robust is the Environmental Kuznets curve? *Environment and Development Economics*, *8*(4), 557-580.
22. Cole, M.A. (2004). Trade, the Pollution Haven Hypothesis and the Environmental Kuznets Curve: Examining the Linkages. *Ecological Economics, 48*(1), 71-81.
23. Cole, M.A. & Elliot R.J. (2003). Determining the Trade-Environment Composition Effect: The Role of Capital, Labor and Environmental Regulations. Journal *of Environmental Economics and Management*, *46*(3), 363-383.
24. Cole, M.A. & Elliot, R.J. (2005). FDI and the Capital Intensity of ‘Dirty’ Sectors: a Missing Piece of the Pollution Haven Puzzle. *Review of Development Economics*, *9*(4), 530-548.
25. Cole, Matthew A., Robert J.R. Elliott, & Kenichi Shimamoto. (2006). Globalization, firm-level characteristics and environmental management: A study of Japan. *Ecological Economics*, *59*(2), 312-323.

26. Copeland, B.R. & Taylor, M.S. (1994). North-South trade and the environment. *The Quarterly Journal of Economics*, *109*, 755-787.
27. De Bruyn, S.M., Van Den Berg, J.C.J.M., & Opschoor, J.B. (1998). Economic Growth and Emissions: Reconsidering the Empirical Basis of Environmental Kuznets Curve. *Ecological Economics*, *25*(2), 161-175.
28. Dinh, H.L., & Lin, S.M. (2012). CO_2 Emissions, Energy Consumption, Economic Growth and FDI in Vietnam. *Managing Global Transitions*, *12* (3), 219-232.
29. Dinda, S. (2004). Environmental Kuznets curve hypothesis: A survey. *Ecological Economics*, *49*(4), 431-455.
30. Dunning, John H. (1988), *Explaining International Production*. London: Unwin Hyman.
31. Elliot R.J.R., & Shimamoto, K. (2008). Are ASEAN Countries Havens for Japanese Pollution-Intensive Industry? *World Economy*, *31*(2), 236- 254.
32. Ehrhardt-Martinez, K., Crenshaw, E.M., & Jenkin, J.C. (2002). Deforestation and the environmental Kuznets curve: a cross-national investigation of intervening mechanisms. *Social Science Quarterly*, *83*(1), 226-243.
33. Ekins, P. (1997). The Kuznets Curve for the Environment and Economic Growth: Examining the Evidence. *Environment and Planning A, 29*(5), 805-830.
34. Eskland, Gunnar S. & Ann E. Harrison. (2003). Moving to greener pastures? Multinationals and the pollution haven hypothesis. *Journal of Development Economics, 70*(1), 1-23.
35. Esty, D C., & Porter, M.E. (2005). National environmental performance: an empirical analysis of policy results and determinants. *Environment and Development Economics*, *10*(4), 391-434.
36. European External Action Service. (2012). Framework agreement on comprehensive partnership and cooperation between the European Union and its member states, of the one part, and the socialist republic of Vietnam, of the other part. 1- 169. https://eeas.europa.eu/sites/eeas/files/pca.pdf
37. Freeman, N.J. (2002, September). Foreign Direct Investment in Vietnam: An overview. Paper prepared at the DfID Workshop on Globalisation and Poverty, Vietnam. Retrieved from http://phamtrung.wikispaces.com/file/view/425-+FDI+report+Vietnam.pdf
38. Frankel, J.A. & Rose, A.K. (2005). Is trade good or bad for the environment? Sorting out the causality. *Review of Economics and Statistics*, *87*(1), 85-91.
39. General Statistical Office. (2013). Statistical Yearbook 2012. Hanoi: Statistical

Publishing House, Vietnam.

40. General Statistical Office. Statistical Yearbook 1994-2015. Hanoi: Statistical Publishing House, Vietnam.

41. General Statistical Office. (2016). Effectiveness of business of FDI enterprises in the period 2005 – 2014. Hanoi: Statistical Publishing House, Vietnam.

