FACTORS AFFECTING CO_2 EMISSIONS IN THE DEVELOPING COUNTRIES AND DEVELOPED COUNTRIES

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MASTER OF ECONOMICS

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THIS THESIS HAS BEEN APPROVED TO BE A PARTIAL FULFILLMENT OF THE REQUIREMENRS FOR THE DEGREE OF MASTER OF ECONOMICS

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หัวข้อวิทยานิพนธ์	ปัจจัยที่ส่งผลกระทบต่อการปลดปล่อยก๊าซคาร์บอนไดออกไซด์ออกสู่ชั้นบรรยากาศในประเทศกำลังพัฒนาและประเทศที่พัฒนาแล้ว	
ผู้เขียน	นางสาวเย่ฝาน โจว	
ปริญญา	เศรษฐศาสตรมหาบัณฑิต	
คณะกรรมการที่ปรึกษา	อ.ดร.จิราคม สิริศรีสกุลชัย	อาจารย์ที่ปรึกษาหลัก
	อ.ดร.เจียงซู หลิว	อาจารย์ที่ปรึกษาร่วม

บทคัดย่อ

ในปัจจุบัน ปัญหาอุณหภูมิโลกที่ถูกสร้างขึ้นโดยการปล่อยสารคาร์บอนมากเกินไปนั้นได้รับความสนใจในวงกว้างจากนานาชาติ ปัญหานี้เป็นระดับโลกที่ครอบคลุมทั้งในเรื่องการเมืองระหว่างประเทศ เศรษฐกิจ วิทยาศาสตร์พลังงาน แนวคิดทางวิทยาศาสตร์และเรื่องใหญ่ๆอีกหลายๆเรื่อง การศึกษาครั้งนี้วินิจฉัยถึงผลกระทบที่การปล่อยสารคาร์บอนนั้นมีต่อการเจริญเติบโตทางเศรษฐกิจ การใช้พลังงาน และตัวแปรควบคุมอื่นๆ (อาทิ การพัฒนาทางการเงิน และ การเปิดรับการค้า) โดยมี 10 ประเทศที่ถูกเลือกมาจากรายชื่อ 20 ประเทศที่มีการปล่อยสารคาร์บอนมากที่สุดของโลก

มี 5 ประเทศกำลังพัฒนาที่ถูกเลือกมาเพื่อร่วมวิจัยในครั้งนี้ ประกอบด้วย จีน อินเดีย บราซิล เม็กซิโก และ อเมริกาใต้ ส่วนประเทศพัฒนาแล้วที่ถูกเลือกมาเพื่อร่วมวิจัยได้แก่ สหภาพยุโรป สหรัฐอเมริกา แคนาดา อังกฤษ และ ญี่ปุ่น งานวิจัยฉบับนี้ใช้แบบจำลองการถดถอยเชิงปริมาณในการวิเคราะห์ โดยนำทั้งความแตกต่างที่ไม่ถูกสังเกต และความแตกต่างที่มีอยู่ทั่วไปมาใช้ในการพิจารณา ยิ่งไปกว่านั้นในการที่จะหลีกเลี่ยงความขัดแย้งเชิงตัวแปร ตัวแปรควบคุมที่เกี่ยวข้องบางอันก็ได้ถูกรวมเข้ามาอยู่ในแบบจำลองเช่นเดียวกัน ผลการศึกษาก่อนหน้านี้ได้แสดงให้เห็นว่าผลกระทบของตัวแปรอิสระต่อการปล่อยสารคาร์บอนนั้นแตกต่างไปในแต่ละควอนไทล์ ส่วนการใช้พลังงานที่มากขึ้นก็ได้ส่งผลให้มีการปล่อยสารคาร์บอนที่มากขึ้น โดยผลที่กระทบมากที่สุดนั้นปรากฏในควอนไทล์แตกต่างกันไปในประเทศที่ถูกเลือกทั้งสิบ อย่างไรก็ตามการใช้พลังงานของประเทศที่พัฒนาแล้วนั้นมีมากกว่าประเทศที่กำลังพัฒนา ขั้นตอนทางคุณลักษณะของวิธีการปล่อยแก๊สนั้นถูกแสดงให้เห็นอย่าง

ชัดแจ้งอย่างแตกต่างกันในประเทศทั้งสองแบบ ประเทศพัฒนาแล้วหลักๆนั้นได้ผ่านช่วงเวลาของยุคอุตสาหกรรมไปแล้ว ทว่ายังหลงเหลือทรัพยากรหรือปัจจัยทุนที่ใช้พลังงานสูงและมีการปล่อยแก๊สคาร์บอนสูงเช่นเดียวกัน ทว่าประเทศกำลังพัฒนานั้นยังคงอยู่ในกระบวนการของอุตสาหกรรมขั้นแรกเริ่ม หากมีรายได้น้อยการปล่อยแก๊สก็จะยังคงน้อยอยู่และการปล่อยสารคาร์บอนมากขึ้นจะส่งผลให้เศรษฐกิจพัฒนามากขึ้น นอกเหนือจากกนั้นวิจัยฉบับนี้ยังได้ค้นพบหลักฐานชิ้นสำคัญที่จะช่วยสนับสนุนในเรื่องของโค้ง Inverted U-Shape ของทั้งประเทศกำลังพัฒนาและประเทศที่พัฒนาแล้ว กล่าวคือการค้าที่เสรีมากขึ้นนั้นสามารถช่วยลดปริมาณการปล่อยสารคาร์บอนสู่อากาศได้ โดยเฉพาะในประเทศที่มีการปล่อยแก๊สต่ำ และ สูง โดยในท้ายสุดวิจัยฉบับนี้ยังสามารถช่วยผู้ออกนโยบายด้วยการให้คำแนะนำการสร้างนโยบายที่สำคัญ โปยการออกโปรแกรมพัฒนาทางด้านพลังงานให้ย้ายจากการพึ่งพิงทรัพยากรเชื้อเพลิงเช่น น้ำมัน ให้กลายไปเป็นการใช้พลังงานทดแทนที่สร้างขึ้นใหม่ได้ขึ้นอยู่สภาวะของแต่ละประเทศ ในทางกลับกัน งานวิจัยของเราได้แสดงให้เห็นว่าประเทศที่มีการปล่อยสารคาร์บอนสูงสามารถมีการเจริญเติบโตทางเศรษฐกิจสูงที่สุด ดังนั้นมาตรการที่จะนำมาใช้ควบคุมควรจะถูกปรับปรุงให้สอดคล้องอย่างแตกต่างไปในประเทศที่มีการปล่อยแก๊สสูงและต่ำ

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ABSTRACT

At present, the problem of global climate change caused by the excessive carbon emissions is received extensive attention of the international community. It is the global problem covering the international political, economics, energy science and environmental aspects and so on. This study investigates the impact of economic growth, energy consumption, and other control variables (including financial development, trade openness) on carbon emissions in ten selected countries which the top twenty total carbon emissions in the world. It was selected five developing countries (China, India, Brazil, Mexico and South Africa) and five developed countries (European Union, the United States, Canada, the United Kingdom and Japan) for the different period (including 1983-2013,1983-1998 and 1999-2013). This paper employs a panel quantile regression model that takes unobserved individual heterogeneity and distributional heterogeneity into consideration. Moreover, to avoid an omitted variable bias, certain related control variables are included in our model. Our empirical results show that the effect of the independent variables on carbon emissions is heterogeneous across quantiles. Energy consumption increases the carbon dioxide emissions, with the strongest effects occurring at different quantiles for sample groups data. But the effects of energy consumption on carbon emissions for developed countries greater than developing countries. In view of the economic development, developing countries and developed countries present the obvious stage characteristics.

The empirical observations in support of the Environmental Kuznets Curve (EKC) theory in the selected developed countries during the period of 1983-2013, 1983 to 1998 and 1999 to 2013. However, developing countries (1999-2013) and all selected countries (1999-2013) can support the Environmental Kuznets curve (EKC) theory. 4The main developed countries have finished the industrialization development of high energy consumption and high carbon emissions. But, developing countries are still in the process of industrialization that low carbon emission per capital and low the level of income. In addition, CO_2 emissions will decrease over the time when income increases. Finally, the results of the study also provide policymakers with important policy recommendations. Energy development program to shift from fossil fuels, such as oil, to clean and renewable energy, based on the existing condition of each country. In addition, our findings suggest carbon emissions control measures should be tailored differently across low-emissions and high-emissions nations.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

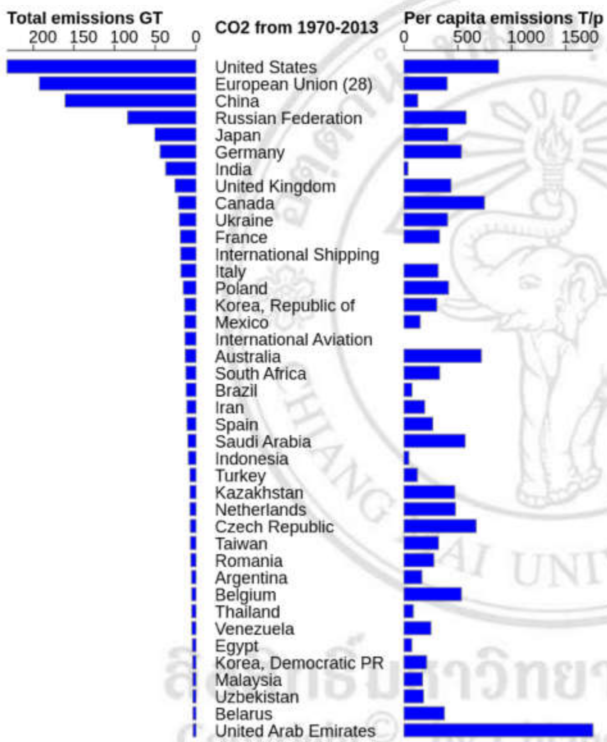
Introduction

1.1 Principle and Rationale of the Study

In recent years, the issue of atmospheric environment pollution caused by the excessive carbon emissions is gradually received extensive attention of the international community. It is a global environmental pollution problem involved in social production, life and other fields. Therefore, not only will it affect development of the economy in the future, but also the choice of the current economic development path. In addition, it will affect distribution of patterns of economic interests and the policy choice of countries around the world. In the view of the world economic development, all countries present the obvious stage characteristics. The main developed countries have finished the industrialization development of high energy consumption and high CO_2 emission. Also, industry structure of developed countries is mainly composed of the tertiary industry which has low energy consumption and low CO_2 emissions. However, developing countries are still at the process of industrialization and the economic development pattern is given priority to the secondary industry, which is high energy consumption with high CO_2 emissions. Who should take the primary responsibilities for carbon emissions made by those countries producing the products and services or those consuming countries?

The developing countries will naturally suffer from environmental degradation due to their large amount of CO_2 emission. These issues have led to extensive and heated debates all over the world. Developed countries have reached the high level of economic development. However, CO_2 emissions need to spend 50 to 200 years to metabolize, so the developed countries are still responsible.

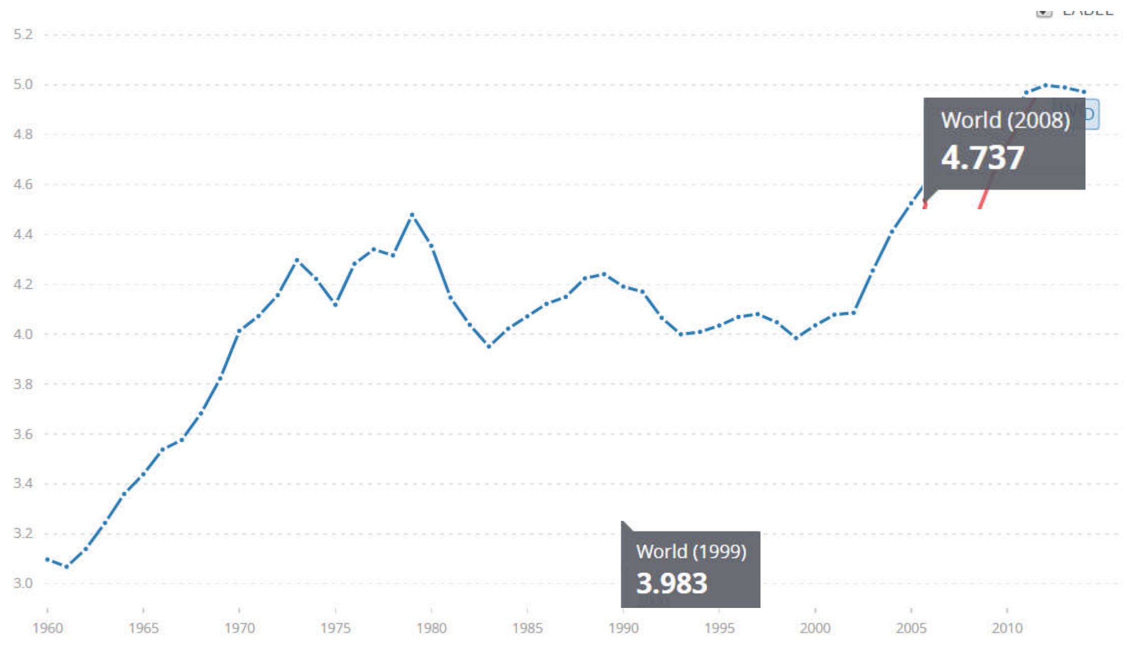
With the rapid growth of the economy, the industrial structure has changed. Continuous and rapid economic growth generates a series of benefits such as increased income, social stability and increased employment. However, rapid economic growth has also generated some negative phenomena, including excessive energy waste and environmental degradation. When the agricultural sector has switched from agricultural sector to non-agricultural sector, it spends lots of energy sources and high-polluting carbon and oil accounted for a large number of the total energy consumption for a long time. The developed countries have finished the industrialization period already and are coming into the times of knowledge economy. The CO_2 emissions show a downward trend, but they should not ignore the historical responsibility of the high CO_2 emissions during the industrialization period of the developed countries. Developed countries should work together with developing countries to control CO_2 emissions



Source: World Bank

Figure 1.1**:** Overview of the CO_2 emissions in the world

Figure 1.1 illustrates the total CO_2 emissions and the CO_2 emissions per capita. From 1970 to 2013, developed countries accounted for 6 countries in the total of carbon emission top ten countries, including the United States, European Union, United Kingdom, Canada, Japan and Germany. In addition, the five members of the BRICS countries, including to Brazil, Russia, India ,China and South Africa were all ranked among the twentieth largest emitters.



Source: The World Bank

Figure 1.2**:** The trend of world carbon emission (metric tons per capita) from 1960 to 2013

In Figure 1.2, the CO_2 emission of the world sharply raised from 1960 to 1974. The environmental pollution effects of carbon emissions are of significant interest. Carbon dioxide (CO_2) account for the largest share of the greenhouse gases resulting in global warming and climate change. Over the six decades, the world has witnessed the unequalled economic globalization development. The GDP increases from 1,423.6 billion US dollars in 1961 to 76,124 billion US dollars in 2013, accounting for nearly 53.4 times with an annual average rate of 8.1%. On one hand, in order to develop the economics and to improve the level of income, many countries had to rely on energy consumption in their development process. On the other hand, the main reason of environmental pollution is the energy consumption issue.

Despite the global efforts towards the climate change mitigation, the global CO_2 emissions from fossil-fuel combustion and cement production have been growing for decades. While previous crisis (e.g. the oil crisis in 1973, the US savings and loan crisis in 1979, the collapse of the Former Soviet Union in 1990, and the Asian Financial Crisis in 1997) has seriously slowed down the global growth of CO_2 emissions for several years, the impact of the 2008 financial crisis on emissions has been very short-lived. The global CO_2 emissions from fossil-fuel combustion only decreased by 1.90%, from 28.87 Gt in 2008 to 28.32 Gt in 2009 and then sharply increased to 29.84 Gt in 2010 –5.36% increase – reaching the highest annual growth rate recorded since 2004. Ever since then, the emissions have continued to grow, reaching 32.30 Gt in 2014 (IEA, 2015). Such persistent growth and the potential for even higher future growth of CO_2 emissions have led to extensive worries about the target for limiting global warming to less than 2 °C.

The United States is the most important country in the pattern of high carbon development all the time and it has the highest GDP per capita around the world with the large amount of CO_2 emissions. As early as 1990, the rate of CO_2 emissions per capita in the United States reached 19 tons per year and it exceeded 20 tons per year in 2000. Even though the rate of emissions per capita in the United States has stabilized, the pace of economic development has been significantly affected when the global economic crisis occurred in 2008. In addition, the CO_2 emissions per capita decreased to 16 tons in 2013. The development model of Canada is relatively close to Australia. From 1990 to the early Twenty-First Century, the trend of economy growth and CO_2 emissions per capita increased steadily. But the CO_2 emissions per capita of Canada was 18 tons in 2003.

The European developed countries like Germany, Britain and France existed the same carbon development path. With the steady development of economic, the trend of CO_2 emission per capita became to decrease which means that the CO_2 emissions and economic development have decoupled.

After 1990, the development of economy in Japan was basically at a steady pace except the 1997 Asian financial crisis and the 2008 year global economic crisis. Yet, the corresponding CO_2 emissions per capita entered the plateau in the late 90s. In 2013, Japan's CO_2 emission per capita output was 10 tons which was slightly higher than that of Germany.

As the largest developing country, China is still in the state of rapid economic development. It is the upper middle income country, listed by the World Bank. Over the past 20 years, the growth rate of GDP per capita was very impressive while the corresponding CO_2 emissions per capita were basically at the same stage of growth and the overall rate of CO_2 emissions reached the level of Korea in the middle of 90s.

Energy is the prerequisite to guarantee the economic development. No matter how the stage of economic development and the level of development of a country are, energy consumption cannot be separated. The study of the relationship between energy and economic growth began in the early 1970s. Energy is the basis and guarantee of economic growth, which provides impetus for the development of the national economy. The degree of industrial structure evolution determines the primary energy demand under economic growth. For developing countries, the rapid economic development is required a lot of energy resources because of the backward technology and being kept in the process of industrialization. Moreover, the increase of energy consumption per capita is greater than the speed of economic growth, or than the speed of economic growth which is equal to the increase of energy consumption per capita. At the same time, the correlation between the primary energy demand and economic growth is absolutely positive.

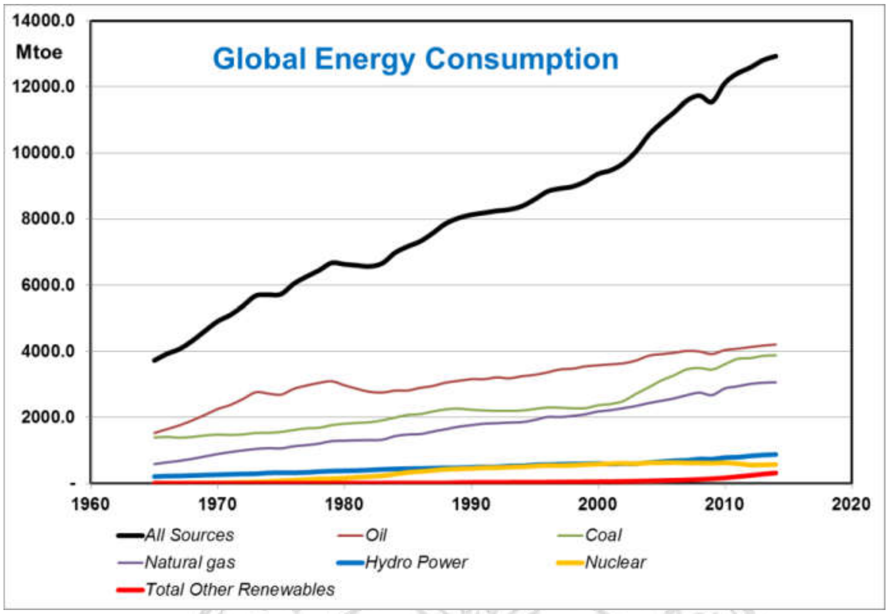
In different stages of economic development, national economy may differentiate the production and development of leading industries, and the level of the economic development impacts primary energy consumption and CO_2 emissions. Constant change and transformation of energy are an important symbol for human society development. Once the countries intend to promote economic growth and development, it will surely produce a large amount of CO_2 emissions and cause the damage to the environment and climate change. Moreover, each country could not continue to keep the current economic growth model because the current international traditional energy reserves and environmental carrying capacity are limited. Therefore, it is significant for both developed and developing countries to deal with energy consumption and CO_2 emission issues with effective measures.

From the development of the industrial structure analysis, 1920-1945 years is a period of rapid development of industrialization in the United States, which energy consumption and CO_2 emissions were a rapid increase of the national economy. Then, the focus of the United States shifted to technology intensive industries. Traditional industries and high energy consumption were gradually transferred to Japan and West Germany and that decreased energy consumption and carbon emissions of the United States. Especially after 1945, the United States entered the service economy development stage which low energy consumption of the Third Industry was developing rapidly. Also, the labor intensive manufacturing industry were transferred to developing countries. Therefore, the decreasing trend of energy consumption and carbon emissions were expected to be showed in this stage.

For other developed countries, before 1990s, Japanese economy was oriented development mode by the government. Although the rapid growth of the economy enhanced the industrial structure, the development speed of Japanese Second Industry was slow and that caused foreign countries to produce Industrial Hollowing phenomenon, resulting in strongly support of the high-speed development of the national economy industry. Finally, economies of Japan became a bubble and entered the depression stage.

Economic growth often shows the rapid increase of energy consumption and the large amount of CO_2 emissions. For the time being, the "high energy consumption and CO_2 emissions" developing mode sustains the economic growth of developing countries as well as some developed countries. Therefore, the whole world is now facing with the great pressure to reduce the increase of CO_2 emissions, and from the macroeconomic perspective, the rising energy consumption greatly impacts energy price and its fluctuations in the world market. It is quite needed to solve the current issue of energy consumption and CO_2 emissions to maintain the economic growth.

Carbon emissions of the country's level of development directly reflect the degree of the development of the social economy and low carbon economy. Many social and economic factors, such as population, income level, energy structure, industrial structure, policy guidance, and consumption mode, will affect the country's carbon emissions. Different countries have different stages of economic development as well as the degree of carbon emissions. Global climate change is not the result of greenhouse gas emissions, but the cumulative effect of historical emissions. However, the rate of carbon dioxide in the atmosphere increased mainly in the developed industrialized countries in the past 200 years. Also, carbon emissions from developing countries have increased rapidly in recent years.



Source:2015 BP Statistical Energy Review

Figure 1.3: Global energy consumption 1965-2014

The 1971 Nobel Prize winner, Simon Kuznets, stated that as income per capita increases, income inequality also increases at first but then after a turning point, it starts to decline. Traditional Environmental Kuznets curve (EKC) shows a hypothesis that presents the relationship between the level of income and environmental quality. It assumes the existence of an inverted U-shaped relationship between economic growth per capita and the environmental pollution, suggesting that when levels of environmental damage increase first with the raise of GDP per capita, they then subsequently decline (Grossman and Krueger, 1991; Shafik and Bandyopadhyay, 1992). Ever since, the EKC hypothesis has become an independent research issue, agitating a large body of theoretical and empirical literature .The EKC growth mode “grow now clean later” has brought the world to the environmental change including global warming and climate change. The high-income growth in emerging economies has generated a very high environment cost in terms of water and air pollution, deforestation, deteriorated air quality, accumulation of urban and industrial wastes and loss of biodiversity. These environment problems have very dangerous implications for the survival of human life. According to the Environmental Kuznets Curve, a typical inverted "U" relationship between economic growth and pollutant emissions, before the GDP per capita reaches the inflection point of the inverted "U" type, the CO_2 emissions increases to the break point first and declines.

However, there is still an issue that has been debated about the existence of Environmental Kuznets Curve. (Galeotti, 2009; Buehn and Farzanegan, 2013) According to Focacci (2005), availability hypothesis research supports Environmental Kuznets curve that there is inverted "U" relationship between environmental pollution and GDP per capita. However, Richmond and Kaufman (2006) pointed that there is no obvious relationship between economic growth and environmental pollution. These arguments suggest that CO_2 emissions do not necessarily increase as a result of economic growth first and then decrease. Environmental Kuznets curve can be used to analyze the relationship between economic growth and CO_2 emissions through other analytical frameworks.

The motivation behind using a panel quantile regression and fixed effect model on emissions is threefold: First, the panel data framework is employed to research the determinants of CO_2 emissions in developing countries and developed countries because it is more advantageous than focusing on one country of providing more informative data, more variability, more degrees of freedom and thus greater efficiency in estimation. However, tradition regression techniques focus on mean effect, which may lead to under or overestimate the relevant efficient or even fail to detect important relationship. Moreover, panel data model accommodates the special heterogeneity indicated by region-specific, non-observable and time-invariant intercepts. Therefore, it is significant to examine the determinants of CO_2 emissions for developing countries and developed countries within the panel data framework. Second, this method can describe the entire conditional distribution of the dependent variable; therefore, it helps obtain a more complete picture of the factors associated with pollutant emissions. Especially, quantile regression estimators provide one solution to each quantile. Using this methodology, the determinants of emissions can be assessed throughout the conditional distribution, especially in the countries with the most and least emissions. From a policy perspective, it is more interesting to know what occurs at the extremes of a distribution. By contrast, OLS regression techniques are not suitable for making environmental protection policies for high-emissions countries. Third, the panel quantile regression estimation results are robust to outlying observations of the explained variable and more effective than OLS regression, especially when the error term is non-normal, which will help policymakers formulate more accurate environmental protection policies. However, only a few papers have applied a panel quantile regression fixed effect model to investigate the relationship among variables.

1.2 Purpose of the Study

This study investigates the impact of economic growth (GDP), energy consumption, financial development, trade openness, and the lag variable of carbon emissions in developed countries (European Union, the United States, Canada, the United Kingdom and Japan) and developing countries (China, India, Brazil, Mexico and South Africa). It is to find out the evidence to support an inverted U-shaped curve for the developing countries and developed countries. Finally, the researcher compares the data with the different economic growth level, the different carbon emissions of developing and developed countries.

1.3 Advantage of the Study

The advantages of this research are displayed as follows:

First, this study provides the details of typical developing and developed countries analyzed by calculating the turning points of EKC in the different period. These findings reveal the gaps between carbon emission status and theoretical turning points, which are helpful for effective and specific policy-making, and contribute particularly for global carbon emission reduction.

Second, this study provides the benchmark for the each income level, which is useful for guiding carbon emission reduction at income level.

Lastly, this research gives panel quantile regression analysis in the different period to identify the turning points in different countries and different income levels. By doing so, the results can be enriched. The results of quantile data can ensure that the results from panel data are more reliable.

1.4 Scope of the Study

This study took 310 observations from the annual yearly data from 1982 to 2013 for analyzing the relationships among carbon emissions, economic growth, trade openness, energy consumption, financial development and other factors as well. It also adopt a multivariate approach to avoid omitted-variable bias appropriately. The data used to both dependent and independent variables from the World Development Indicators.

CHAPTER 2

Literature review and theoretical background

2.1 Theoretical Background

Economic growth accompanied by the evolution of industrial structure, in the process of industrial evolution and economic growth, consumed a large amount of energy resources, and produced a large amount of carbon emissions, threatening the global atmospheric environment.

2.1.1 The Environmental Kuznets curve (EKC) hypothesis

In 1940s, on the basis of Clark's research, Simon Kuznets, an American economist, explored the relationship between industrial structure evolution and economic development from two perspectives: Labor Distribution and National income. Agriculture, Industry and Services respectively defined in three Industries.

Economic growth accompanied by the evolution of industrial structure, in the process of industrial structure evolution, consumed a large amount of energy resources, and produced a large amount of carbon emissions, threatening the global atmospheric environment.

The Kuznets' rule clarifies not only the transfer of labor force and national income among the Three Industries, but also the breakdown of the agricultural, industrial and service sectors. Clark clearly pointed out that as evolution formed the Three Industries along with the economic development. In the initial stage of industrialization, the proportion of primary industry is relatively high, and the proportion of second industry is low. With the development of industrialization, the proportion of the second industry is gradually rising, reaching the middle stage of industrialization development. When the proportion of the first industry is reduced to about 10%, the Second Industry accounts for the largest proportion of GDP. The country will come into the late industrialization stage of development.

The environmental Kuznets curve is a hypothesized relationship between environmental quality and economic development. Various indicators of environmental degradation tend to get worse as modern economic growth occurs until average income reaches a certain point over the course of development. Although the subject of Environmental Kuznets curve is continually debated, some evidence supports the claim that environmental health indicators, such as water and air pollution, show the inverted U-shaped curve. It has been argued that this trend occurs in the level of many of the environmental pollutants, such as sulfur dioxide, nitrogen oxide, lead, DDT, chlorofluorocarbons, sewage, and other chemicals previously released directly into the air or water.

Grossman and Krueger (1995) for the first time examined the basic relationship between the size of an economy and the intensity of its emissions, discovering that pollution tends to rise during the earliest stages of a country's development, and then to decrease after reaching a certain income level.

$$E_{it} = \beta_0 + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \gamma_i + \lambda_t + \varepsilon_{it} \qquad (1)$$

where E_{it} is a measure of emissions per capita for a given pollutant for country i in year t, Y_{it} is GDP per capita in country i at time t, γ_i is a fixed-effect term which controls for country-specific heterogeneity; λ_t controls for global year effects; and ε_{it} is treated as a stochastic, normally distributed error term, often after correcting for serial correlation and heteroscedasticity. The coefficients β_0, β_1, and β_2 and the intercepts for each country and year are estimated using a panel fixed-effect regression.

Economists offer a wide range of explanations for the shape of the observed EKC. One explanation involves the evolution of institutional structures capable of internalizing pollution-related externalities (Andreoni and Levinson, 2001). At modest income levels, a society may focus on creating jobs, generating wealth, and consuming more without much regard to environmental damage. As a country develops, improving awareness or rising disutility from pollutants may increase the demand for abatement and clean up. This demand could manifest itself in several ways. Companies identified as polluters could become targets of organized boycotts. Indeed, merely the threat of boycotts may result in private firms curbing emissions rather than risking lost revenue from protesting consumers. Alternatively, collective demand for abatement may appear through the political process.

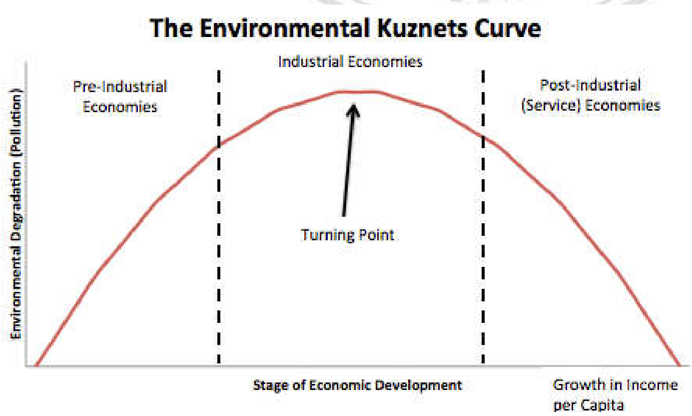
A second theory explains the observed U-shape by changes in the composition of a country's output, particularly for air pollutants and greenhouse gases. Some maintain that economies naturally progress from relatively clean agrarian economies to “dirty” industrial economies based on heavy manufacturing, and then to “clean” services economies. One by product of this is that developed service-based economies will likely import consumption goods from less-developed manufacturing-based economies, effectively exporting emissions. This model of economic development provides an explanation for the formation of pollution havens.

A third explanation for the EKC is that economic expansion may also coincide with technological improvements in efficiency resulting in deliberate or unintentional cuts in emissions. As Dasgupta et al. (2002) pointed out, if clean technology spreads quickly, developing countries could experience lower emissions than predicted by the EKC at every stage of growth, reflected as a downward shift in the EKC.

There is little evidence that the relationship holds true for other pollutants, for natural resource use or for biodiversity conservation. For example, energy, land and resource use, which are sometimes called the "ecological footprint", do not fall with rising income in most developed countries. Another example is the emission of many greenhouse gas, which is much higher in industrialized countries. In addition, the status of many key "ecosystem services" provided by ecosystems, such as freshwater provision and regulation (Perman, et al., 2003), soil fertility, and fisheries, have continued to decline in developed countries.

In general, Kuznets curves have been found for some environmental health concerns (such as air pollution) but not for others (such as landfills and biodiversity). Advocates of the EKC argue that this does not necessarily invalidate the hypothesis – the scale of the Kuznets curves may differ for different environmental impacts and different regions. If the search for scalar and regional effects can salvage the concept, it may yet be the case that a given area will need more wealth in order to see a decline in environmental pollutants. In contrast, a thermodynamically enlightened economics suggests that outputs of degraded matter and energy are an inescapable consequence of any use of matter and energy (so holds the second law); some of those degraded outputs will be noxious wastes, and whether and how their production is eliminated depends more on regulatory schemes and technologies at use than on income or production levels. In one view, then, the EKC suggests that "the solution to pollution is more economic growth;" in the other, pollution is seen as a regrettable output that should be reduced when the benefits brought by its production are exceeded by the costs it imposes in externalities like health decrements and loss of ecosystem services.

The environmental Kuznets curve (EKC) is a conceptual model that suggests that a country's pollution concentrations rise with development and industrialization up to a turning point, after which they fall again as the country uses its increased affluence to reduce pollution concentrations, suggesting that the cleaner environment in developed countries comes at the expense of a dirtier environment in developing countries. In this sense, the EKC is potentially a reflection of the Pollution Haven Hypothesis, because one of the factors that may drive the increase in environmental degradation seen in pre-industrial economies is an influx of waste from post-industrial economies. This same transfer of polluting firms through trade and foreign investment could lead to the decrease in environmental degradation seen in downward-sloping section of the EKC, which models post-industrial (service) economies.



Source: Wikipedia

Figure 2.1: The modified Kuznets curve, which represents the application of the Kuznets curve in Environmental Studies.

According to the EKC, there are three stages in the intensity of pollution in Figure 2.1. Each stage corresponds to a step in the growth process. At the pre-industrial stage where income per capita is low, environment pollution increases. This increase in pollution is explained by factors such as unclean technology used in economic activities, lack of awareness, prioritization of income growth and profits at the early stage of growth. However, with the increment in income per capita and economic growth, followed by improved social indicators, more investments are made for safer technologies. Households become more willing to target their expenditures towards cleaner goods and assets (water, houses, cars, etc.). This stage marks the turning point to lower environment pollution. As the economy crosses the pre-industrialization stage and moves to the post-industrialization phase, environmental depletion reduces.

2.2 Literature Reviews

Nasreen and Anwar (2000) conducted the research of "Causal relationship between trade openness, economic growth and energy consumption: A panel data analysis of Asian countries" in order to provide new ways in the evaluation of public policies and technological innovations in the energy sector of the Asian countries. A panel data set of 15 countries over the period 1980 - 2011 is used by using appropriate panel data techniques, the effects of energy price, economic growth and trade openness on energy consumption for India, Indonesia, Iran, Japan, Jordan, Korea dam, Malaysia, Nepal, Philippines, Sri Lanka, Thailand, Vietnam, Pakistan and China. The impact of economic growth and trade openness on energy consumption is found to be positive. The panel Granger causality analysis revealed the bidirectional causality between economic growth and energy consumption, trade openness and energy consumption.

Ang (2007) examined the dynamic causal relationships between pollutant emissions, energy consumption, and output for France using cointegration and vector error-correction modelling techniques. He argued that these variables were strongly inter-related and therefore their relationship must be examined using an integrated framework. The results provided the evidence for the existence of a fairly robust long-run relationship between these variables for the period 1960–2000. The causality results supported the argument that economic growth exerted a causal influence on growth of energy use and growth of pollution in the long run. The results also pointed to a unidirectional causality running from growth of energy use to output growth in the short run.