42. General Statistical Office. http://www.gso.gov.vn/Default.aspx?tabid=706&ItemID=13412

43. Grossman, G.M, & Krueger, A.B. (1991). Environmental Impacts of a North American Free Trade Agreement. *NBER Working Paper No. 3914,* National Bureau of Economic Research, Inc., published in The U.S –Mexico free trade agreement, 1994 Garber, P. (ed). Cambridge, MA: *MIT Press*.

44. Grossman, G. M, & Krueger, A. B. (1995). Economic growth and the environment. Quarterly Journal of Economics, 110(2), 353-377.

45. Holtz-Eakin, D., Newey, W., & Rosen, H. (1988). Estimating vector autoregressions with panel data. *Econometrics*, *56*, 1371-1395.

46. He, J. (2006). Pollution Haven Hypothesis and Environmental Impact of Foreign Direct Investment: the case of Industrial Emission of Sulfur Dioxide (SO2) in Chinese Provinces. *Ecological Economics*, *60*, 228-245.

47. Holtz-Eakin, D., Newey, W., & Rosen, H. (1989). The revenues-expenditure nexus: evidence from local government data. *International Economic Review*, *30*, 415-429.

48. Huang, B., M.J. Hwang, & C.W, Yang. (2008). Causal relationship between energy consumption and GDP revisited: a dynamic panel data approach. Ecological Economics, *67*, 41-54.

49. International Energy Agency. (2012). http://www.iea.org/

50. International Energy Agency: https://www.iea.org/countries/Vietnam/

51. Institute of Energy, Vietnam: http://www.ievn.com.vn/

52. Institute of Energy. (2016). Report on Assessment of Energy saving potential and energy efficiency from implemented tasks under the Vietnam National Target Program on Energy Efficiency and Conservation in the period 2011-2015. Hanoi, 2016.

53. Jaffe, A.B., Peterson, S.R., Portney, P.R. & Stavins, R.N. (1995). Environmental regulation and the competitiveness of US manufacturing: What does the evidence tell us? *Journal of Economic Literature*, *50,* 132-163.

54. Jaunky, V.C. (2011). The CO_2 emissions-income nexus: Evidence from rich countries. *Energy Policy*, *39*, 1228-1240.

55. Jha, V. (1999). Investment Liberalization and Environmental Protection: Conflicts and

Compatibilities in the case of India. Occasional Paper No.1, UNCATD/CBS Project on Cross Border Environmental Management in Transnational Corporations, Copenhagen Business School.

56. Johnston, J, & Dinardo, J. (1997). *Econometrics Methods*. 4. ed. Singapore: McGraw-Hill International Editions.
57. Kao, C. (1999). Spurious Regression and Residual-Based Tests for Cointegration in Panel data. *Journal of Econometrics*, *90*, 1-44.
58. Kao, C., & Chiang, M.H. (2000). On the estimation and inference of a cointegrated regression in panel data. In: Baltagi B, H. (Ed). Advances in Econometrics: Nonstationary Panels, Panel Cointegration and Dynamic Panels. 15, 179-222.
59. Khanh Toan, P., Bao, N.M., & Dieu, N.H. (2011). Energy supply, demand, and policy in Vietnam, with future projection. *Energy Policy*, *39*, 6814-6826.
60. Kheder, S.B. (2010). French FDI and Pollution Emissions: an empirical investigation. *University of Paris 1 Panthe'non – Sorbonne*, 1-44.
61. Lau, E., Chye, X.H., & Choong, C.K. (2011). Energy-Growth Causality: Asian Countries Revisted. *International Journal of Energy Economics and Policy*, *1*(4), 140-149.
62. Lee, C.C. (2005). Energy consumption and GDP in developing countries: a cointegrated panel analysis. *Energy Economics*, *27*, 415-427.
63. Lee, C.C. (2006). The causality relationship between energy consumption and GDP in 11 countries revisited. *Energy Policy*, *34*, 1086-1093.
64. Lee, C.C., & Chang, C.P. (2008). Energy consumption and economic growth in Asian economies: a more comprehensive analysis using panel data. *Resource and Energy Economics*, *30*, 50-65.
65. Lee, C.C., Chang, C.P., & Chen, P.F. (2008). Energy-income causality in OECD countries revisited: the key role of capital stock. *Energy Economics*, *30*, 2359-2373.
66. Levin, A., Lin, C.F., Chu, C.S.J. (2002). Unit root test in panel data: Asymptotic and finite sample properties. *Journal of Econometrics*, *108*, 1-24.
67. Liang, F.H. (2006). Does Foreign Direct Investment harm the host country's environment? Evidence from China.1-24. Retrieved from http://faculty.haas.berkeley.edu/fenliang/research/pollution&fdi/fdi_pollution.pdf
68. Loi, ND. (2012). Energy consumption and economic development: Granger causality analysis for Vietnam. Vietnam development and polices research centre (DEPOCEN). Working paper no.14: 2012, 1-24.
69. Lomborg, B. (2001). *The Skeptical Environmentalist: measuring the real state of the*