Acaravci and Ozturk's (2010) study on the causal relationship between carbon dioxide emissions, energy consumption, and economic growth by using autoregressive distributed lag (ARDL) bounds testing approach of cointegration for nineteen European countries found a positive long-run elasticity estimate of emissions with respect to energy consumption at 1% significant level in Denmark, Germany, Greece, Italy and Portugal. Positive long-run elasticity estimates of carbon emissions with respect to real GDP and the negative long-run elasticity estimates of carbon emissions with respect to the square of per capita real GDP at 1% significance level in Denmark and 5% significant level in Italy were also found. These results supported the validity of environmental Kuznets curve (EKC) hypothesis in Denmark and Italy. This study also explored causal relationship between the variables by using error-correction based Granger causality models.

Sadorsky (2011) examined the causal relationship between total economic growth, energy consumption and trade openness. The panel meant group cointegration and panel Granger causality approached for the panel of 8 Middle Eastern countries, namely, Bahrain, Iran, Jordan, Oman, Qatar, Saudi Arabia, Syria and UAE. The empirical evidence reported that a long-run relationship existed between the variables. Sadorsky found that 1% increase in real GDP per capita increased energy consumption per capita by 0.62%. 1% increase in real per capita exports increased energy consumption per capita by 0.11% while 1% increase in real per capita imports increased energy consumption per capita by 0.04%. Panel Granger causality analysis revealed that Granger's exports caused energy consumption and feedback was found between imports and energy consumption in the short run. Similarly, bidirectional causality existed between GDP and energy consumption in the short run

Table 2.1: Summary of Literature review

Author(s)	Title	Variable	Model	Findings
Samia Nasreen Sofia Anwar (2014)	Causal relationship between trade openness, economic growth and energy consumption: A panel data analysis of Asian countries	1.Total energy consumption 2.Economic growth 3.Trade openness(imports US$ plus exports US$) 4.Energy price	Panel Granger Causality analysis	Empirical results confirmed the presence of cointegration between variables. The impact of economic growth and trade openness on energy consumption was found to be positive
Md. Mahmudul Alam , Md. Wahid Murad , Abu Hanifa Md. Noman , Ilhan Ozturk （2016）	Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing Environmental Kuznets	1.income, 2.energy consumption 3.population growth 4.CO_2 emissions	Autoregressive Distributed Lag (ARDL) bounds test approach	The results showed that CO_2 emissions have increased statistically significantly with increases in income and energy consumption in all four countries(Brazil, China,India and Indonesia).
James B.Ang （2007）	Causal relationship between trade openness, economic growth and energy consumption: A panel	1.Total energy consumption 2.Economic growth 3.Trade openness(imports US $plus exports US$)	Panel Granger Causality analysis	Empirical results confirm the presence of cointegration between variables. The impact of economic growth and trade openness on energy

	data analysis of Asian countries	4.Energy price		consumption is found to be positive

Table 2.1: Summary of Literature Reviews(Continued)

Author(s)	Title	Variable	Model	Findings
Nikolaos Antonakakis, Ioannis Chatziantonio, George Filis (2017)	Energy consumption, CO_2 emissions, and economic growth: An ethical dilemma	1.Energy consumption (total energy consumption) 2.Economic growth (real GDP per capita (in 2005 US$)) 3. CO_2 emission (metric tones per capita)	Panel Granger causality test panel vector autoregression (PVAR)	Our results reveal that the effects of the various types of energy consumption on economic growth and emissions are heterogeneous on the various groups of countries.
Shenggang REN , Baolong YUAN , Xie MA , Xiaohong CHEN (2014)	International trade, FDI (foreign direct investment) and embodied CO2 emissions: A case study of Chinas industrial sectors	1.FDI(FDI in sector/industrial GDP) 2.Per capita income 3.Trade openness(Total goods exports and imports/industrial GDP) 4.Embodied CO_2 emission	GMM estimation	China's growing trade surplus is one of the important reasons for the rapidly rising CO_2 emis -sions and large FDI flows further aggravate China's CO_2 emissions. And the industrial sector's per capita income and CO_2emissions relationship showed inverted-U environmental Kuznets curve.

Table 2.1: Summary of Literature Reviews(Continued)

Author(s)	Title	Variable	Model	Findings
Xingrong Zhao Xi Zhang Ning Li Shuai Shao Yong Geng (2016)	Decoupling economic growth from carbon dioxide emissions in China: A sectoral factor decomposition analysis	1.Carbon emission 2.GDP 3.Energy consumption	Decoupling determinant model	The results show that China performed the weak decoupling of economic growth from CO2 emissions during 1992–2012, and so did all its five major sectors. Such a state did not occur smoothly and presented five different stages.
HU Zongyi, Liu Yiwei, Tang Liwei （2014）	Research on the Relationship of Energy Consumption,Carbon Emission and Economic Growth in China	1. Carbon emission 2. GDP 3. Energy consumption 4. labour	Granger causality	The results show that China's energy consumption and the corresponding carbon dioxide emission in the coming decades will continue to grow．Therefore，China should actively formulate and implement policies to reduce carbon dioxide emission．

CHAPTER 3

Methodology

3.1 Research Methodologies /Data Calculating Method

We will investigate the impact of economic growth (real GDP per capita), energy consumption (kg of oil equivalents per capita), trade openness, financial development on carbon emissions. In this study will separate five groups to examine. The first group will select five developed countries which are largest producers of total CO2 emissions (including European Union, the United States, Canada, the United Kingdom and Japan. The second group will consider five developing countries which are the largest producers of CO_2 emissions including China, India, Brazil, Mexico and South Africa. The third group will examine ten countries including selected five developed countries and five developing countries. The fourth group will examine ten selected countries from 1999 to 2008. And the last group will examine ten selected countries from 1983 to 1998.

3.1.1 Unit Root Test

In the stability testing of data by unit root test, this case used the Augmented Dickey–Fuller test, Philps and Perron (PP) test, Levin–Lin–Chu test, the Breitung test and the IPS test.

Unit root test is to test whether a time series variable is stationary or not. The null hypothesis is generally defined as the presence of a unit root and the alternative hypothesis is either stationary, trend stationary or explosive root depending on the test used. A commonly used test that is valid in large samples is the augmented Dickey–Fuller test. And other popular tests include Phillips-Perron test and KPSS test etc.

1) Philps and Perron (PP) test

Phillips and Perron (PP) test (1988) developed a number of unit tests that have become popular in the analysis of financial time series. The Phillips and Perron(PP) unit root tests differ from the ADF tests mainly in how they deal with serial correlation and heteroskedastic in the errors. It builds on the Dickey–Fuller test of the null hypothesis $\rho = 0$ in $\Delta y_t = \rho y_{t-1} + u_t$, where ρ is the first difference operator. Like the augmented Dickey–Fuller test, the Phillips–Perron test addresses the issue that the process generating data for y_t might have a higher order of autocorrelation than is admitted in the test equation-making y_{t-1} endogenous and thus invalidating the Dickey–Fuller t-test. Whilst the augmented Dickey–Fuller test addresses this issue by introducing lags of Δy_t as regressors in the test equation, the Phillips–Perron test makes a non-parametric correction to the t-test statistic. The test is robust with respect to unspecified autocorrelation and heteroscedasticity in the disturbance process of the test equation

2) Dickey–Fuller test

Dickey–Fuller test tests the null hypothesis of whether a unit root is present in an autoregressive model. The alternative hypothesis is different depending on which version of the test is used, but is usually stationarity or trend-stationarity. It is named after the statisticians David Dickey and Wayne Fuller, who developed the test in 1979.

DF test is to be displayed by using an AR(1) model below:

$$y_t = \hat{c} + \hat{\beta} y_{t-1} + \hat{\mu}_t \ , \quad \hat{\mu}_t \sim i.i.d\ (0, \sigma^2) \tag{1}$$

Consider the hypothesis is:

$$H_0: |\hat{\alpha}| \geq 1,$$

$$H_0: |\hat{\alpha}| < 1,$$

if $|\hat{\alpha}| \geq 1$, y is a nonstationary series and the variance of increases with time and approaches infinity. If $|\hat{\alpha}| < 1$, y is a (trend-)stationary series.Thus, the hypothesis of (trend-)stationarity can be evaluated by testing whether the absolute value of $\hat{\alpha}$ is strictly less than one.

To simplify the computation, take the first difference of an AR(1) process,

$$\Delta y_t = \hat{\psi}\, y_{t-1} + \hat{u_t}, \tag{2}$$

Where $\widehat{\psi}$ =$(\hat{\alpha}-1)$.Consider the hypothesis is:

$$H_0: |\hat{\alpha}| = 1,$$

$$H_0: |\hat{\alpha}| < 1.$$

2）Augmented Dickey and Fuller(ADF)test

Augmented Dickey–Fuller test (ADF) tests the null hypothesis of a unit root is present in a time series sample. The alternative hypothesis is different depending on which version of the test is used, but is usually stationarity or trend-stationarity. It is an augmented version of the Dickey–Fuller test for a larger and more complicated set of time series models.The augmented Dickey–Fuller (ADF) statistic, used in the test, is a negative number. The more negative it is, the stronger the rejection of the hypothesis that there is a unit root at some level of confidence.

The testing procedure for the ADF test is the same as for the Dickey–Fuller test but it is applied to the model:

$$y_t = \beta D_t + \phi y_{t-1} + \sum_{j=1}^{p} \Psi_j \Delta y_{t-j} + \varepsilon_t, \tag{3}$$

Where D_t is a vector of deterministic terms (constant, trend etc.) The p lagged difference terms, Δy_{t-j}, are used to approximate the ARMA structure of the errors, and the value of p is set so that the error ε_t is serially uncorrelated. The error term is also assumed to be homoscedastic. Consider the hypothesis is:

$$H_0: \phi = 1,$$

$$H_0: |\phi| < 1.$$

Under the null hypothesis, y_t is I (1) which implies that =1, and the alternative is y_t is stationary. The ADF t-statistic and normalized bias statistic are based on the least squares estimates of (3) and are given by

$$ADF_t = t_{\phi=1} = \frac{\widehat{\phi}-1}{SE(\phi)} \tag{4}$$

Table 3.1: Summary of panel unit root tests and hypothesis

Unit Root Test	**Common Unit Root Process**	**Individual Unit Root Process**		
Methods	LLC	IPS	Breitung	Fisher-PP and ADF
Null Hypothesis	Has Unit root	Has unit root	Has unit root	Has Unit root
Alternative Hypothesis	Has no unit root (stationary)	Has no unit root (stationary)	Has no unit root (stationary)	Has no unit root (stationary)
Statistics Test	T – statistics	W - statistics	T statistics	Chi square statistics
Prob<0.1	0.00-0.10	0.00-0.10	0.00-0.10	0.00-0.10

3.1.2 Panel Cointegration

The Johansen Fisher panel cointegration test is a panel version of the individual Johansen (1988) cointegration test. Based on the same principles underpinning the Fisher ADF panel unit root test described above, the Johansen Fisher panel cointegration test aggregates the p-values of individual Johansen maximum eigenvalue and trace statistics. If πi is the p-value from an individual cointegration test for cross-section i, under the null hypothesis for the panel.

In case the linear combinations of non-stable series at the non-trend levels become stable in the long term, cointegration linkage emerges. In case there is cointegration linkage between series, alternative cointegration analyses such as Engle-Granger (1987), Johansen (1988), Johansen-Jesulius (1990), Paseran (1999) may be run (Engle & Granger, 1987 (Johansen, 1988; Johansen & Jusehus 1990; Pesaran & Shin, 1999). The Engle-Granger (1987) approach is able to find single cointegration vector in the series whose first difference is stable (Engle & Granger, 1987).

In the Johansen (1988) and Johansen-Jesulius (1990) cointegration approach, all variables included in the model are identified as inherent; as a result, a VAR model where more than one cointegration vectors are existent Johansen & Jusehus. In the

Paseran (2001) test, regardless of whether the variables are static at the different levels, more than one cointegration vectors may be found (Pesaran, Shin, & Smith, 2001). Because the series used in the analysis is I(1), multivariable cointegration analysis developed by Johansen-Jesulius (1990) is used to detect cointegration linkage between the variables Johansen & Jusehus. To find the number of cointegration vectors, two likelihood ratios (LR), trace statistics (trace, trace statistic) and maximum Eigen statistic (max, maximum Eigen statistic), are used (Pazarhoglu 2007). These tests are used in the prediction of number of cointegrated vectors. To this end;

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \ln(1 - \lambda_i) \tag{5}$$

$$\lambda_{max} = (r, r+1) = -T \bullet In(1 - \lambda_{r+1}) \tag{6}$$

λ_i is the value of characteristic rootd whereas T is the number of observations. At (5), the zero by hypothesis for trace statistic (λ_{trace})is "There are r cointegrated vectors at most." Zero hypothesis for maximum eigen statistic at (6) (λ_{max})here are r+1 cointegrated vectors at most". Johansen (1990) and Johansen-Jesulius(1990) assume that in both tests ,there is optimal delay length for Var(vector autoregressive)process(Johansen, 1988: Johansen Juselus, 1990)

3.1.3 Ordinary Least Square (OLS) Estimator

In statistics, ordinary least squares (OLS) is a method for estimating the unknown parameters in a linear regression model, with the goal of minimizing the sum of the squares of the differences between the observed responses in the given dataset and those predicted by a linear function of a set of explanatory variables (visually this is seen as the sum of the vertical distances between each data point in the set and the corresponding point on the regression line the smaller the differences, the better the model fits the data). The resulting estimator can be expressed by a simple formula, especially in the case of a single regressor on the right-hand side. The OLS estimator is consistent when the regressors are exogenous, and optimal in the class of linear unbiased estimators when the errors are homoscedastic and serially uncorrelated. Under these conditions, the method of OLS provides minimum-variance mean-unbiased estimation when the errors have finite variances. Under the additional assumption that the errors be normally distributed, OLS is the maximum likelihood estimator. OLS is used in fields as diverse as economics (econometrics), political science, psychology and electrical engineering (control theory and signal processing).

In this research will apply the panel of Ordinary least square by Kao and Chiang (1997), FMOLS by Pedroni (1999) by Kao and Chiang (1997) and Pedroni (2001) to estimate the long run relationship between dependent variale and independent variables. Kao and Chiang (1997) found that OLS estimator. The FMOLS and DOLS may be more assurance in assenting the panel co-integration regression Saikkonen (1991), Stock and Waston (1993). The general equation is as follow:

$$\hat{\beta}_{OLS} = N^{-1}\sum_{i=1}^{n}[\sum_{t=1}^{T}(X_{it} - X_i^*)^2]^{-1}[\sum_{t=1}^{n}(X_{it} - X_i^*)Y_{it}^* - Y^*{}_i \quad (7)$$

where,

$\hat{\beta}_{OlS}$ = ordinary least square

X_{it} = independent variables in the model

Y_{it}^* = dependent variable in the model

X^* = the mean of independent variables in the model

$Y^*{}_i$ = is the mean of dependent variable in the model

3.2 Panel Quantile Regression

In this paper, I will use a fixed effect panel quantile regression model to investigate the impact of economic growth, trade openness and energy consumption on carbon emissions. By using a panel quantile regression methodology, we can examine the determinants of carbon emissions throughout the conditional distribution, especially in the countries with the most and least emissions. However, traditional regression techniques focus on the mean effects, which may lead to under- or over-estimating the relevant coefficient or even failing to detect important relationships.

Quantile regression is a type of regression analysis used in statistics and econometrics. Whereas the method of least squares results in estimates that approximate the conditional mean of the response variable given certain values of the predictor variables, quantile regression aims at estimating either the conditional median or other quantiles of the response variable.

The quantile regression technique was introduced in the seminal paper by Koenker and Bassett (1978). This method is a generalization of median regression analysis to other quantiles. The conditional quantile of y_i given χ_i is as follows

$$Q_{y_i}(\tau|\chi_i) = \chi_i^{T}\beta_\tau \tag{8}$$

Quantile regression is robust to outliers and heavy distributions. However, these methods do not take into account the unobserved heterogeneity of a country. In this paper, we employ a panel quantile method with fixed effects, which makes it possible to estimate the conditional heterogeneous covariance effects of carbon emissions drivers, thus controlling for unobserved individual heterogeneity. Some works, such as those by Koenker (2004); Lamarche (2010); Galvao (2011) and Canay (2011), are focused on the econometric theory of applying quantile regressions to panel data. Consider thefollowing fixed effect panel quantile regression model:

$$Q_{y_{it}}\left(\tau_\kappa\middle|\alpha_{i,}\chi_{it}\right) = \alpha_i + \chi_{it}'\beta(\tau_\kappa). \tag{9}$$

The major problem with fixed effect panel quantile regression is that the inclusion of a considerable amount of fixed effects (αi) is subject to the incidental parameters problem (Lancaster, 2000; Neyman and Scott, 1948). The estimator will be inconsistent when the number of individuals goes to infinity but the number of observations for each cross-sectional unit is fixed. The main reason why the literature on fixed effect panel quantile regression is relatively scarce is that the inferior approaches to eliminating unobserved fixed effects are unfeasible in the quantile regression model. These methods rely on the fact that expectations are linear operators, which is not the case for conditional quantiles.

Koenker (2004) proposes an appropriate method for addressing such problems. The author treats unobservable fixed effect as parameters to be jointly estimated with the covariate effects for different quantiles. The unique characteristic of this method is the introduction of a penalty term in the minimization to address the computational problem of estimating a mass of parameters specifically; the parameter estimate is calculated as follows

$$\min_{(\alpha,\beta)} \sum_{\kappa=1}^{K}\sum_{t=1}^{T}\sum_{i=1}^{N}\omega_\kappa\,\rho_{\tau_\kappa}\left(y_{it}-\alpha_i-\chi_{it}^{T}\beta(\tau_\kappa)\right)+\lambda\sum_{i}^{N}|\alpha_i| \tag{10}$$

where i is the index for countries (N), T is the index for the number of observations per countries, K is the index for quantiles, x is the matrix of explanatory variables, ρ_{τ_k} is the quantile loss function. In addition, w_k is the relative weight given to the k-th quantile, which controls for the contribution of the k-th quantile on the estimation of the fixed effect. We employ equally weighted quantiles w_k =1/K (Alexander et al., 2011; Lamarche, 2011). λ is the tuning parameter that reduces the individual effects to zero to improve the performance of the estimate of β. If the λ term goes to zero, then the penalty term disappears, and we obtain the usual fixed effects estimator. However, if the λ term goes to infinity, then we obtain an estimate of the model without individual effects. In this paper, we set λ =1.

Furthermore, we study the effect of economic growth, trade openness, energy consumption, financial development and lag one of carbon emissions on carbon emissions by modifying the specifications of previous studies. We specify the conditional quantiles function for quantile τ as follows

$$Q_{y_{it}}(\tau|\alpha_i,\xi_t,\chi_{it}) = \alpha_i + \xi_t + \beta_{1\tau}ENC_{it} + \beta_{2\tau}GDP_{it} + \beta_{3\tau}TO_{it} + \beta_{4\tau}GDP2_{it} + \beta_{5\tau}CO2_{it-1} + \beta_{6\tau}FIN_{it} \quad (11)$$

where the countries are indexed by i and time by time t. y_{it} is the emissions indicator.

3.3 The econometric model of EKC hypothesis

EKC hypothesis in its general format can be specified as follows (Saboori et al., 2012):

$$E = f(Y, Y^2) \quad (12)$$

where E is an environmental indicator, Y is income . As the main objective of this study is to identify the TP of carbon emission per capita with the increase of the GDP per capita, namely EKC hypothesis, therefore other additional variables are not considered in our model. The estimation model in logarithm form is as follows :

$$\ln E_{it} = \alpha_i + \beta_{1t}\ln Y_{it} + \beta_{2t}(\ln Y_{it})^2 \quad (13)$$

where i indicates the country samples (i=1,2,3 …), t indicates the study period. α_i represents the fixed effect, E_{it} represents carbon emission per capita of the group i in the period t, Y_{it} represents GDP per capita of group i the period t in year t which is measured with 2,010 US dollars. β_{1t} and β_{2t} denote the estimated coefficients. After establishing the estimation model of EKC hypothesis, a TP can be identified by taking the derivative of the known quadratic functions of the EKC hypothesis above, the process is as follows.

$$\text{Let } \frac{\mathrm{d}}{\mathrm{d}(Y_{it})}\ln(E)_{it} = \frac{\beta_{1t}}{Y_{it}} + \frac{2\beta_{2t}\ln Y_{it}}{Y_{it}} = 0 \tag{14}$$

Therefore, the TP of GDP per capita is $Y_{it} = \exp(\frac{-\beta_{1t}}{2\beta_{2t}})$

CHAPTER 4

The empirical results

Firstly, this chapter explains the results from testing stationary by employing vary from unit root models such as Levin, Lin, and Chu (LLC) Test, Breitung t-stat Test , Im,Pesaran and Shin W-stat (IPS) Test and Fisher Type Test by using Fisher-ADF and Fisher-PP in order to make a comparison for the best model which suits to data structure. And this part explains whether there is a long-run relationship among these variables using Johansen Fisher panel cointegration test proposed by Maddala and Wu (1999). Secondly, this chapter explains the different between the traditional regression techniques focus (OLS) and quantile regression. Finally, compare with the different between the three groups.

4.1 Data Collection

This study used the secondary data using annual years data from 1981 to 2013 obtain 310 observations yearly for analyzing the impact of economic growth, trade openness, energy consumption and financial development on carbon emissions in developing countries (China, India, Brazil, Mexico and South Africa) and developed countries (European Union , the United States, Canada , the United Kingdom and Japan). The data used to both dependent and independent variables from the World Development Indicators of the World Bank. In additional, all variables are transformed into natural logarithms prior to empirical analysis.

Table 4.1: Variable definitions.

Variable	Definition	Source
CO_2	Carbon dioxide emissions (metric tons per capita)	World Development Indicators
ENC	Energy consumption (kg of oil equivalents per capita)	World Development Indicators
GDP	Economic growth (real GDP per capita constant USD at 2010 prices)	World Development Indicators
TRADE	Trade openness (% of GDP)	World Development Indicators
FIN	Financial development, domestic credit to the private sector (% of GDP)	World Development Indicators

4.2 Descriptive Statistics

Summary Statistics presents an overview of the descriptive statistics. Clearly, the distributions of all of the variables are skewed, and the kurtosis values show that five series distributions are more concentrated than the normal distribution with longer tails. The Jarque-Bera statistical test strongly rejects the null hypothesis of normality, indicating the non-normality of the unconditional distribution of all of the variables.

First**,** comparing with Table 4.1 and Table 4.3, we can observed the mean of carbon emissions in developed countries is three times more as developing countries. And the GDP per capita for developed countries almost 6.7 times more than developing countries.One explanation of this phenomenon is that developed countries have been finished The Industrial Revolution already, and the level of economic development of developed countries reached higher than the developing countries. In terms of energy consumption(measured to kg of oil quivalents per capita), developed countries are 3.84 times more than developing countries.And the financial development of developed countries is two times higher than the developing countries. But for the level of trade openness, developing countries as much as developed countries.

Table 4.2: Summary Statistics for Developing Countries

Variable	CO2	ENC	FIN	GDP	TO
Mean	3.800320	1339.149	50.55407	5361.487	32.81338
Median	2.748938	1250.943	44.86623	6300.222	32.36729
Maximum	10.04072	2963.363	133.8003	11912.15	63.96637
Minimum	0.475150	294.6755	11.11396	403.8780	9.051853
Std. Dev.	2.965295	759.0486	32.36816	3421.766	15.03530
Skewness	0.897143	0.527005	0.894289	-0.250725	0.232003
Kurtosis	2.404932	2.193302	2.910495	1.630544	1.948303
Jarque-Bera	23.82378	11.74466	21.38014	14.17908	8.809127
Probability	0.000007	0.002816	0.000023	0.000834	0.012221
Sum	608.0512	214263.9	8088.651	857837.9	5250.141
Sum Sq. Dev.	1398.083	91608617	166584.0	1.86E+09	35943.60
Observations	160	160	160	160	160

Source: Calculation from Eviews 8

Table 4.3: Summary Statistics for Developed Countries

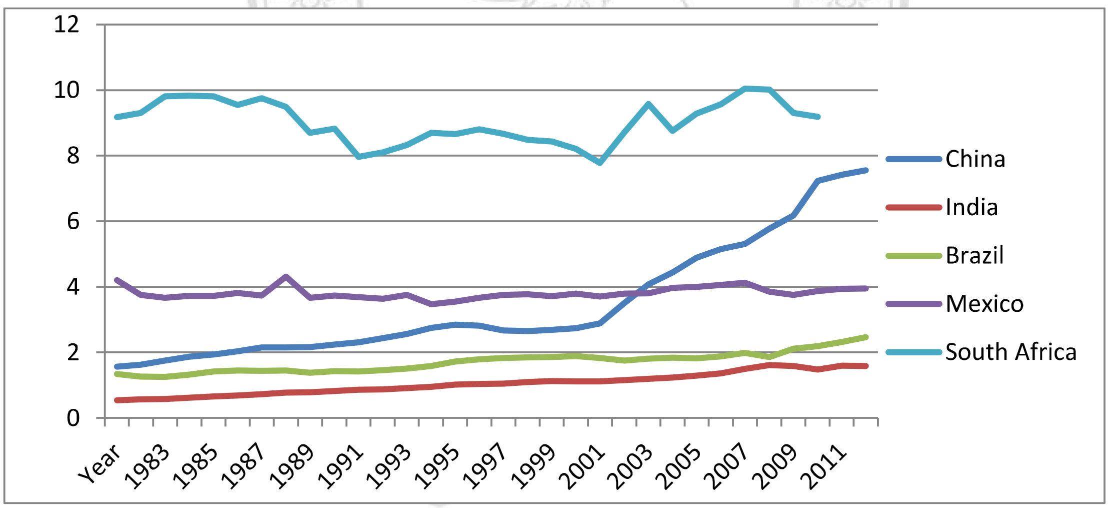
Variable	CO2	ENC	FIN	GDP	TO
Mean	12.25716	5148.565	95.23078	35867.64	35.34004
Median	9.627200	3786.431	91.79441	36030.74	37.55270
Maximum	20.20761	8441.185	195.6766	49979.53	70.24459
Minimum	6.733852	2823.877	30.86014	19914.02	13.07034
Std. Dev.	4.571400	2065.834	41.56500	7802.392	16.07964
Skewness	0.531317	0.462814	0.729834	-0.111806	0.277642
Kurtosis	1.547687	1.318249	2.668725	2.166365	2.004958
Jarque-Bera	21.31948	24.26006	14.74915	4.904248	8.548128
Probability	0.000023	0.000005	0.000627	0.086111	0.013925
Sum	1936.631	813473.3	15046.46	5667088.	5583.726
Sum Sq. Dev.	3280.939	6.70E+08	271241.0	9.56E+09	40593.11
Observations	158	158	158	158	158

Source: Calculation from Eviews 8

Table 4.4: Summary Statistics for All Countries

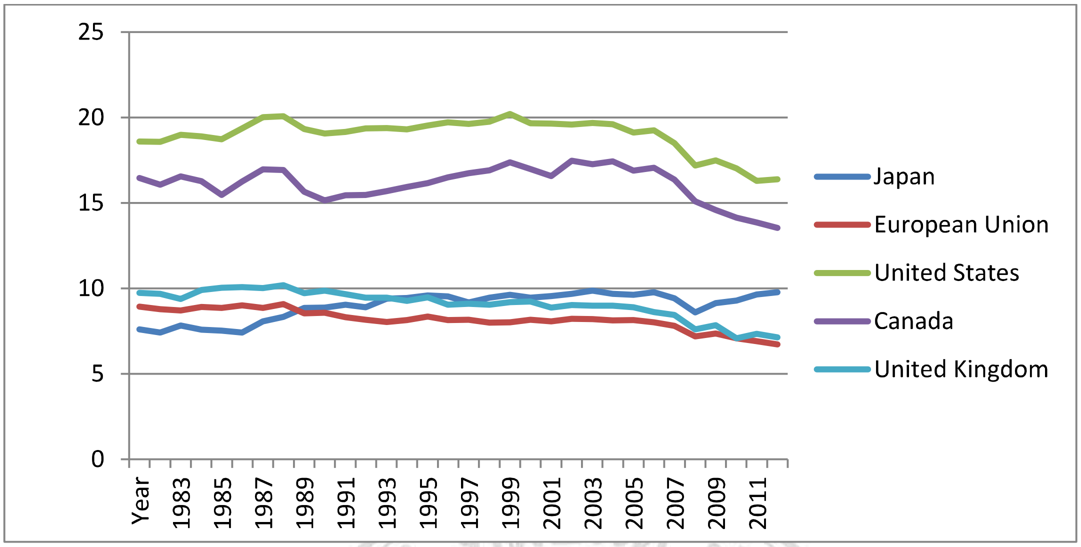
Variable	CO_2	ENC	FIN	GDP	TO
Mean	8.002144	3231.878	72.75193	20518.63	34.06877
Median	8.157739	2832.243	63.85608	11791.66	34.78063
Maximum	20.20761	8441.185	195.6766	49979.53	70.24459
Minimum	0.475150	294.6755	11.11396	403.8780	9.051853
Std. Dev.	5.718001	2458.016	43.37866	16413.54	15.58979
Skewness	0.611983	0.858503	0.783899	0.257047	0.271086
Kurtosis	2.409330	2.548996	3.085311	1.489638	2.017944
Jarque-Bera	24.47253	41.75761	32.66483	33.72769	16.67361
Probability	0.000005	0.000000	0.000000	0.000000	0.000240
Sum	2544.682	1027737.	23135.12	6524926.	10833.87
Sum Sq. Dev.	10364.48	1.92E+09	596501.4	8.54E+10	77044.22
Observations	318	318	318	318	318

Source: Calculation from Eviews 8



Source: Secondary data from World Bank(1981-2013)

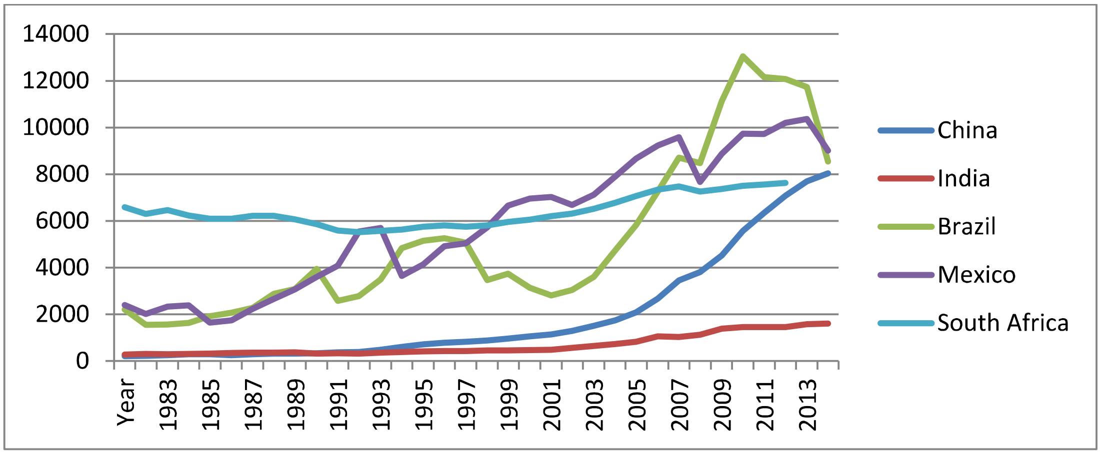
Figure 4.1:CO_2 emissions (measured in metric tons per capita) for developing countrie



Source: Secondary data from World Bank(1981-2013)

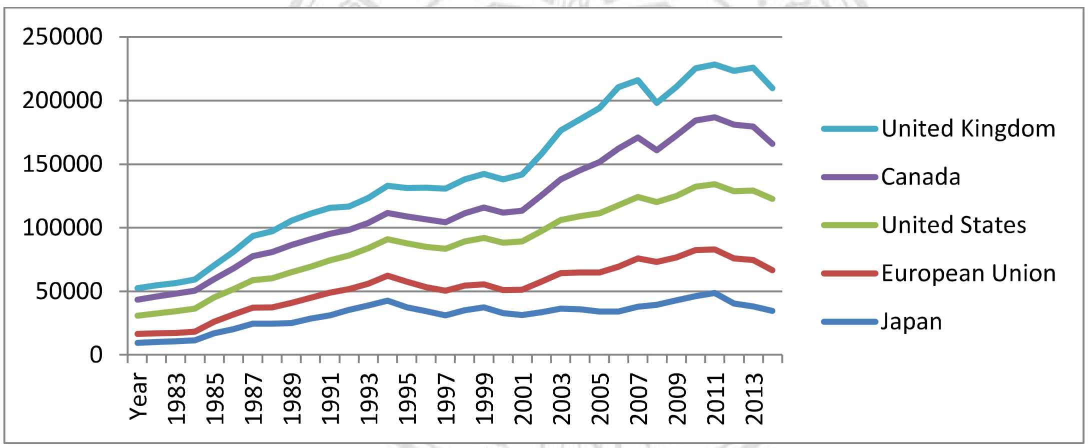
Figure 4.2:CO_2 emissions (measured in metric tons per capita) for developed countries

Figure 4.1 & Figure 4.2 depict the time series of carbon emissions for selected ten countries. The carbon emissions in China initially stable increase and signicantlly increase from 2002. But for United States and Canada initially increase and then decrease. This finding is not surprising because United States and Canada are developed country, which arrived the high level of economic growth to supports the EKC hypothesis, i.e., an inverted U-shaped relationship between environmental pollution and income. However, there is a persistent slowly increase in the emissions level can be observed in the other six countries (including Mexico, Brazil, India, Japan, European Union, UK); thus, the trends for carbon emissions, economic growth and energy consumption are similar. This finding indicates that the factors that have prompted the persistent increase in carbon emissions are somehow related to increase in economic activity and energy consumption.



Source: Secondary data from World Bank(1981-2013)

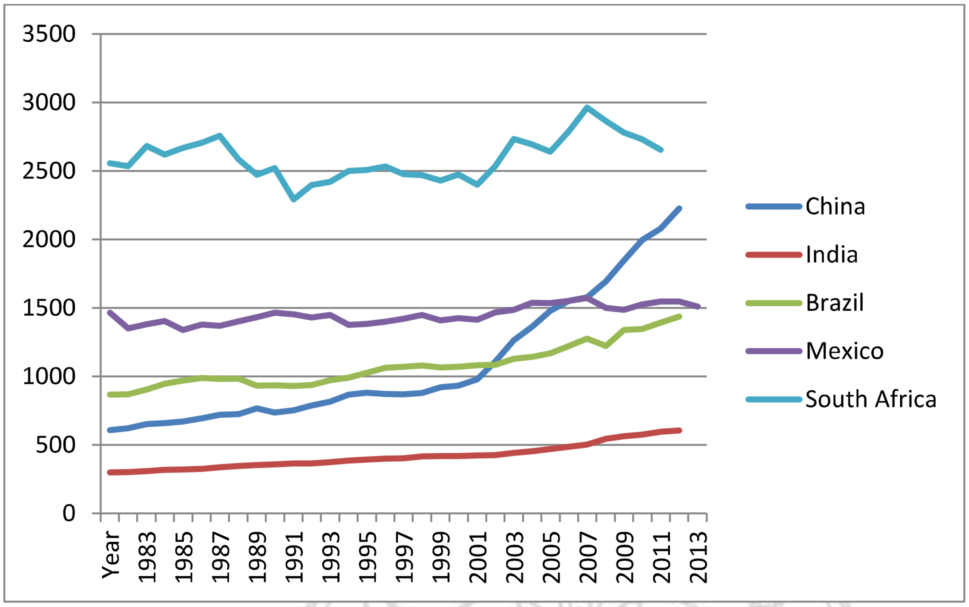
Figure 4.3: GDP per capita for developing countries



Source: Secondary data from World Bank(1981-2013)

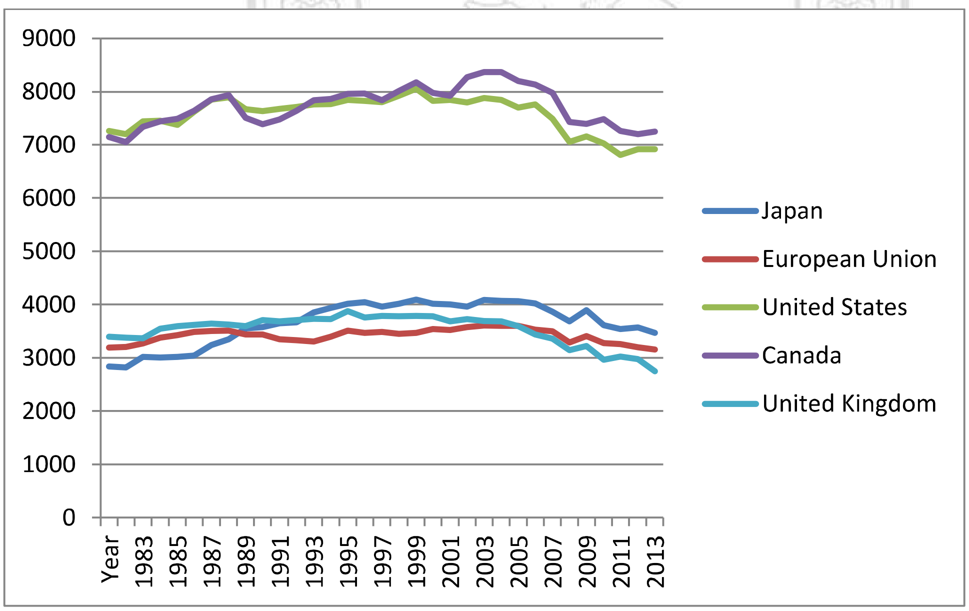
Figure 4.4:GDP per capita for developed countries

Figure 4.3 & Figure 4.4 show the time series of GDP per capita for five selected developing countries and developed countries. There are some factors that may cause the difference in the level of economic development between developed countries, such as differences in natural resources, scientific and technological levels and the quality of the related policies. Indeed, compared with the other countries in the sample, Developed countries show the highest variation in terms of not only GDP per capita, but also carbon emissions and energy consumption.