world. Cambridge: Cambridge University Press.

70. Maddala, G.S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulltetin of Economics and Statistics*, *61*, 631-652.
71. Mani, M. & Wheeler, D. (1998). In search of pollution havens? Dirty industry in the world economy, 1960 to 1995. *The Journal of Environment and Development*, *7*(3), 215-247.
72. Masih, A.M.M., & Masih, R. (1996). Energy consumption, real income and temporal causality: results from a multi-country study based on cointegration and erro-correction modeling techniques. *Energy Economics*, *18*, 165-183.
73. Mazzanti, M., Montini, A., & Zoboli, R. (2009). Municipal waste generation and the EKC hypothesis new evidence exploiting province-based panel data. *Applied Economics Letters*, *16*(7), 719-725.
74. Mihci, H., Cagatay, S., & Koska O. (2005). The Impact of Environmental Stringency of the Foreign Direct Investments of the OECD Countries. *Journal of Environmental Assessment Policy and Management*, *7*(4), 679-704.
75. Ministry of Investment and Planning. http://fia.mpi.gov.vn/Home
76. Ministry of Investment and Planning. (2013). Report of 25 years of Foreign Direct Investment in Vietnam. Retrieved fromhttp://fia.mpi.gov.vn/_layouts/fiaportal/uploads/old_data/uploads/Doc/Ky per cent20yeu per cent2025 per cent20nam per cent20DTNN_final.pdf (Vietnamese).
77. Ministry of Industry and Trade. (2017). Vietnam energy outlook report 2017, 1-78.
78. Ministry of Natural Resources and Environment. (2015). Report of the current circumstance of environment in Vietnam in the period 2011-2015. 1-280.
79. Ministry of Natural Resources and Environment. (2014). National strategy on environmental protection to 2020 and vision to 2030. Decision No.166/QD-TTg dated 21 January 2014, Hanoi, Vietnam.
80. Muhammad, S., Samia, N., & Talat, A. (2011). Environmental Consequences of Economic Growth and Foreign Direct Investment: Evidence from Panel Data Analysis. *Munich Personal RePEc Archive Paper*, *32547*, 1-16.
81. Nahman, A. & Antrobus, G. (2005). The Environmental Kuznets Curve: A Literature Survey. *South African Journal of Economics*, *73*(1), 105-120.
82. Narayan, P.K., & Narayan, S. (2010). Carbon dioxide emissions and economic growth: Panel data evidence from developing countries. *Energy Policy*, *38*, 661-666.