Source: Secondary data from World Bank

Figure4.5:Energy Consumption(measured in kg of oil equivalents) for developing countries



Source: Secondary data from World Bank

Figure 4.6: Energy Consumption(measured in kg of oil equivalents) for developed countries

Figure 4.5&4.6 show the time series of energy consumption for selected countries. The trend of energy consumption is similar with carbon emissions.

4.3 Panel Unit Root Tests Result

Firstly, before estimating the panel quantile regression, all variables are transformed into natural logarithms prior to empirical analysis. Secondly, we test whether the variables used are stationary. Stationary tests are essential for standard econometric theory and without them, we cannot obtain consistent estimators which in turn give doubtful or spurious regression results. In order to test for the presence of unit roots, the data is examined using the Levin, Lin, and Chu (LLC) Test, Breitung t-stat Test, Im, Pesaran and Shin W-stat (IPS) Test and Fisher Type Test by using Fisher-ADF and Fisher-PP Test.

Moreover, Table 4.4, Table 4.5 and Table 4.6 present the results of the panel unit root tests. These results indicate that null hypothesis of the existence of a unit root could be rejected for one of the variables at the selected level. However, the unit root null hypothesis for one of the variables at the first difference could almost be completely rejected at 1% level. Therefore, an empirical analysis that uses the first difference sequence is necessary.

Table 4.5: Penal Unit Root Test for Developing Countries

Variable	CO_2		ENC		GDP		FIN		TO	
Levels	Statistic	Prob.**	Statistic	Prob.**	Statistic	Prob.**	Statistic	Prob.**	Statistic	Prob.**
LLC	-0.33	0.37	1.02	0.84	-1.21	0.11	-0.79	0.21	-1.45	0.07
Breitung	-0.02	0.48	1.14	0.87	0.82	0.79	-0.92	0.17	-0.96	0.16
IPS	-0.48	0.31	1.51	0.93	-0.35	0.36	-0.44	0.32	-2.13	0.01
ADF	11.70	0.30	5.60	0.84	14.317	0.15	9.75	0.46	19.82	0.03
PP	11.66	0.30	5.89	0.82	11.085	0.35	11.2	0.33	16.85	0.07
First Difference										
LLC	-7.97	0.00	-5.80	0.00	-8.35	0.00	-8.36	0.00	-12.3	0.00
Breitung	-5.23	0.00	-6.10	0.00	-6.47	0.00	-7.03	0.00	-8.58	0.00
IPS	-8.75	0.00	-8.07	0.00	-6.51	0.00	-8.88	0.00	-16.3	0.00
ADF	81.29	0.00	68.86	0.00	54.38	0.00	81.35	0.00	175.94	0.00
PP	97.43	0.00	69.33	0.00	54.66	0.00	83.84	0.00	849.95	0.00

Source: Calculation from Eviews 8

Table 4.6: Penal Unit Root Test for Developed Countries

Variable	CO_2		ENC		GDP		FIN		TO	
Levels	Statistic	Prob.**	Statistic	Prob.**	Statistic	Prob.**	Statistic	Prob.**	Statistic	Prob.**
LLC	2.520	0.99	2.01	0.97	0.08	0.53	-0.429	0.33	-2.042	0.02
Breitung	1.798	0.96	3.50	0.99	1.75	0.96	1.49	0.93	-0.29	0.38
IPS	3.187	0.99	4.13	1.00	1.512	0.93	-0.74	0.22	-0.778	0.21
ADF	1.152	0.99	0.63	1.00	5.1	0.88	11.57	0.31	17.031	0.07
PP	1.53	0.99	0.91	0.99	1.916	0.99	6.11	0.80	24.195	0.00
First Difference										
LLC	-12.328	0.00	-13.171	0.00	-7.353	0.00	-4.483	0.00	-11.744	0.00
Breitung	-7.25	0.00	-6.61	0.00	-3.56	0.00	-7.03	0.00	-6.5305	0.00
IPS	-12.080	0.00	-13.104	0.00	-6.004	0.00	-5.015	0.00	-9.9040	0.00
ADF	123.64	0.00	124.88	0.00	49.15	0.00	42.49	0.00	85.062	0.00
PP	127.69	0.00	148.61	0.00	47.96	0.00	52.62	0.00	445.77	0.00

Source: Calculation from Eviews 8

Table 4.7: Penal Unit Root Test for All Countries

Variable	CO_2		ENC		GDP		FIN		TO	
Levels	Statistic	Prob.**	Statistic	Prob.**	Statistic	Prob.**	Statistic	Prob.**	Statistic	Prob.**
LLC	1.31	0.90	2.110	0.98	-1.91	0.11	-0.17	0.432	-3.28	0.01
Breitung	1.06	0.85	3.443	0.99	1.70	0.79	1.32	0.907	-0.88	0.18
IPS	1.91	0.97	3.990	1.00	0.81	0.11	-0.56	0.284	-2.06	0.19
ADF	12.86	0.88	6.238	0.99	19.62	0.95	22.98	0.291	36.85	0.12
PP	13.19	0.86	6.808	0.99	13.00	0.87	17.38	0.628	44.98	0.01
First Difference										
LLC	-13.98	0.00	-13.18	0.00	-11.2	0.00	-8.73	0.000	-15.55	0.00
Breitung	-8.60	0.00	-8.997	0.00	-6.56	0.00	-8.60	0.000	-9.81	0.00
IPS	-14.7	0.00	-14.99	0.00	-8.98	0.00	-9.84	0.000	-14.14	0.00
ADF	204.9	0.00	193.7	0.00	104.8	0.00	123.8	0.000	174.0	0.00
PP	225.1	0.00	217.9	0.00	102.1	0.00	136.4	0.000	605.4	0.00

Source: Calculation from Eviews8

4.4 Johansen-Type Panel Cointegration

Fisher (1932) derives a combined test that uses the results of the individual independent tests. Maddala and Wu (1999) use Fisher's result to propose an alternative approach to testing for cointegration in panel data by combining tests from individual cross-sections to obtain at test statistic for the full panel.

If $\pi_i$is the p-value from an individual cointegration test for cross-section i, then under the null hypothesis for the panel,

$$2\sum_{i=1}^{N}\log(\pi_i) \rightarrow x^2 2N \qquad (15)$$

By default, EViews reports the χ^2 value based on MacKinnon-Haug-Michelis (1999) p-values for Johansen's cointegration trace test and maximum eigenvalue test.

Table 4.8: Johansen Fisher panel cointegration test for Developing Countries

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	110.1	0.0000	62.48	0.0000
At most 1	54.47	0.0000	18.13	0.0528
At most 2	42.23	0.0000	19.91	0.0301
At most 3	32.43	0.0003	14.92	0.1349
At most 4	47.50	0.0000	47.50	0.0000

Source: Calculation from Eviews 8

Table 4.9: Johansen Fisher panel cointegration test for Developed Countries

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	89.78	0.0000	59.94	0.0000
At most 1	40.55	0.0000	24.95	0.0054
At most 2	22.57	0.0125	13.55	0.0844
At most 3	17.24	0.0693	9.716	0.0958
At most 4	27.64	0.0021	27.64	0.0021

Source: Calculation from Eviews 8

Table 4.10: Johansen Fisher panel cointegration test for All Countries

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	232.8	0.0000	147.8	0.0000
At most 1	107.2	0.0000	50.95	0.0002
At most 2	68.87	0.0000	28.69	0.0941
At most 3	59.51	0.0000	30.26	0.0657
At most 4	85.05	0.0000	85.05	0.0000

Source: Calculation from Eviews 8

As the results of the panel unit root tests indicate that the variables contain a panel unit root, we can proceed to examine whether there is a long-run relationship among these variables using the Johansen Fisher panel cointegration test proposed by Maddala and Wu (1999). In the Johansen-type panel cointegration test, results are known to depend heavily on the VAR system lag order. Table 4.7, Table 4.8 and Table 4.9 present the results, which use one lag and indicate that four cointegrating vectors exist.

4.5 Quantile Regression

To control for the distributional heterogeneity, the quantile regression with fixed effects in Koenker (2004) is used. As noted above, the omission of time-period fixed effects could bias the estimates in a typical time series study, which is the source of power for our focus on quantile regression analysis with a two-way fixed effect. Table 4.12~4.17 presents the results of the panel quantile regression estimation for the different groups. The results are reported for the 5th, 10th, 20th, 30th, 40th, 50th, 60th, 70th, 80th, 90th and 95th percentiles of the conditional emissions distribution.

4.5.1 Quantile Regression For Developing Countries

Regarding economic growth, we can observe that the impact of economic growth on carbon emissions is positive. There are some significant different percentiles in the conditional distribution of ΔCO_2. Initially, the coefficient of ΔGDP slightly decreases then turns to slightly increase and reach at the peak along with the increasing of carbon emissions from the 5^{th} quantile to the 30^{th} quantile. But the increasing level of carbon emission fluctuates the coefficient of ΔGDP from 40^{th} quantile to 95^{th} quantile, and as GDP per capita increases 1% the level of carbon emissions increase by 0.266%-0.332%. Regarding as ΔGDP^2, the coefficient of ΔGDP^2 is negative and we can observe that ΔGDP^2 is clearly heterogeneous. There are highly significant differences across different percentiles in the conditional distribution of ΔCO_2. Overall, GDP per capita reflects a country's income and level of development, the group exhibit an inversed U-shaped curve, meaning that the economic growth level initial increase and then decrease along with the carbon emissions increases. But for ordinary least squares regression model, it is insignificant for one and two fixed effect OLS. And the coefficient of ΔGDP^2 is positive can not EKC hypothesis. Therefore, it is inappropriate to use OLS regression method represent the relationship among variable. And our results are consistent with those of Narayan and Narayan (2010) and Chandran and Tang (2013). Overall, compared with previous research, these results provide not only evidence that tests the validity of EKC hypothesis but also a more complete picture of economic growth in pollution emissions.

The energy consumption has positive effect on carbon emission. The coefficient of ΔENC is strongly significant at different quantiles. Firstly, the coefficient of ΔENC rises along with the increasing of carbon emission reach at the peak of 40th quantile and then turns to decreasing. The The results imply that, as energy consumption increases by 1%, the level of carbon emissions increases by 0.848%-0.930%, which is consistent that energy consumption cause more carbon emissions for developing countries. However, the coefficient of ΔENC in panel quantile regression less than panel OLS regression. There is a common point that the impact of energy consumption is highly on environment pollution.

The other results for the control variables included in the model are trade openness. financial development and the lag of carbon emission. Firstly, we can observe the impact of the ΔTO on carbon emissions, the coefficient of ΔTO is positive at all quantile and strongly significant at high quantile from 70th quantile to 95th quantile, indicating that a higher level of trade openness can increase environment in high-emissions for developing countries. Second, we can observe that the coefficient of ΔFIN is negative at different quantiles except 5th quantile and 60th quantile. And it is highly significant in high carbon emission, which implying that the large size financial development can relieve air pollution at high level of carbon emission. Finally, it is positive and highly significant for the lag of carbon emission at all different quantiles, which indicates the lag of carbon emission increasing 1%, the level of carbon emission increases by 0.0511%-0.0757%. However, there is different results on panel OLS regression. It is negative and insignificant for carbon emission. Therefore, it is inappropriate to use OLS regression method to analyse among variables.

Table 4.11: Panel Regression Results for Developing Countries（1983-2013）

VARIABLES	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95
ΔENC	0.888***	0.903***	0.906***	0.848***	0.930***	0.876***	0.894***	0.875***	0.906***	0.873***	0.890***
	(54.14)	(58.55)	(30.63)	(28.91)	(31.92)	(36.03)	(19.33)	(19.16)	(94.31)	(26.82)	(374.6)
ΔFIN	-0.003	-0.007***	-0.006*	-0.005**	-0.009***	0.010***	-0.005	-0.008***	-0.012***	-0.008***	-0.008***
	(-0.881)	(-4.118)	(-1.915)	(-2.010)	(-3.916)	(-4.242)	(-1.604)	(-3.191)	(-19.86)	(-3.291)	(-10.76)
ΔGDP	0.380***	0.250***	0.270***	0.393***	0.266***	0.312***	0.332***	0.317***	0.298***	0.313***	0.330***
	(7.567)	(6.097)	(4.195)	(10.75)	(7.735)	(6.574)	(6.140)	(4.654)	(30.03)	(21.90)	(34.72)
ΔGDP^2	-2.294***	-1.232***	-1.481***	-2.334***	-1.605***	-1.73***	-1.971***	-1.847***	-1.787***	-1.584***	-1.955***
	(-6.467)	(-3.156)	(-3.108)	(-7.529)	(-9.133)	(-4.342)	(-5.518)	(-4.095)	(-17.47)	(-9.636)	(-19.04)
ΔTO	0.017**	0.023***	0.020*	0.019***	0.015**	0.025***	0.016***	0.026***	0.018***	0.022***	0.014***
	(2.429)	(4.143)	(1.865)	(3.584)	(2.452)	(2.946)	(3.563)	(3.835)	(12.13)	(5.066)	(5.548)
ΔCO_2LAG	0.051***	0.075***	0.066***	0.076***	0.071***	0.072***	0.051***	0.069***	0.069***	0.080***	0.084***
	(6.748)	(4.425)	(4.604)	(5.864)	(6.869)	(6.210)	(4.015)	(4.097)	(17.33)	(10.22)	(28.94)

Source: Calculation from STATA 14

Note: 1) This table shows the results of the panel quantile regression model with different carbon emissions as dependent variables and economic growth, energy consumption and control variables as independent variables. 2) Figures in parentheses are t-values

*** Statistical significance at the 1% level.

** Statistical significance at the 5% level.

* Statistical significance at the 10% level.

Table 4.12: OLS Regression results for developing countries （1983-2013）

VARIABLE	OLS pooled	OLS one-way effect	OLS two-way effect
ΔENC	0.938***	0.939***	0.972***
	(9.457)	(9.381)	(9.210)
ΔFIN	-0.00584	-0.00549	-0.0119
	(-0.509)	(-0.478)	(-0.958)
ΔGDP	0.227**	0.166	0.103
	(2.010)	(1.320)	(0.684)
ΔGDP^2	-0.594	0.120	0.560
	(-0.507)	(0.0860)	(0.350)
ΔTO	0.00382	-0.00126	0.00257
	(0.165)	(-0.0539)	(0.0890)
ΔCO_2LAG	-0.0162	-0.0450	-0.0467
	(-0.277)	(-0.739)	(-0.688)

Source: Calculation from STATA14

4.5.2 Quantile Regression For Developed Countries

Table 4.14 illustrates panel quantile regression estimation for developed countries from 1983 to 2013. Regarding economic growth, we can observe that the GDP per capita in developed countries is the highest by a large margin from Figure 4.9. There are all strongly significant different percentiles in the conditional distribution of ΔCO_2. The coefficient of ΔGDP fluctuates from the 5^{th} quantile to 95^{th} quantile. As real GDP per capita increases by 1%, the level of carbon emissions increases by 0.172%-0.486%. At the 5^{th} quantile, the coefficient of ΔGDP is the highest among all quantiles and the coefficient of ΔGDP decreases from 70^{th} quantile to 95^{th} quantile. This indicates that when the higher level of economic development can mitigate the increase of carbon emission for higher income of the countries. In terms of ΔGDP^2, the impact of ΔGDP^2 on carbon emissions is clearly heterogeneous. It is significant and negative at different quantiles. Therefore, the results support EKC hypothesis that the environmental degeneration rises at the first stage with increasing economic growth and then turns to decrease at the final stage after reaching a threshold level given the level of income. In addition, the developed countries of the coefficient of ΔGDP are greater than developing countries. One possible explanation of this phenomenon is that developing countries may not have achieved desired level of income at the development stage.

For the impact of energy consumption on carbon emission, the coefficient of ΔENC is positive and highly significant at different quantiles, which is consistent with the expectations because energy consumption is expected to cause more carbon emissions unless the country is utilizing mostly renewable sources of energy.

The other results for the control variables included in the model are also informative. First, we can observe the impact of the variable ΔCO_2LAG for carbon emissions that the coefficient of ΔCO_2LAG is negative and significant at different quantiles, indicating the lag of carbon emission has a negative effect on carbon emission. Second, the coefficient of ΔTO is negative and insignificant at 5^{th} quantile and then turns to positive and significant from 10^{th} quantile to 95^{th} quantile, except middle quantile. This indicates that trade openness can grow carbon emission. Finally, we can observe that the coefficient of ΔFIN is positive and strongly significant at all quantile which is different from developing countries, implying that financial development cannot relieve carbon emission.

Table 4.13: Panel Regression Results for Developed Countries（1983-2013）

VARIABLES	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95
ΔENC	1.054***	1.103***	1.026***	1.048***	1.075***	1.082***	1.106***	1.079***	1.013***	1.042***	1.053***
	(56.44)	(72.13)	(203.6)	(111.9)	(1,287)	(392.1)	(471.6)	(1,435)	(1,393)	(2,103)	(2,671)
ΔFIN	0.035***	0.016***	0.015***	0.013***	0.021***	0.012***	0.025***	0.015***	0.007***	0.01***	0.005***
	(4.861)	(3.652)	(30.25)	(10.99)	(42.41)	(10.47)	(25.38)	(95.88)	(41.55)	(317.6)	(48.49)
ΔGDP	0.486***	0.255***	0.418***	0.270***	0.172***	0.378***	0.389***	0.253***	0.286***	0.273***	0.279***
	(7.708)	(29.66)	(40.47)	(31.91)	(45.80)	(39.90)	(89.10)	(289.3)	(316.3)	(867.2)	(507.5)
ΔGDP²	-9.437***	-3.752***	-6.973***	-5.522***	-4.697***	-5.995***	-8.953***	-6.302***	-6.302***	-6.269***	-6.351***
	(-9.516)	(-3.098)	(-82.17)	(-33.775)	(-93.432)	(-73.351)	(-82.656)	(-409.2)	(-321.3)	(-1,076)	(-797.7)
ΔTO	-0.006	0.017***	0.017***	0.009***	0.020***	-0.02***	0.018***	0.008***	0.007***	0.010***	0.006***
	(-1.078)	(2.832)	(14.39)	(6.980)	(34.73)	(-10.2)	(19.97)	(83.01)	(44.68)	(116.3)	(30.88)
ΔCO2LAG	-0.145***	-0.067***	-0.093***	-0.071***	-0.053***	-0.112***	-0.023***	-0.058***	-0.082***	-0.071***	-0.089***
	(-8.409)	(-19.90)	(-45.73)	(-9.507)	(-173.3)	(-58.1)	(-66.96)	(-256.5)	(-189.7)	(-362.3)	(-670.1)

Source: Calculation from STATA14
Note: 1) This table shows the results of the panel quantile regression model with different carbon emissions as dependent variables and economic growth, energy consumption and control variables as independent variables. 2) Figures in parentheses are t-values*** Statistical significance at the 1% level. ** Statistical significance at the 5% level.* Statistical significance at the 10% level.

Table 4.14 OLS Regression results for developed countries （1983-2013）

VARIABLE	OLS pooled	OLS one-way effect	OLS two-way effect
ΔENC	0.921***	0.878***	0.930***
	(13.03)	(12.12)	(10.05)
ΔFIN	0.000588	0.0112	0.0218
	(0.0354)	(0.666)	(1.225)
ΔGDP	0.256**	0.306***	0.292
	(2.487)	(2.948)	(1.503)
ΔGDP2	-3.693*	-4.564**	-3.199
	(-1.836)	(-2.301)	(-0.850)
ΔTO	0.0319	0.0324	0.0388
	(1.520)	(1.581)	(1.330)
ΔCO2LAG	-0.0120	-0.0521	-0.0860
	(-0.258)	(-1.085)	(-1.226)
Constant	-0.007	-0.008	-0.017
	(-3.242)	(-3.528)	(-1.835)

Source: Calculation from STATA14

4.5.3 Quantile Regression For All Countries(1983-2013)

Table 4.14 depicts panel quantile regression estimation for all countries from 1983 to 2013. Regarding economic growth, we can observe that the impact of economic growth on carbon emissions is a little heterogeneous. There are all strongly significant different percentiles in the conditional distribution of ΔCO_2. The coefficient of ΔGDP fluctuates from the 5^{th} quantile to 95^{th} quantile, as real GDP per capita increases by 1%, the level of carbon emissions increases by 0.176%-0.271%. In addition, ΔGDP^2 is insignificant and negative at low quantile (5^{th} quantile and 10^{th} quantile). And at 30^{th} quantile, 50^{th} quantile and 60^{th} quantile, the coefficient of ΔGDP^2 is positive and insignificant, implys that at middle quantile GDP per capital can not support EKC hythpothesis. However it becomes strongly significant and has a negative sign from 70^{th} quantile 95^{th} quantile, which confirming the shape of EKC that inverse U and implying that the high emissions countries may have achieved a desired level of income at the development stage in the third group. EKC hypothesis that the level of environmental pollution first increases with income and then stabilizes and declines. Overall, our results provide not only evidence that tests the validity of EKC hypothesis but also a more complete picture of economic growth in pollution emissions.

In terms of energy consumption, the coefficient of ΔENC is positive and highly significant at all quantiles, which is consistent with our expectations because energy consumption is expected to cause more carbon emissions unless the country is utilizing mostly renewable sources of energy. Initially, the coefficient of ΔENC decreases along with the increasing of carbon emissions. But on one hand from 20^{th} quantile to 50^{th} quantile, the coefficient of ΔENC is increasing when the carbon emissions growth, as energy consumption increases by 1%, the level of carbon emission increases by 0.958%-1.006%, the increasing level of low-middle quantile more than the OLS regression of energy consumption for carbon emissions. imply that, as energy consumption increases by 1%, the level of carbon emissions increases by 0.841%-1.144%, which is consistent with our expectations because energy consumption is expected to cause more carbon emissions unless the country is utilizing mostly renewable sources of energy. On the other hand, the level of energy consumption becomes the decreasing trend at high carbon emission countries (70^{th} quantile to 95^{th} quantile), which explains the environmental degeneration rises at the first stage with increasing energy consumption and then turns to decrease at the last stage after reaching at a threshold level given high energy consumption. Overall, the result of energy consumption on carbon emissions shows with strong evidence to validated EKC hypothesis and maintains long run relationship.

The other results for the control variables included in the model are also informative. First, we can observe the impact of the variable ΔCO_2LAG for carbon emissions, the coefficient of ΔCO_2LAG is positive and negative at different quantiles except 30th quantile, indicating lag carbon emission has positive effect on carbon emission. However, Table 4.14 shows the coefficient of ΔCO_2LAG are negative (except the pooled ols) and insignificant in the different OLS regression method. This findingshows the results under- or over- estimate the effect of factors. Second, the coefficient of ΔTO is negative and significant on all quantile (except 40th quantile) , indicating trade openness can growth carbon emission .Finally, we can observe that the coefficient of ΔFIN is negative and strongly significant at all quantile, implying that financial development can relieve carbon emission.

Table 4.15: Panel Regression Results for All Countries（1983-2013）

VARIABLES	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95
ΔENC	0.978***	0.941***	0.958***	0.987***	0.983***	1.006***	0.993***	1.009***	1.032***	1.004***	0.990***
	(39.17)	(93.92)	(58.43)	(50.68)	(30.72)	(36.64)	(89.67)	(65.41)	(204.3)	(158.2)	(352.4)
ΔFIN	-0.006***	-0.003***	-0.004***	-0.00263	-0.004***	-0.003***	-0.01***	-0.06***	-0.003***	-0.003***	-0.0013**
	(-4.482)	(-4.644)	(-4.042)	(-1.214)	(-6.307)	(-5.660)	(-3.360)	(-9.041)	(-3.788)	(-5.223)	(-2.557)
ΔGDP	0.220***	0.271***	0.196***	0.252***	0.191***	0.210***	0.176***	0.250***	0.238***	0.258***	0.226***
	(16.09)	(10.47)	(9.868)	(5.512)	(3.763)	(9.212)	(11.05)	(15.58)	(54.39)	(30.54)	(48.96)
ΔGDP2	-0.281	-0.709	0.539***	0.486	-0.163	0.350*	0.316	-0.96***	-0.145***	-0.695***	-0.306***
	(-1.014)	(-1.397)	(5.190)	(0.714)	(-0.542)	(1.773)	(1.428)	(-6.525)	(-3.093)	(-7.655)	(-6.005)
ΔTO	0.013*	0.017***	0.011***	0.018***	0.006	0.019**	0.013***	0.019***	0.0148***	0.0302***	0.0144***
	(1.846)	(2.698)	(5.256)	(4.067)	(1.409)	(4.940)	(6.751)	(10.98)	(11.88)	(25.40)	(20.19)
ΔCO2LAG	0.079***	0.030***	0.083***	0.0234	0.075***	0.059***	0.067***	0.052***	0.0607***	0.0615***	0.0541***
	(5.014)	(3.460)	(17.28)	(1.200)	(11.70)	(5.046)	(10.96)	(17.34)	(13.45)	(10.83)	(57.31)

Source: Calculation from STATA 14

Note: 1) This table shows the results of the panel quantile regression model with different carbon emissions as dependent variables and economic growth, energy consumption and control variables as independent variables. 2) Figures in parentheses are t-values

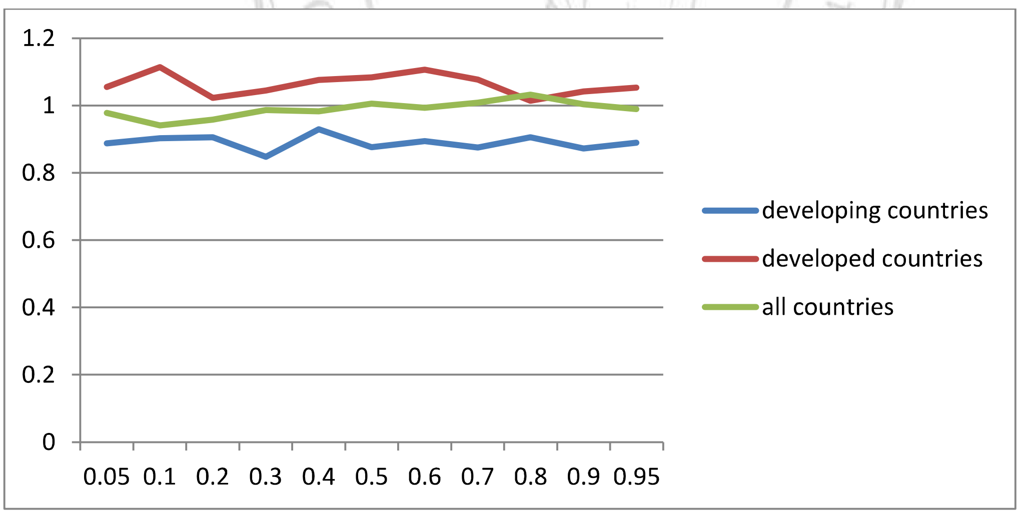
*** Statistical significance at the 1% level. ** Statistical significance at the 5% level. * Statistical significance at the 10% level.

Table 4.16: OLS Regression results for all countries （1983-2013）

VARIABLE	OLS pooled	OLS one-way effect	OLS two-way effect
ΔENC	0.963***	0.921***	0.941***
	(15.74)	(14.72)	(14.61)
ΔFIN	-0.00622	-0.00568	-0.0101
	(-0.731)	(-0.673)	(-1.185)
ΔGDP	0.216***	0.221***	0.138
	(2.894)	(2.770)	(1.480)
ΔGDP2	-0.349	-0.667	0.305
	(-0.443)	(-0.668)	(0.276)
ΔTO	0.0151	0.0126	0.00444
	(0.984)	(0.830)	(0.233)
ΔCO_2LAG	0.0111	-0.0342	-0.0443
	(0.297)	(-0.884)	(-1.050)
Constant	-0.00489**	-0.00370	-0.00723
	(-2.556)	(-1.537)	(-0.875)

Source: Calculation from STATA14

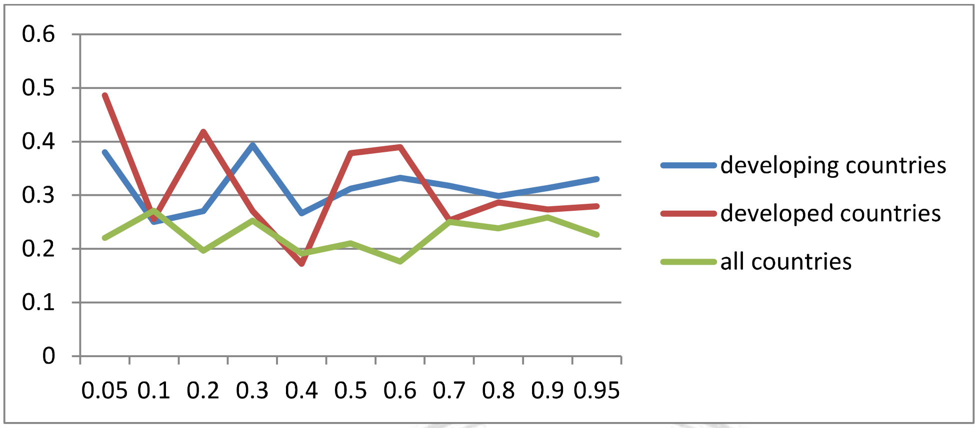
4.5.4 Comparing the different level of economic growth, energy consumption and other control variable, the different carbon emission for developing countries, developed countries and all countries from 1983 to 2013



Source: Secondary Data from World Bank

Figure 4.7: Change in panel quantile regression coefficient for energy consumption （1983-2013）

In Figure 4.7 illustrates the effects of energy consumption on carbon emissions, developed countries greater than developing countries under the different quantiles. The results indicate that although the developed countries finish the industrialization period and come into the times of knowledge economy, carbon emissions need to spend 50 to 200 years to metabolize. So the developed countries are still responsible together with developing countries.



Source: Secondary Data from World Bank

Figure 4.8: Change in panel quantile regression coefficient for economic growth.

First, for control variable of financial development, we can observe that the coefficient of developing countries and all countries are negative at different quantiles (except 50th to 60th for developing countries). However, the coefficient of developed countries and all countries are positive at different quantiles. It indicates that the influence of financial development can relieve carbon emission at low-middle level of income countries. However, regarding as developed countries, the level of financial development increases carbon emissions. Second, trade openness increases carbon emission for developing countries and all countries while the negative effect of trade openness for developed countries is between 40th quantiles and 50th quantiles. Finally, the first-order lag of carbon emission decreases carbon emission for developed countries. The results show that a higher level of economic development can relieve carbon emissions.

4.5.5 The evidence of EKC in the different periods and panel groups

Environmental Kuznets Curve is the empirical curve obtained from the actual data, which reflects the nonlinear relationship between environmental quality and economic growth. Environmental quality is expressed by carbon emissions per capita. The total carbon emissions cannot describe population size and development level, but carbon emission per capita can make up for the lack of total carbon emissions. Economic growth is indicated by real GDP per capita because real GDP per capita can reflect the. impact of economic growth on environmental quality, compared with the total GDP

Table 4.20 shows the sign of coefficient of ΔGDP^2 in the different quantile regression. It can be observed that the coefficient of ΔGDP and ΔGDP^2 for developed countries are significant at 1% level from 1983 to 2013 and support the existence of an EKC hypothesis. The results indicate that the carbon emission of developed countries increases and then turns to decrease along with the increasing level of income from 1983 to 2013. In addition, the turning point of developed countries is $54415.798 per capita at 80^{th} quantile, $42192 per capita at 90^{th} quantile and $40667 per capita at 95^{th} quantile during 1983 to 2013. The results indicate that in terms of the level of high income countries, the turning point appears at higher quantiles. However, the coefficient of ΔGDP^2 for developed countries is negative from 30^{th} quantile to 95^{th} quantile during the period of 1983 to 1998 (in Table 4.18) while the coefficient of ΔGDP^2 for developed countries is also negative from 10^{th} quantile during the period of 1999 to 2013 (in Table 4.18). The turning point of developed countries is $13976.059 per capita less than the period of 1999 to 2013 ($38117.059 per capita). For the developed countries during the period of 1999 to 2013, the level of income increases three times than the period of 1983 to 1998, but the carbon emission per capita is less than the period of 1983 to 1998. The results indicate that developed countries have finished the industrialization, development of high energy consumption and high carbon emissions. They pay more attention to environmental quality and the government invest more fund to transfer the mode of economic growth.

Regarding as the developing countries, we can observe that the coefficient of ΔGDP and ΔGDP^2 are significant at 1% level from 1983 to 2013 and supports the existence of an EKC hypothesis. The results indicate that the carbon emission of developing countries increases first and then turns to decrease along with the level of income increasing from 1983 to 2013. The results show that inverted U-shaped relationship between GDP per capita and CO_2 emission per capita is hypothesized. The result supports the Environmental Kuznets Curve (EKC) hypothesis from the period of 1983 to 2013. The turning point hovers around $3723.601 per capita. However, the coefficient of ΔGDP^2 for developing countries is positive and significant at different quantile except 10^{th} quantile during the period of 1983 to 1998. One possible explanation of this phenomenon is that developing countries may not have achieved a desired level of income at the development stage. However, after Asian Financial Crisis (1999 to 2013), the coefficient of ΔGDP^2 for developing countries is negative and strongly significant at different quantile. The turning point increases to $4376.035 per capita more than the period of 1983 and 1998 ($3723.601 per capita). One possible explanation of this phenomenon is that developing countries may have achieved a desired level of income at the development stage after Asian Financial Crisis. Another explanation is that CO_2 emissions and economic growth (by decoupling greenhouse gas emission of CO_2 and economic growth) provide more conclusive evidence on the phenomenon of the environmental Kuznets curve (EKC) over the period of 1999 and 2013. This result gives a clear policy roadmap on the pursuance of long run economic growth in favor of environmental quality. Besides, significance of the turning point lies with the need to explore other structural policies, such as articulated demographic and energy policies, rather than passively waiting for the arrival of the inflexion point.