83. Narayan, P.K., & Smyth, R. (2008). Energy consumption and real GDP in G7 countries: New evidence from panel cointegration with structural breaks. *Energy Economics*, *30*, 2331-2341.
84. Nasreen, S., & Anwar, S. (2014). Causal relationship between trade openness, economic growth and energy consumption: A panel data analysis of Asian countries. *Energy Policy*, *69*, 82-91.
85. Nguyen, DL. (2015). A critical review on energy efficiency and conservation policies and programs in Vietnam. *Renewable and Sustainable Energy Reviews*, *52*, 623-634.
86. OECD: https://www.iea.org/countries/Vietnam/
87. OECD. (2002). Environmental Benefits of Foreign Direct Investment: A Literature Review, ENV/EPOC/GSP (2001) 10/FINAL, Paris: OECD.
88. Ozler, S.I., & Obach, B.K. (2009). Capitalism, state economic policy and ecological footprint. *Global Environmental Politics*, *9*(1), 79-108.
89. Ozturk, I. (2010). A literature survey on energy-growth nexus. *Energy Policy*, *38*, 340-349.
90. Ozturk, I., & Acaravci, A. (2010). The causal relationship between energy consumption and GDP in Albania, Bulgaria, Hungary and Romania: Evidence from ADRL bound testing approach. *Applied Energy*, *87*, 1938-1943.
91. Panayotou, T. (1997). Demystifying the environmental Kuznets Curve: Turning a Black Box into a Policy Tool". *Environment and Development Economics*, *2*(4), 465-484.
92. Panopoulou, E., & Pittis, N. (2004). A comparison of autoregressive distributed lag and dynamic OLS cointegration estimators in the case of a serially correlated cointegration error. *Econometrics, 7,* 585-617.
93. Payne, J.E. (2010). Survey of the International evidence on the causal relationship between energy consumption and growth. *Journal of Economic Studies*, 37, 53-95.
94. Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics*, *61*, 653-670.
95. Pedroni, P. (2000). Fully modified OLS for heterogeneous cointegrated panels. *Advances in Econometrics*, *15*, 93-130.
96. Pedroni, P. (2001). Purchasing power parity tests in cointegrated panels. *The Review of Economics and Statistics*, *83*, 727-731.
97. Pedroni, P. (2004). Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric Theory*, *20*, 597-625.

98. Pesaran, M.H., & Shin, Y. (1998). *An Autoregressive Distributed Lag Modeling Approach to Cointegration Analysis*. Chapter 11 in Frisch Centennial Symposium, Strom S. ed. Econometrics and Economic Theory in the 20th Century: The Ragnar. Cambridge, UK: *Cambridge University Press*.

99. Pesaran, M.H., Shin, Y., & J. Smith, R. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, *16*(3), 289-326. doi: 10.1002/jae.616

100. Pham, T.H. (2017). The impact of foreign direct investment and economic growth on carbon dioxide emissions in Vietnam. *The Keizai Ronkyu*, *159*, 45-58.

101. Phuong Hoa, N.T. (2004). Foreign *Direct Investment and its contribution to economic growth and poverty reduction in Vietnam (1986-2001)*. Frankfurt: Peter Lang.

102. Phuong Hoa, N.T., & Hemmer, H.R. (2002). *Contribution of foreign direct investment to poverty reduction: the case of Vietnam in 1990s.* Germany: Univ. Giessen, Fachbereich Wirtschaftswiss.

103. Quang Canh, L. (2011). Electricity Consumption and Economic Growth in Vietnam: A Cointegration and Causality Analysis. *Journal of Economics and Development*, *3*(13), 24-36.

104. Ramstetter, E.D. (2011). Ownership and Pollution in Vietnam's Manufacturing firms. Working Paper Series Volume 08, March 2011, 1-56.

105. Ramstetter, E.D., Ahmad, S.B.H., Kohpaiboon, A. & Narjoko, D. (2013). MNEs and Energy Efficiency in Southeast Asian Manufacturing. *Asian Economic Papers, 12*(3), 120-147.

106. Rothman, D.S. (1998). Environmental Kuznets Curves-Real Progress or Passing the Buck? A case for consumption-based approaches. *Ecological Economics, 25*(2), 177-194.

107. Saatci, M., & Dumrul, Y., (2013). The relationship between Energy consumption and Economic growth: evidence from a structural break analysis for Turkey. *International Journal of Energy Economics and Policy*, *1*(3), 20-29.

108. Shafik, N. & Bandyopadhyay, S. (1992). Economic Growth and Environmental Quality: Time Series and Cross-country Evidence. World Bank Policy Research Working Papers, No.WPS904.

109. Shahbaz, M. & Feridum, M. (2012). Electricity consumption and economic growth empirical evidence from Pakistan. *Quality & Quantity*, *46*, 1583-1599.