Table 4.17: The sign of coefficient of ΔGDP^2 in quantile regression

	Developing countries	Developed Countries	All countries
1983-2013	- (5^{th} ~95^{th})***	- (5^{th} ~95^{th})***	- (70^{th} ~95^{th}) ***
1983-1998	+(5^{th} ,20^{th} ~95^{th})***	-(40^{th} ~95^{th})***	+ (60^{th} ~95^{th})***
1999-2013	-(5^{th} ~95^{th})***	-(10^{th} ~95^{th})***	-(5^{th} ~95^{th})***

Source: The result from panel quantile regression

Table 4.18 The optional values of GDP and CO_2 at turning point in EKC

Sample	Period	Result	Turning Points
Developing countries	1983-2013	∩ support EKC hypothesis	$3723.601 per capita
	1983-1998	The results can not support EKC hypothesis	
	1998-2013	∩ support EKC hypothesis	$4376.035 per capita
Developed Countries	1983-2013	∩ support EKC hypothesis	$38117.059 per capita
	1983-1998	∩ support EKC hypothesis	$23976.059 per capita
	1998-2013	∩support EKC hypothesis	$54415.798 per capita
All Countries	1983-2013	∩support EKC hypothesis quantile	$35261.254 per capita
	1983-1998	The results can not support EKC hypothesis	
	1998-2013	∩support EKC hypothesis	$41211.79 per capita

Overall, the higher income level may result in a higher possibility for countries accepting the EKC hypothesis. Additionally, a richer countries have the higher top peak and they can reach the top peak faster than poor countries.

Table 4.19: Panel Regression Results for All Countries (Period:1983-1998& 1999-2013)

Period:1983-1998	Quantile										
VARIABLES	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95
ΔENC	1.038***	0.906***	0.917***	1.043***	0.960***	0.994***	1.026***	1.026***	1.005***	1.009***	0.982***
	(11.74)	(13.34)	(17.30)	(42.38)	(45.02)	(40.17)	(37.27)	(55.09)	(79.78)	(82.66)	(695.7)
ΔFIN	-0.00664	-0.0042*	-0.00214	-0.00103	-0.00539	0.00158*	0.0023	-0.002*	-0.001**	0.0019***	0.0019***
	(-1.448)	(-1.920)	(-0.627)	(-1.407)	(-1.339)	(1.896)	(1.351)	(-1.77)	(-2.015)	(7.553)	(6.109)
ΔGDP	0.161	0.156***	0.298***	0.100***	0.210***	0.0662	0.0652**	-0.0124	0.0593**	0.104***	0.122***
	(1.470)	(2.829)	(4.185)	(2.745)	(3.456)	(1.494)	(2.064)	(-0.265)	(2.539)	(6.002)	(58.74)
ΔGDP2	1.079	1.465**	-0.00913	1.484***	-0.0354	1.078**	0.960***	1.886***	1.171***	0.670***	0.641***
	(1.202)	(2.457)	(-0.0190)	(6.322)	(-0.0788)	(2.389)	(5.163)	(4.585)	(5.920)	(5.903)	(17.31)
ΔTO	-0.00275	0.00300	0.00809*	-0.00369	0.00294	-0.00151	-0.0043	0.0019	-0.0059*	5.00e-05	-6.97e-06
	(-0.240)	(0.768)	(1.662)	(-0.904)	(1.453)	(-0.445)	(-1.15)	(0.396)	(-1.690)	(0.0405)	(-0.018)
ΔCO2LAG	0.0429**	0.0437**	0.0143	-0.00129	0.0944***	0.0916***	0.087***	0.0451	0.0883***	0.0946***	0.101***
	(2.177)	(2.486)	(0.585)	(-0.0510)	(18.89)	(13.62)	(9.732)	(1.620)	(10.69)	(29.15)	(57.80)
Period:1999-2013											
ΔENC	1.109***	1.129***	1.121***	1.129***	1.078***	1.053***	1.101***	1.125***	1.118***	1.139***	1.091***
	(15.15)	(31.58)	(45.90)	(34.37)	(15.51)	(16.26)	(60.57)	(91.68)	(199.7)	(164.9)	(127.6)
ΔFIN	-0.0041	0.00114	0.000876	0.00187	-0.00139	-0.00447	-0.00098	0.000790	-0.003***	-0.00151	0.000318
	(-0.569)	(0.385)	(0.375)	(0.449)	(-0.320)	(-0.634)	(-0.476)	(0.403)	(-3.105)	(-0.859)	(0.204)
ΔGDP	0.127***	0.154***	0.105***	0.165***	0.192***	0.177***	0.162***	0.134***	0.201***	0.130***	0.201***
	(4.152)	(4.135)	(3.196)	(4.363)	(2.800)	(2.864)	(4.349)	(3.455)	(13.98)	(6.908)	(10.30)
ΔGDP2	-2.202**	-3.196***	-2.603***	-2.296***	-3.013***	-2.22***	-2.71***	-2.97***	-3.234***	-2.487***	-3.793***
	(-2.047)	(-8.549)	(-6.793)	(-5.989)	(-5.553)	(-2.615)	(-5.854)	(-6.974)	(-14.13)	(-22.22)	(-15.44)
ΔTO	0.0383***	0.0201	0.0291***	-0.0162	0.0182*	0.0297***	0.0138	0.0189	0.0311***	0.0390***	0.0247***
	(4.599)	(1.420)	(3.205)	(-0.912)	(1.810)	(2.798)	(1.553)	(1.640)	(14.06)	(17.94)	(13.60)
ΔCO2LAG	0.0820***	0.0861***	0.113***	0.0598***	0.0855***	0.0946***	0.066***	0.081***	0.070***	0.0838***	0.129***
	(6.114)	(2.983)	(5.986)	(4.312)	(3.034)	(4.312)	(8.673)	(3.888)	(12.56)	(28.40)	(11.25)

Source: Calculation from STATA 14

Note: Figures in parentheses are t-values*** Statistical significance at the 1% level. ** Statistical significance at the 5% level. * Statistical significance at the 10% level.

Table 4.20: Panel Regression Results for Developed Countries (Period:1983-1998 & 1999-2013)

Period:1983-1998	Quantile										
VARIABLES	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95
ΔENC	1.069***	1.068***	1.054***	1.072***	1.037***	0.980***	1.091***	1.028***	1.100***	1.082***	1.095***
	(20.03)	(20.83)	(53.47)	(261.5)	(31.82)	(123.1)	(399.7)	(679.3)	(2,446)	(2,497)	(4,096)
ΔFIN	0.0188***	0.00885	0.00380	0.0167***	0.0206***	0.00728***	0.0131***	0.0166***	0.0102***	0.0207***	0.0165***
	(2.807)	(1.192)	(0.458)	(21.72)	(18.01)	(7.583)	(32.69)	(53.72)	(132.3)	(260.8)	(395.4)
ΔGDP	-0.0574	0.276	0.171***	0.227***	0.249***	0.344***	0.201***	0.367***	0.276***	0.277***	0.209***
	(-0.210)	(1.615)	(3.124)	(21.28)	(10.75)	(43.54)	(47.42)	(117.8)	(254.7)	(615.0)	(347.5)
ΔGDP2	7.472	-0.594	0.797	-0.383*	-1.285***	-0.352***	-0.235**	-0.974***	-0.987***	-1.248***	-0.957***
	(1.573)	(-0.280)	(0.735)	(-1.806)	(-2.736)	(-2.756)	(-2.091)	(-10.67)	(-56.49)	(-111.4)	(-78.35)
ΔTO	0.0111	0.0202	0.0180***	0.0208***	0.0199***	-0.00497**	0.0160***	0.0227***	0.0165***	0.0126***	0.0196***
	(0.554)	(1.031)	(4.347)	(7.989)	(12.18)	(-2.517)	(17.24)	(72.37)	(199.9)	(204.9)	(411.7)
ΔCO2LAG	-0.0744	-0.102*	-0.0317***	-0.0442***	-0.0702***	-0.103***	-0.031***	-0.052***	-0.035***	-0.056***	-0.047***
	(-0.992)	(-1.656)	(-3.766)	(-8.558)	(-10.43)	(-19.07)	(-9.623)	(-58.13)	(-160.4)	(-342.5)	(-237.1)
Period:1999-2013											
ΔENC	0.795***	1.099***	0.765***	0.765***	1.062***	0.831***	1.026***	1.019***	0.849***	0.896***	0.944***
	(30.196)	(35.222)	(14.853)	(8.912)	(16.341)	(27.195)	(38.908)	(16.839)	(274.251)	(2,078.27)	(79.403)
ΔFIN	0.036*	0.008	0.018*	0.010**	0.007*	0.010***	0.017***	0.017*	0.001*	0.004***	0.010***
	(1.924)	(1.493)	(1.685)	(2.026)	(1.897)	(4.972)	(3.318)	(1.812)	(1.816)	(63.947)	(3.186)
ΔGDP	0.202	0.382***	0.453***	0.647***	0.303***	0.464***	0.184***	-0.005	0.289***	0.327***	0.381***
	(0.890)	(4.465)	(2.870)	(5.023)	(5.848)	(8.458)	(3.818)	(-0.028)	(55.309)	(633.646)	(14.376)
ΔGDP2	-2.186	-12.300***	-21.968***	-11.263***	-6.697***	-10.356***	-8.72***	-4.206*	-7.717***	-11.56***	-8.581***
	(-0.861)	(-5.238)	(-4.935)	(-5.616)	(-5.488)	(-10.810)	(-37.894)	(-1.716)	(-81.879)	(-401.686)	(-26.492)
ΔTO	0.050**	-0.063***	-0.009	0.023	-0.008	0.001	-0.011*	0.033	0.022***	-0.001***	-0.009
	(1.989)	(-4.084)	(-1.167)	(1.251)	(-0.738)	(0.134)	(-1.702)	(0.991)	(45.295)	(-7.947)	(-1.543)
ΔCO2LAG	-0.056	-0.041**	-0.145***	-0.130***	-0.086***	-0.173***	0.004	0.126**	-0.093***	-0.079***	0.013
	(-0.876)	(-2.246)	(-4.592)	(-5.971)	(-2.600)	(-6.427)	(0.346)	(2.231)	(-32.562)	(-164.433)	(0.721)

Source: Calculation from STATA 14

Note: Figures in parentheses are t-values*** Statistical significance at the 1% level. ** Statistical significance at the 5% level. * Statistical significance at the 10% level

Table 4.21: Panel Regression Results for Developing Countries (Period:1983-1998 & 1999-2013)

Period:1983-1998	Quantile										
VARIABLES	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95
ΔENC	1.087***	1.160***	1.170***	1.245***	1.272***	1.222***	1.260***	1.269***	1.172***	1.107***	1.049***
	(15.08)	(10.46)	(41.56)	(10.71)	(29.65)	(46.35)	(36.30)	(29.88)	(83.54)	(28.03)	(87.36)
ΔFIN	-0.0189*	-0.00924	-0.00516	0.00108	-0.0135	-0.00466	0.00746	-0.054***	-0.0151**	0.0146**	0.0226***
	(-1.908)	(-0.685)	(-0.651)	(0.102)	(-1.173)	(-0.732)	(0.767)	(-4.938)	(-2.466)	(2.328)	(8.302)
ΔGDP	-0.0614	-0.456	0.398***	0.304***	0.348***	0.228*	0.223**	0.0735	0.240***	0.382***	0.447***
	(-0.300)	(-1.361)	(10.64)	(4.057)	(5.958)	(1.656)	(2.314)	(1.090)	(4.373)	(8.300)	(35.08)
ΔGDP2	0.0617***	-0.0417	0.0642***	0.0398***	0.0590***	0.0355**	0.0248**	0.0912***	0.0456***	0.0378***	0.0506***
	(6.040)	(-0.919)	(9.352)	(4.194)	(5.712)	(2.506)	(2.318)	(8.468)	(7.341)	(4.313)	(14.31)
ΔTO	1.220	6.904	-5.101***	-6.609***	-5.641***	-5.346***	-6.024***	-3.249***	-3.394***	-4.779***	-5.340***
	(0.659)	(1.137)	(-15.50)	(-3.558)	(-8.282)	(-12.11)	(-2.967)	(-6.068)	(-6.645)	(-18.21)	(-33.02)
ΔCO2LAG	0.0998***	0.0209	0.103***	0.0755**	0.106***	0.0646***	0.0397*	0.0418	0.112***	0.106***	0.140***
	(3.585)	(0.395)	(5.641)	(2.164)	(9.179)	(4.245)	(1.739)	(1.449)	(15.00)	(5.752)	(14.96)
Period:1999-2013											
ΔENC	0.595***	0.837***	0.674***	0.680***	0.515***	0.879***	0.743***	0.673***	0.761***	0.697***	0.695***
	(9.826)	(24.368)	(4.759)	(44.366)	(10.876)	(13.130)	(14.450)	(895.01)	(226.850)	(126.918)	(642.330)
ΔFIN	-0.007***	0.012***	-0.009**	-0.001**	-0.005**	0.008	0.001	- 0.001***	-0.003***	-0.001**	-0.000
	(-3.314)	(4.639)	(-2.482)	(-2.562)	(-2.489)	(0.813)	(0.373)	(-38.335)	(-42.165)	(-2.478)	(-0.677)
ΔGDP	0.416***	0.619***	0.418***	0.450***	0.371***	0.265***	0.325***	0.437***	0.367***	0.457***	0.401***
	(7.056)	(9.495)	(6.315)	(99.560)	(8.462)	(3.870)	(10.553)	(603.22)	(135.839)	(62.391)	(122.541)
ΔGDP2	-1.880**	-2.683**	-2.162***	-2.680***	-2.269***	0.625	-2.06***	-2.26***	-2.364***	-2.647***	-1.878***
	(-2.185)	(-2.058)	(-4.219)	(-48.535)	(-6.342)	(1.083)	(-5.784)	(-348.08)	(-81.431)	(-34.026)	(-185.910)
ΔTO	-0.010	0.009	0.009	0.011***	-0.015**	0.004	-0.03***	0.002***	-0.015***	-0.002	-0.014***
	(-0.742)	(0.608)	(0.529)	(9.252)	(-2.536)	(0.382)	(-3.183)	(13.676)	(-19.274)	(-1.036)	(-39.218)
ΔCO2LAG	0.129***	0.161***	0.197**	0.088***	0.141***	0.147***	0.168***	0.086***	0.142***	0.088***	0.092***
	(4.349)	(3.596)	(2.251)	(31.753)	(9.495)	(8.307)	(10.079)	(235.66)	(145.271)	(33.452)	(68.787)

Source: Calculation from STATA 14

Note: Figures in parentheses are t-values*** Statistical significance at the 1% level. ** Statistical significance at the 5% level. * Statistical significance at the 10% level.

CHAPTER 5

Conclusions and policy implications

5.1 Conclusions

The main purpose of this study is to explore the impact of economic growth and energy consumption and other control variables on carbon emissions. The panel quantile regression method is used to achieve the objectives. This method takes the unobserved individual heterogeneity and distributional heterogeneity into consideration. In addition, to avoid an omitted-variable bias, certain related control variables are included in the model. The results indicate that panel quantile regression models can help obtain a more complete picture of the factors that affect carbon emissions. This study covers the annual sample period from 1981 to 2013 in ten selected countries.

Energy is the prerequisite and guarantee of economic development. No matter what the stage of economic development and the level of development of the country is, energy consumption, economic development, and the use of a large number of energy resources cannot be separated. The empirical results indicate that the impacts of various factors on carbon emission are evidently heterogeneous. It is also found that energy consumption has a positive and significant effect on carbon emissions for every selected panel group data. Energy consumption increases carbon emissions, with the strongest effects on carbon emissions observed at all quantiles for all selected group. However, the level of the coefficient of energy consumption on carbon emissions for developed countries is more than developing countries. The results indicate that although the developed countries finished the industrialization period and came into the times of knowledge economy, they still have to spend 50 to 200 years to metabolize carbon emissions. So the developed countries are still responsible for carbon emissions together with developing countries.

CO_2 emissions are mainly affected by energy consumption, and economic growth is determined by the industrial structure. The level of carbon emissions of a country directly reflects its social and economic development and the development of low-carbon economy. The major developed countries have gone through the industrialization period, and now they are in the last industrialization period dominated by the third industry. The carbon emissions of the Tertiary Industries are low, and some industries are even zero CO_2 emissions. It determines that CO_2 emissions in developed countries have passed through the peak period, and some developed countries, such as European Union, United States, Canada, have shown a downward trend in carbon emissions per capita. However, the developing countries are still in the process of industrialization. The mode of economic development in the Second Industries is a high CO_2 emission and a high energy consumption industry model. This mode determines the development of developing countries cannot reduce the high carbon emissions in the short term. Developing countries needs more carbon space to meet the development needs.

Environmental Kuznets curve is used to measure environmental variables and economic variables. With the growth of a country's economy, national disposable income will increase energy consumption, carbon emissions generated by the upward trend. Therefore, the atmospheric environmental quality and economic growth have obvious inverted-U relationship. This study also examines the validity of the EKC hypothesis in sample groups including the group of developing countries (1983-2013), the group of developed countries (1983-2013), the group of all selected countries (1983-2013), the group of selected developing countries during the period of 1983 and 1998 and the period 1999 and 2013, and the group of selected developing countries during the period of 1983 and 1998 and the period 1999 and 2013. The results indicate that the inverted U-shaped EKC hypothesis is applicable to the developed countries, developing countries, and all countries (at upper quantiles). The level of economic development for developed country is obviously faster than developing countries. The most important finding of this study is the consistency of the estimation results from panel quantile regression and the confirmation of the validity of ECK in sample group. In all the estimation results, CO_2 emissions increase when GDP per capita increases. Also, the growth of energy consumption increases CO_2 emission in long run. However, GDP per capita reduces CO_2 emission at the turning point. Regarding the EKC hypothesis, the results confirm that this phenomenon exists in sample since the coefficient of GDP square in the estimation results is negative for developed countries at every sample period. In addition, the coefficient of GDP square in the estimation results is positive for developing countries (1983-1998) and all selected countries (1983-1998). The process of industrial structure evolution consumes a large amount of energy resources and produces a large amount of carbon emissions. It leads to threaten the global atmospheric environment. In the initial stage of industrialization, the carbon emissions per capita increases along with the rapidly increase of income per capita. But after the completion of heavy industrialization, the carbon emissions per capita gradually become saturated. Therefore, it is possible to explain why the developing countries and all selected countries during the period of 1983 and 1998 cannot support the EKC hypothesis is that carbon emissions of these countries increase along with the level of income before Asian Financial Crisis. After Asian Financial Crisis, the developing countries and all selected countries during the period of 1999 and 2013 can support the EKC hypothesis that at the development stage, the carbon emissions turn to decrease along with the increasing level of income.

Finally, comparing with the panel quantile regression fixed effect model and OLS regression on emissions is threefold: First, the panel data framework is employed to research the determinants of CO_2 emissions in developing countries and developed countries because it is more advantageous than focusing on one country of providing more informative data, more variability, more degrees of freedom and thus greater efficiency in estimation. Moreover, panel data model accommodates the special heterogeneity indicated by region-specific, non-observable and time-invariant intercepts for these two groups countries within the panel data framework Second, this method can describe the entire conditional distribution of the dependent variable; therefore, it helps obtain a more complete picture of the factors associated with pollutant emissions. Specifically, quantile regression estimators provide one solution to each quantile. Using this methodology, the determinants of emissions can be assessed throughout the conditional distribution, especially in the countries with the most and least emissions. From a policy perspective, it is more interesting to know what occurs at the extremes of a distribution. By contrast, OLS regression techniques are not suitable for making environmental protection policies for high-emissions countries. Third, the panel quantile regression estimation results are robust to outlying observations of the explained variable and more effective than OLS regression, especially when the error term is non-normal, which will help policymakers formulate more accurate environmental protection policies. However, only a few papers have applied a panel quantile regression fixed effect model to investigate the relationship among variables.

5.2 Recommendations and Policy Implications

5.2.1 Recommendation from the study

1) This study allows to estimate the relationship of economic growth, energy consumption and other control variables on carbon emissions including trade openness, financial development, the square of GDP and the lag variables of CO_2.

2) The main factors that affect carbon emissions are energy consumption and economic growth, but investors should consider other variables in order to avoid an omitted variable bias. Certain related control variables are included in the model.

3) In this study, only the panel quantile regression is used. Further studies should consider other models

5.2.2 Policy Implications

While energy consumption was promoting economic growth and leading to the carbon emission increase, energy already achieved its own upgrading and development. Economic growth requires large-scale energy exploitation and utilization, and the limited fossil energy is not enough to satisfy the needs of economic growth. Hence, in order to improve energy efficiency, promoting the development of new energy consumption structure is the focus of economic development in the future. Economic growth is the development and application of new energy fund. Only renewable energy can be used instead of fossil energy for growth of economy of each country. Carbon dioxide emissions can be significantly reduced when the environmental pressure is really reduced, so each country can have the sustainable development of economy.

The development of economies uses a large amount of energy and natural resources. When the energy consumption structure of a country majors on the traditional fossil energy and coal, CO_2 emissions increases to the peak. With the level of economic development and technology improvement, the countries use the oil and gas instead of coal substitute, CO_2 emissions will be mitigated. However, in order to completely solve the problem of CO_2 emissions caused by energy consumption, the countries need to exploit cleaner and more efficient energy technologies, increase and develop the use of renewable energy so that the use of zero emission or closed process can reduce waste and pollutants.

The pressure of global climate and environment is becoming more and more serious. It is important to change the energy consumption patterns and effectively utilize energy. In addition, the government should develop to use renewable energy and encourage to quantify the effects of energy exploitation on the environment in order to protect the environment under the premise to make full use of the source. The country needs to investigate more on the field of energy economics research. Finally, investors should provide a theoretical basis for the research on energy and CO_2 emissions of the association.

Based on the results of the study, the following policy implications must be pursued in order to improve environmental quality in the world. In terms of energy consumption, energy development program needs to shift from fossil fuels, such as oil, to clean and renewable energy, based on the existing condition of each country. The findings suggest that countries with high CO_2 emissions could benefit the most from the economic growth. Therefore, carbon emissions control measures should be tailored differently across the nations with both low and high CO_2 emissions.

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APPENDICES

Table 1 Johansen Fisher panel cointegration test for Developing Countries

Johansen Fisher Panel Cointegration Test
Series: DLNCO2 DLNENC DLNGDP DLNTO DLNFIN
Date: 09/27/17 Time: 08:28
Sample: 1981 2013
Included observations: 165
Trend assumption: Linear deterministic trend
Lags interval (in first differences): 1 1

Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	112.0	0.0000	57.03	0.0000
At most 1	65.01	0.0000	24.21	0.0071
At most 2	48.95	0.0000	21.58	0.0174
At most 3	39.21	0.0000	21.04	0.0208
At most 4	44.36	0.0000	44.36	0.0000

* Probabilities are computed using asymptotic Chi-square distribution.

Individual cross section results

Cross Section	Trace Test Statistics	Prob.**	Max-Eign Test Statistics	Prob.**
Hypothesis of no cointegration				
1	108.0735	0.0000	41.9595	0.0044
2	69.7535	0.0506	24.2961	0.4341
3	123.0634	0.0000	54.5418	0.0001
4	107.4972	0.0000	38.8706	0.0117
5	106.4066	0.0000	49.6190	0.0003
Hypothesis of at most 1 cointegration relationship				
1	66.1140	0.0004	29.0316	0.0324
2	45.4574	0.0826	22.4026	0.2004
3	68.5216	0.0002	30.2889	0.0219
4	68.6266	0.0002	25.7355	0.0846
5	56.7876	0.0058	18.4267	0.4600
Hypothesis of at most 2 cointegration relationship				
1	37.0824	0.0061	19.9662	0.0721
2	23.0548	0.2434	10.2973	0.7163
3	38.2327	0.0042	22.0898	0.0366
4	42.8910	0.0009	20.1038	0.0691
5	38.3609	0.0041	17.3076	0.1580
Hypothesis of at most 3 cointegration relationship				
1	17.1162	0.0283	11.9523	0.1125
2	12.7575	0.1240	8.0077	0.3779
3	16.1429	0.0399	10.9759	0.1554

4	22.7873	0.0033	13.8414	0.0582
5	21.0534	0.0065	13.3124	0.0703
Hypothesis of at most 4 cointegration relationship				
1	5.1639	0.0231	5.1639	0.0231
2	4.7498	0.0293	4.7498	0.0293
3	5.1669	0.0230	5.1669	0.0230
4	8.9459	0.0028	8.9459	0.0028
5	7.7409	0.0054	7.7409	0.0054

**MacKinnon-Haug-Michelis (1999) p-values

Table 2 Johansen Fisher panel cointegration test for Developed Countries

Johansen Fisher Panel Cointegration Test
Series: DLNCO2 DLNENC DLNFIN DLNGDP DLNTO
Date: 09/27/17 Time: 08:32
Sample: 1981 2013
Included observations: 165
Trend assumption: Linear deterministic trend
Lags interval (in first differences): 1 1

Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	89.78	0.0000	59.94	0.0000
At most 1	40.55	0.0000	24.95	0.0054
At most 2	22.57	0.0125	13.55	0.0844
At most 3	17.24	0.0693	9.716	0.09 58
At most 4	27.64	0.0021	27.64	0.0021

* Probabilities are computed using asymptotic Chi-square distribution.

Individual cross section results

Cross Section	Trace Test Statistics	Prob.**	Max-Eign Test Statistics	Prob.**
Hypothesis of no cointegration				
1	72.2087	0.0318	32.9879	0.0636
2	88.0441	0.0009	33.7794	0.0514
3	93.0264	0.0003	39.5905	0.0093
4	134.9116	0.0000	74.8357	0.0000
5	86.6825	0.0013	34.1916	0.0459
Hypothesis of at most 1 cointegration relationship				
1	39.2208	0.2516	15.3951	0.7164
2	54.2647	0.0111	27.4204	0.0524
3	53.4359	0.0137	24.7822	0.1096
4	60.0759	0.0024	28.7800	0.0350
5	52.4909	0.0172	29.6795	0.0265
Hypothesis of at most 2 cointegration relationship				
1	23.8257	0.2079	13.2787	0.4269
2	26.8443	0.1055	18.4653	0.1134
3	28.6537	0.0673	13.5590	0.4022
4	31.2959	0.0334	16.7819	0.1825
5	22.8114	0.2555	14.5626	0.3207
Hypothesis of at most 3 cointegration relationship				
1	10.5470	0.2410	8.8014	0.3031
2	8.3790	0.4258	4.8598	0.7594
3	15.0947	0.0574	8.8798	0.2963
4	14.5140	0.0699	9.8877	0.2194
5	8.2488	0.4392	6.7503	0.5191

Hypothesis of at most 4 cointegration relationship

1	1.7456	0.1864	1.7456	0.1864
2	3.5192	0.0607	3.5192	0.0607
3	6.2149	0.0127	6.2149	0.0127
4	4.6263	0.0315	4.6263	0.0315
5	1.4984	0.2209	1.4984	0.2209

**MacKinnon-Haug-Michelis (1999) p-values

Table 3 Johansen Fisher panel cointegration test for All Countries

Johansen Fisher Panel Cointegration Test
Series: DLNCO2 DLNENC DLNFIN DLNTO DLNGDP
Date: 09/27/17 Time: 08:34
Sample: 1981 2013
Included observations: 330
Trend assumption: Linear deterministic trend
Lags interval (in first differences): 1 1

Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	211.4	0.0000	124.5	0.0000
At most 1	109.7	0.0000	56.92	0.0000
At most 2	68.75	0.0000	33.57	0.0292
At most 3	55.05	0.0000	29.65	0.0757
At most 4	71.64	0.0000	71.64	0.0000

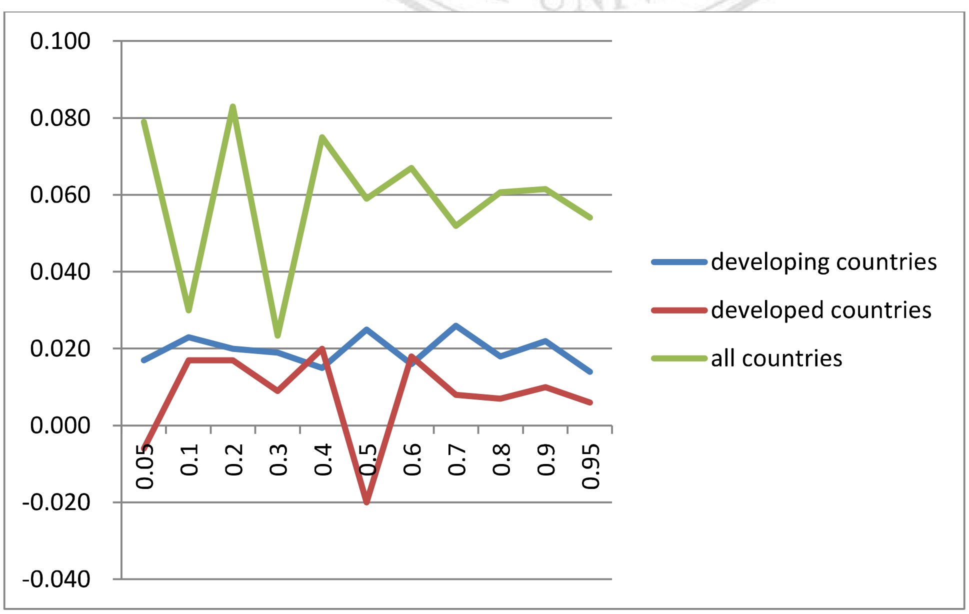
* Probabilities are computed using asymptotic Chi-square distribution.

Individual cross section results

Cross Section	Trace Test Statistics	Prob.**	Max-Eign Test Statistics	Prob.**
Hypothesis of no cointegration				
1	72.2087	0.0318	32.9879	0.0636
2	88.0441	0.0009	33.7794	0.0514
3	93.0264	0.0003	39.5905	0.0093
4	134.9116	0.0000	74.8357	0.0000
5	86.6825	0.0013	34.1916	0.0459
6	125.8768	0.0000	52.9870	0.0001
7	69.7535	0.0506	24.2961	0.4341
8	123.0634	0.0000	54.5418	0.0001
9	107.4972	0.0000	38.8706	0.0117
10	106.4066	0.0000	49.6190	0.0003
Hypothesis of at most 1 cointegration relationship				
1	39.2208	0.2516	15.3951	0.7164
2	54.2647	0.0111	27.4204	0.0524
3	53.4359	0.0137	24.7822	0.1096
4	60.0759	0.0024	28.7800	0.0350
5	52.4909	0.0172	29.6795	0.0265
6	72.8898	0.0001	40.4487	0.0007
7	45.4574	0.0826	22.4026	0.2004
8	68.5216	0.0002	30.2889	0.0219
9	68.6266	0.0002	25.7355	0.0846
10	56.7876	0.0058	18.4267	0.4600
Hypothesis of at most 2 cointegration relationship				
1	23.8257	0.2079	13.2787	0.4269

2	26.8443	0.1055	18.4653	0.1134
3	28.6537	0.0673	13.5590	0.4022
4	31.2959	0.0334	16.7819	0.1825
5	22.8114	0.2555	14.5626	0.3207
6	32.4412	0.0242	17.3183	0.1575
7	23.0548	0.2434	10.2973	0.7163
8	38.2327	0.0042	22.0898	0.0366
9	42.8910	0.0009	20.1038	0.0691
10	38.3609	0.0041	17.3076	0.1580
Hypothesis of at most 3 cointegration relationship				
1	10.5470	0.2410	8.8014	0.3031
2	8.3790	0.4258	4.8598	0.7594
3	15.0947	0.0574	8.8798	0.2963
4	14.5140	0.0699	9.8877	0.2194
5	8.2488	0.4392	6.7503	0.5191
6	15.1229	0.0568	10.2641	0.1952
7	12.7575	0.1240	8.0077	0.3779
8	16.1429	0.0399	10.9759	0.1554
9	22.7873	0.0033	13.8414	0.0582
10	21.0534	0.0065	13.3124	0.0703
Hypothesis of at most 4 cointegration relationship				
1	1.7456	0.1864	1.7456	0.1864
2	3.5192	0.0607	3.5192	0.0607
3	6.2149	0.0127	6.2149	0.0127
4	4.6263	0.0315	4.6263	0.0315
5	1.4984	0.2209	1.4984	0.2209
6	4.8587	0.0275	4.8587	0.0275
7	4.7498	0.0293	4.7498	0.0293
8	5.1669	0.0230	5.1669	0.0230
9	8.9459	0.0028	8.9459	0.0028
10	7.7409	0.0054	7.7409	0.0054

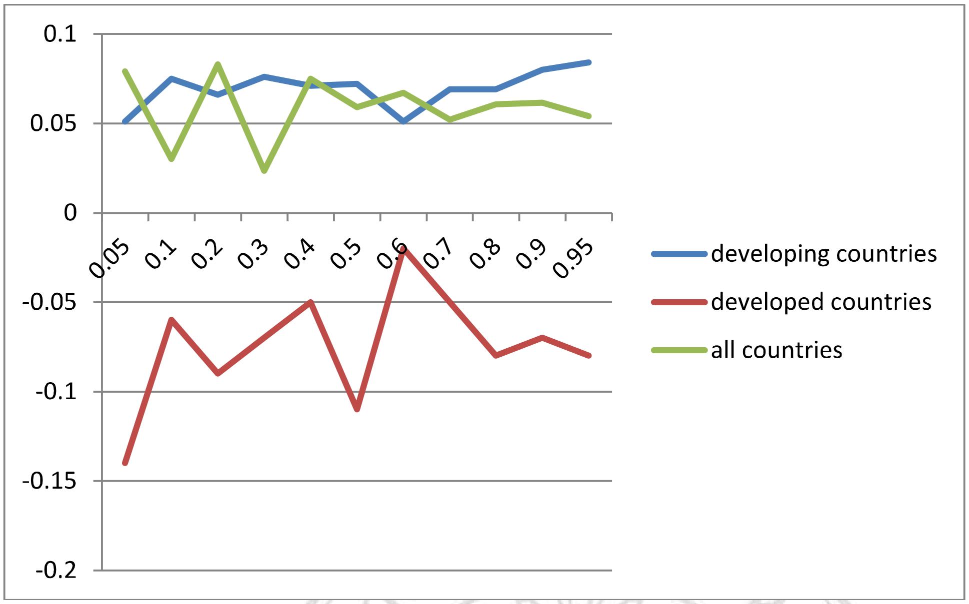
**MacKinnon-Haug-Michelis (1999) p-values



Source:

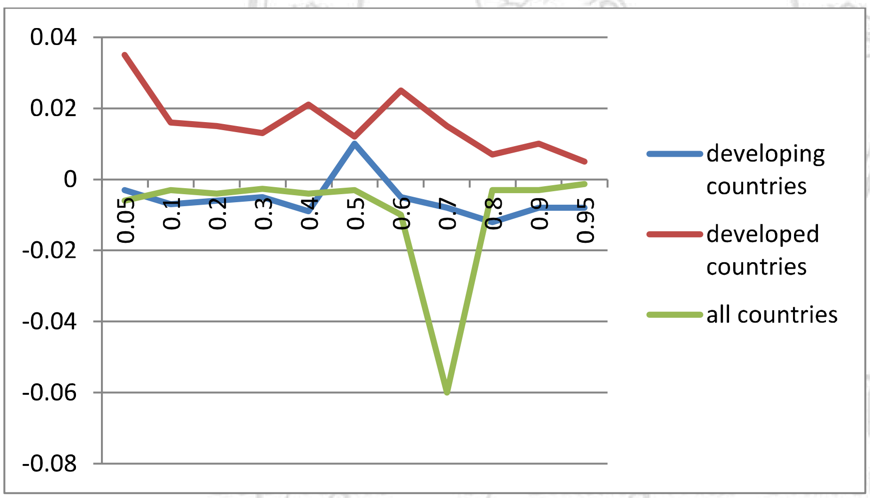
Source: Secondary Data from World Bank(1983-2013)

Figure 1 Change in panel quantile regression coefficient for trade openness



Source: Secondary Data from World Bank(1983-2013)

Figure 2 Change in panel quantile regression coefficient for the trade openness



Source: Secondary Data from World Bank(1983-2013)

Figure 3 Change in panel quantile regression coefficient for financial development

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