110. Shen, J. (2006). A Simultaneous Estimation of Environmental Kuznets Curve: Evidence from China. *China Economic Review*, *17*(4), 383-394.

111. Soytas, U., & Sari, R. (2003a). Energy consumption and GDP: causality relationship in G-7 countries and emerging markets. *Energy Economics*, *25*, 33-37.
112. Soytas, U., & Sari, R. (2003b). Energy consumption and GDP: causality relationship in G-7 countries and emerging markets. *Energy Economics*, *25*, 33-37.
113. Spatareanu, M. (2007). Searching for Pollution Havens: the Impact of Environmental Regulations on Foreign Direct Investment. *Journal of Environment and Development*, *16*(2), 161-182.
114. Stern, D.I. (1998). Progress on the Environmental Kuznets Curve? *Environment and Development Economics, 3*(2), 173-196.
115. Stern, D.I. & Common, M.S. (2001). Is there an environmental Kuznets Curve for Sulphur? *Journal of Environmental Economics and Management, 41*(2), 162-178.
116. Suri, V. & Chapman, D. 1998. Economic Growth, Trade and Energy: Implications for the Environmental Kuznets Curve. *Ecological Economics, 25*(2), 198-208.
117. Tang, C.F., & Tan, B.W. (2015). The impact of energy consumption, income and foreign direct investment on carbon dioxide emissions in Vietnam. *Energy, 79,* 447-554.
118. Tang, C.F., Tan, B.W, & Ozturk, I. (2016). Energy consumption and economic growth in Vietnam. *Renewable and Sustainable Energy Reviews*, *54*, 1506-1514.
119. Thanh Binh, P. (2011). Energy Consumption and Economic Growth in Vietnam: Threshold Cointegration and Causality Analysis. *International Journal of Energy Economics and Policy*, *1*(1), 1-17.
120. Tobey, J.A. (1990). The effects of domestic environmental policies on patterns of world trade: An empirical test. *KYKLOS*, *43*(2), 191-209.
121. United Nations Conference on Trade and Development. (2013). *Promoting low carbon investment* (No.7). Retrieved from http://unctad.org/en/pages/PublicationWebflyer.aspx?publicationid=769
122. United Nations Treaty Collection. (1997). Kyoto Protocol to the United Nations Framework Convention on Climate Change. https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-a&chapter=27&clang=_en
123. United Nations Treaty Collection. (2016). Paris Agreement. https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-7-d&chapter=27&clang=_en
124. VDF, & Ohno, K. (2014). *An approaching middle income trap how Vietnam can escape it*. Vietnam: Vietnam Educational Publishing House.

125. Vincent, J.R., Ali, R.M., & Associates. (1997). Environment and Development in A Resource-Rich Economy: Malaysia Under the New Economic Policy, Cambridge, MA: Havard University Press.
126. Vu, Quoc Huy. (2005). "Vietnam", in Douglas H. Brooks & Simon.J. Evenett, eds., *Competition Policy and Development in Asia*. Hampshire, UK: Palgrave Macmillan, pp. 297-337.
127. World Development Indicators http://unctadstat.unctad.org
128. World Bank: https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?end=2014&start=1986
129. Wooldridge, J.M. (2000). Introductory Econometrics: A Modern Approach, South-Boston: Western College Publishing.
130. Wenhua, D. (2007). Pollution Abatement Cost Savings and FDI Inflows to Polluting Sectors in China. *Environment and Development Economics*, *12* (6), 775-798.
131. Xing, Y. & Kolstad, C.D. 2002. Do Lax Environmental Regulations Attract Foreign Direct Investment? *Environmental and Resource Economics, 21*(1), 1-22.
132. Zarsky, L. (1999). Havens, Halos, and Spaghetti: Untangling the Evidence about Foreign Direct Investment and the Environment. Unclassified OECD Paper for Workshop 3 of the Conference on Foreign Direct Investment and the Environment, The Hague, Netherlands, 28-29 January 1999.
133. Zhang, J. (2013). *Foreign Direct Investment, Governance, and the Environment in China, Regional Dimensions*. The Nottingham China Policy Institute Series. England: PALGRAVE MACMILLAN.